A NEVER ENDING STORY:
THE MULTIPLE RECOVERY CYCLES OF STEEL

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Abstract: This paper provides compelling facts about steel's enormous recycling success and the immense contribution it makes to sustainability. Once iron ore is extracted for making new steel, in combination with recycled scrap, its life never ends. Instead, its original natural resources are amortized over future generations. Steel proves itself as a "green" or "sustainable" building material, benefiting environment, society, and economics.

Steel recycling is truly a never-ending story, as old becomes new, new becomes old, and so on, ad infinitum. Once the original iron ore is extracted from the earth for making steel, in combination with the desired proportion of scrap, its life will never end, as old steel products are routinely recycled back into new steel products. This constant recycling helps make steel a sustainable building material since its original embodied energy and other natural resources in production are amortized over future generations of new steel.

Recycling is thus often acclaimed for saving energy and other resources. It is also credited with reducing the amount of pollution potentially emitted to earth, air, and water. While all of these environmental benefits are praiseworthy, it is simply raw economics that has made recycling happen through the centuries. Mother Nature provides iron ore in abundance; however, it is costly to extract from her vast storehouses and then reduce into its usable forms as a strong, durable metal.

Under "LEED Certification" on www.recycle-steel.org, see the documentation memo and accompanying fact sheet, "The Inherent Recycled Content of Today's Steel". This provides the recycled content values to use in LEED certification. This information is also contained in a new brochure, called "Steel Takes LEED with Recycled Content", produced by the American Institute of Steel Construction and American Iron and Steel Institute. It may be downloaded from www.aisc.org/sustainability.

It is the green color of money that in fact drives the recycling market. During periods of strong demand for scrap, its value naturally goes up. For example, when the construction market is booming, market forces go into play. Steel mills need more scrap so a higher price is paid through scrap processors. The added money causes scrap collectors to go further and further from major metropolitan areas, even into rural areas, to obtain enough scrap to meet demand. These outer areas are the "flywheel" of recycling, storing informal inventories of scrap that will be available for the next peak cycle. If construction slows, then steel production is reduced, and prices for scrap fall accordingly. It is a perfect classic example of how supply and demand work together within an economic system.

Besides offering an abundance of iron ore in the earth's crust, Mother Nature has also given ferrous metals certain other valuable gifts that, in turn, benefit mankind. In sharp contrast to most other substances (and certainly nonmetallic items), ferrous metal is the easiest to separate from other materials because it is attracted to a magnet. This gift is a fundamental, significant advantage since conglomerate products can be shredded by modern machinery and then the ferrous fraction is separated with magnetic systems, virtually automatically. Another advantage is the steel furnace tolerates incidental contamination in this final part of the recycling process. Indeed, at 3000 degrees Fahrenheit, steel is very forgiving, such as with old painted scrap. And, steel does not really "care" what the old product was in its past life, as long as the chemistry is within specifications for the new product.

How does one define the recycling success of a material? There are two ways: *recycling rate* and *recycled content.* These are similar but there are important distinctions. *Recycling rate* tells the story more powerfully, as it helps to document the total level of recycling taking place in a given year. It measures the relative ability of a material to be absorbed back into its own manufacturing system as a raw material resource when old products reach end of life.

The accompanying table, provided by the Steel Recycling Institute, shows the 2003 *recycling rate* for construction materials, as well as automobiles, appliances, and containers. It can also be viewed at www.recycle-steel.org. One may note that for steel construction products, the *recycling rate* for structural beams and plates is 95%, and for rebar is 60%. The steel industry and its customers can proudly emphasize that the overall recycling rate for all types of steel products is extraordinary, achieving 70.7%, with similar percentages, year to year. One could assume from this statistic that about one third of steel is not being recycled, however, this is not the case at all.

Instead, this annual statistic is merely a quick snapshot reflecting the proportion of steel scrap tonnage generated and consumed, compared to the tonnage of new steel products made in a year. It does not take into account the long-term flows of all steel products with lengthy life cycles. Most steel items in service today cannot be recycled right now because they remain in use and will be for some time to come. When the average service lives of steel products are considered, the overall reclamation rate is over 88 percent, with less than 12 percent being lost back to nature.

Recycled content, on the other hand, describes the scrap percentage contained in the material being made. It is a reflection of the proportional amount of scrap typically contained in the new product at beginning of life as provided by a given manufacturing process. This statistic may further defined to identify the sources of the scrap consumed. For example, *post-industrial* and *post-consumer* recycled content are two levels of values used by the US Green Building Council (USGBC) in the Leadership in Energy and Environmental Design (LEED®) rating program.

LEED Version 2.1 can be found at www.usgbc.org. One or two points are potentially available for meeting or exceeding the weighted average recycled content goals for the construction materials used in the building project as a whole. Steel construction products always have significant recycled content and are net contributors toward obtaining these points. This documentation can be done easily with data from the Steel Recycling Institute.

Under "LEED Certification" on www.recycle-steel.org, see the documentation memo and accompanying fact sheet, "The Inherent Recycled Content of Today's Steel". This is information is also contained in a new brochure, called "Steel Takes LEED with Recycled Content", as produced by the American Institute of Steel Construction and American Iron and Steel Institute. This provides the recycled content values to use in LEED certification.

Thus, whether considering the *recycling rate* or the *recycled content*, it can be seen that steel is North America's most recycled material. One may also appreciate how the original embodied energy and other natural resources used in steelmaking are routinely amortized over future generations of new steel. Among the other environmental benefits of steel, recycling reduces waste while new, useful goods are also being created. And yet, recycling is only one of the features that make steel uniquely "green" or *sustainable* as a building material.

Sustainability has been described as a three-legged stool that must have all three legs to function properly: *society*, *economics*, and *environment*. Steel contributes significantly to each. For the first "leg", *society* is dependent in so many ways on steel, whether in commercial and residential buildings, transportation, infrastructure, or innumerable other consumer goods comprising modern life. It provides shelter from the elements, commerce, agriculture, mobility, and indeed, a higher standard of living. Being both highly functional and low cost, steel also provides "affordability" to more people for their needs, thus creating a greater common good.

For the second "leg", steel generates enormous *economic* value throughout its manufacturing and distribution channels, from the steel mill through its treating, shaping, processing, and fabricating, until it is finally installed and in service at the construction site. Steel provides meaningful and well-paying jobs at all levels. Then at the end of steel's long, useful service life, steel recycling brings even more monetary value through the demolition process, as it is deconstructed and reused, or, ultimately processed, transported, and recycled into new steel for a new cycle.

The third "leg" of sustainability is *environmental*. Steel is often evaluated, relative to competing materials, for its relative environmental assets or liabilities. This area is laden with numerous green marketing claims and counter-claims. Virtually every human activity has an environmental impact, many of which are damaging, especially when there is permanent loss of habitat. The use of steel as a construction material can help minimize these impacts. For one, steel literally has a very small "environmental footprint" compared to other materials since little land area is disturbed in extracting natural resources and their reduction to usable product form.

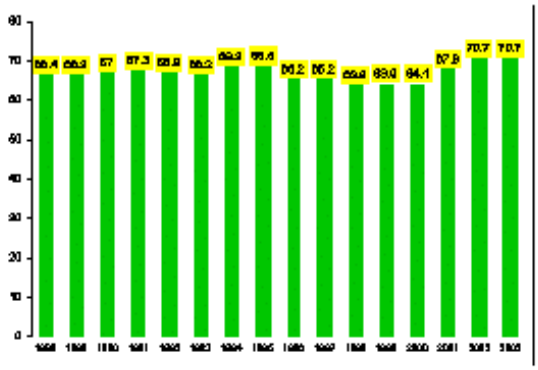
As already described, recycling has a strong role in reducing environmental impacts from steel's manufacture and use. Beyond the scope of this paper, there are extensive input and output data for various life cycle inventory (LCI) systems as well as several methodologies for life cycle assessment (LCA), like ATHENA and BEES. The steel industry is participating in their development since they frame environmental arguments for steel relative to other building materials. For more information about sustainability, visit www.aisc.org and www.sustainablesteel.org.

Steel's invaluable contribution to sustainability – via society, economics, and environment – is quantifiable and credible. It needs far better recognition and promotion within the steel construction industry, as well as its customer base. An essential tool in the environmental marketing of steel is the knowing and the telling of the never-ending story of steel recycling. Learn the story well and repeat it often with well-placed enthusiasm and conviction!

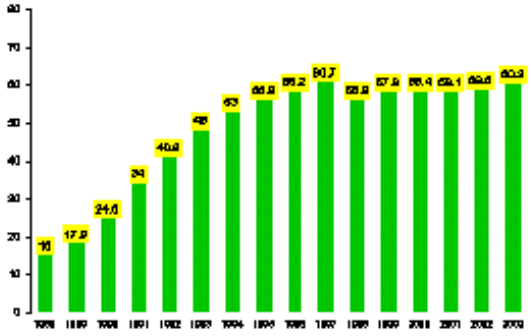
Steel Recycling at a Glance

All Recycling Rates by Percent

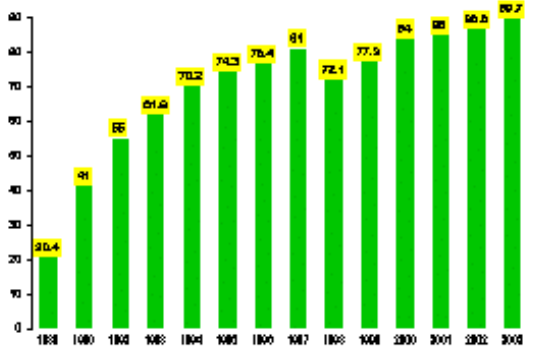
Overall Rates



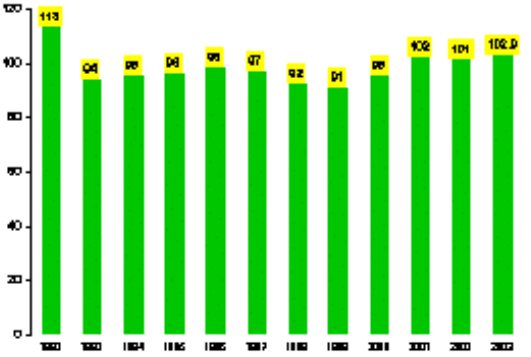
Steel Can Recycling



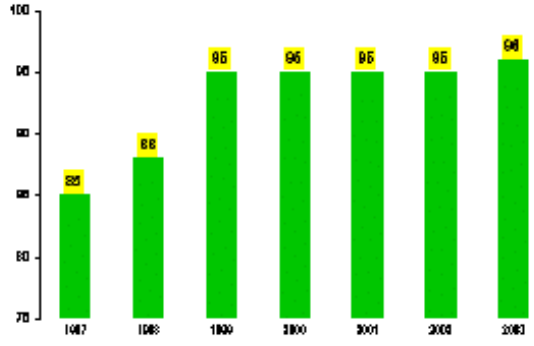
Appliance Recycling



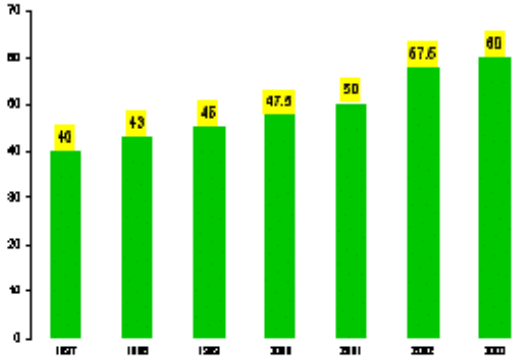
Automobile Recycling



Construction Recycling



Structural Beams & Plates



Reinforcement Bars & Other

Steel Takes LEED™ with Recycled Content

steel beams and columns

steel studs

steel roofing

steel decking

steel doors

ductwork

steel siding

corrugated steel pipe

other steel components

Designers and builders have long recognized and lauded steel for its strength, durability, and functionality. Increasingly, however, architects are recognizing steel's important environmental attributes—especially its high recycled content and high reclamation rate.

For many years, there has been a strong economic motive to incorporate recycling into the process for making steel, but today's environmental concerns make recycling even more important. Recycling saves money while conserving energy and resources, as well as reducing solid, liquid, and gaseous wastes. Recycling also helps to spread the energy impact of the original extraction and manufacturing of the material over infinite generations of new steel.

The efficiency with which a material is recycled can be measured by either its *percentage of recycled content* or its *reclamation rate*. Recycled content is a measure of how much recycled material is contained in a finished product. The reclamation rate is a measure of how often a product is actually recycled at the end of its useful life. Steel is an exceptional performer by both measurements. In the construction industry, recent interest in recycling has been driven largely by the US Green Building Council's *Leadership in Energy and Environmental Design* (LEED™) rating system. The LEED rating system only promotes the use of materials with high levels of recycled content. The equally important reclamation rate of the materials is not currently considered.

Scrap consumption in the United States is maximized between the two types of modern steel mills, each of which generates products with varying levels of recycled content. One type of mill produces much of the steel for light flat-rolled steel products with about 30% *recycled content*. The other type of mill makes steel for a wide range of products, including flat-rolled, but is the only method used domestically for the production of structural shapes and has about 95% *recycled content*. (These processes are covered in detail on the following pages.)

The amount of recycled content in steel products varies over time, both as a function of the cost of steel scrap and its availability. As the world-wide demand for steel increases, the available scrap will be stretched between more and more steel products, meaning that more raw steel will have to enter the production stream to meet the demand. Fortunately, steel is the country's most widely recycled material, and as more steel is used for construction and other products, more scrap is available for future recycling. About 88% of all steel products and nearly 100% of steel that is used in beams and plates in construction, are recycled into new steel products at the end of their useful life—an amazing reclamation rate!

In addition to recycled content, steel can contribute toward several other LEED credits, either directly or indirectly. Steel is dimensionally stable and, when properly designed, can provide an exceptionally tight building envelope, for less air loss and better HVAC performance over time. Steel is made to exact specifications, so on-site waste is minimized. Material from demolition or construction can be easily recycled, with the magnetic properties of steel greatly facilitating its separation from other materials. Thus, in addition to steel's outstanding recycled content and an enviable reclamation rate, steel's other functional properties contribute to the material's solid environmental performance.

As with any building process or material, there are areas for improvement. A great benefit of LEED is that it can help the steel industry recover even more scrap as contractors improve their recycling collection methods at the job site, so less incidental iron and steel scrap escapes to landfills. Similarly, commercial buildings and residential housing can have better disciplined recycling systems for increased recovery.

As steel products reach the end of their useful life, we want to see even more recycled into new steel products for future service to society.

On-Line Steel Recycling Resources

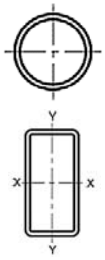
www.recycle-steel.org
Includes detailed information on recycling rates, recycling databases, and the environmental benefits of steel for homes building, steel roofing, and bridges.

www.aisc.org/sustainability
Includes detailed information on how steel factors into the LEED™ rating system, steel mill recycled content documentation, and articles about the use of steel in sustainable projects.

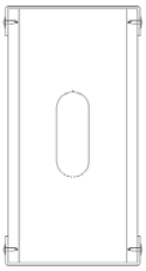
American Iron and Steel Institute

Modern Steel Production Technologies

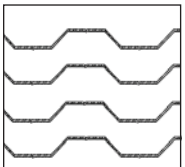
Typical BOF Products



hollow structural sections



steel studs



steel deck

plate

purlins

wall studs

Steel is the world's—as well as North America's—most recycled material. In the United States alone, almost 69 million tons of steel were recycled or exported for recycling in 2003. Modern steel production relies on two technologies, both of which utlize old steel to make new steel: the *basic oxygen furnace* (BOF) and the *electric arc furnace* (EAF).

- The basic oxygen furnace (BOF) process uses 25 to 35 percent old steel to make new. It produces products—such as automotive fenders, encasements of refrigerators, and packaging like soup cans, five-gallon pails, and 55-gallon drums—whose major required characteristic is drawability.
- The electric arc furnace (EAF) process uses 95-100 percent old steel to make new. It is primarily used to manufacture products—such as structural beams, steel plates, and reinforcement bars—whose major required characteristic is strength.

Steel recycling has both an economic and environmental benefit: It is less expensive to recycle steel than to mine virgin ore and move it through the process of making new steel. And today two out of every three pounds of new steel are produced from old steel. However, because steel is such a durable material (that is, cars, appliances, bridges and other steel products last a long time), it is necessary to continue to mine virgin ore to supplement the production of new steel. Economic expansion, domestically and internationally, creates additional demand that cannot be fully met by available scrap supplies.

Unlike other competing industries, recycling is second nature for the steel industry. The North American steel industry has been recycling steel scrap for over 150 years through the 1,800 scrap processors and some 12,000 auto dismantlers. Many of them have been in the business for more than 100 years.

The pre-consumer, post-industrial, post-consumer, and total recycled content of steel products in the United States can be determined for the calendar year 2003 using information from the American Iron and Steel Institute (AISI), the Institute of Scrap Recycling Industries (ISRI), and the U.S. Geological Survey. Additionally, a study prepared for the AISI by William T. Hogan, S.A., and Frank T. Koelble of Fordham University is used to establish pre- and post-consumer fractions of purchased scrap. (Detailed information on these studies can be obtained from the Steel Recycling Institute (call 412.922.2772 or visit www.recycle-steel.org.)

Individual company statistics are usually not applicable or instructive since available scrap typically goes to the closes melting furnace. This open loop recycling allows, for example, an old car to be melted down to produce a new soup can, and then, as the new soup can is recycled, it is melted down to produce a new car, appliance, or structural beam.

Basic Oxygen Furnace

BOF facilities consumed a total of 15,772,900 tons of ferrous scrap in the production of 50,941,700 tons of liquid steel during 2003. Based on U.S. Geological Survey statistics, 1,738,800 of these ferrous scrap tons had been generated as unsalable steel product within the confines of these steelmaking sites. In the steel industry, these tons are classified as "home scrap," but are a mix of pre-consumer scrap and post-industrial scrap. Estimates by the Steel Recycling Institute identify about 80% of this home scrap as post-industrial scrap, equating to 1,391,000 tons (1,738,800 x 80%). Additionally, these operations reported that they consumed 148,800 tons of obsolete scrap (buildings and warehouses dismantled on-site at the mill) during this time frame. This volume is classified as post-consumer scrap.

As a result of the above, based on the total scrap consumed, outside purchases of scrap equate to 13,885,300 tons [15,772,900 - (1,738,800 + 148,800)]. According to the Fordham University study, the post-consumer fraction of the purchased ferrous scrap would be 83.4 percent, while 16.6 percent of these purchases would be pre-consumer. This equates to 2,305,000 tons of pre-consumer scrap (13,885,300 x 16.6%). This "prompt scrap" is mainly scrap generated by manufacturing processes for products made with steel. It is also considered post-industrial scrap.

Therefore, the **total recycled content** to produce the 50,941,700 tons of liquid steel in the BOF is:

15,772,900 / 50,941,700 = 31.0%

(Total Tons Ferrous Scrap / Total Tons Liquid Steel)

Also, the **post-consumer recycled content** is (13,885,300 - 2,305,000) + 148,800 = 11,729,100

and:

11,729,100 / 50,941,700 = 23.0%
(Post-Consumer Scrap / Total Tons Liquid Steel)

Finally, the **post-industrial recycled content** is (1,391,000 + 2,305,000) / 50,941,700 and:

3,696,000/ 50,941,700 = 7.3%
(Post-Industrial Scrap / Total Tons Liquid Steel)

Electric Arc Furnace

EAF facilities consumed a total of 44,661,700 tons of ferrous scrap in the production of 46,310,300 tons of liquid steel during 2003. Based on U.S. Geological Survey adjusted statistics, 12,124,000 of these ferrous scrap tons had been generated as unsalable steel product within the confines of these steelmaking sites. Again, in the steel industry, these tons are classified as "home scrap," but are a mix of pre-consumer scrap and post-industrial scrap. Estimates by the Steel Recycling Institute identify about 80% of this home scrap as post-industrial scrap, equating to 9,699,200 tons (12,124,000 x 80%). Additionally, these operations reported that they consumed 28,700 tons of obsolete scrap (buildings and warehouses dismantled on-site at the mill) during this time frame. This volume is classified as post-consumer scrap.

As a result , based on the total scrap consumed, outside purchases of scrap equate to 32,509,000 tons [44,661,700 - (12,124,000 + 28,700)]. According to the Fordham University study, the post-consumer fraction of the purchased ferrous scrap would be 83.4 percent, while 16.6 percent of these purchases would be pre-consumer.

This equates to 5,396,500 tons of pre-consumer scrap (32,509,000 x 16.6%). This "prompt scrap" is mainly scrap generated by manufacturing processes for products made with steel. It is also considered post-industrial scrap.

Therefore, the **total recycled content** to produce the 46,310,300 tons of liquid steel in the EAF is:

44,661,700 / 46,310,300= 96.4%
(Total Tons Ferrous Scrap / Total Tons Liquid Steel)

Also, the **post-consumer recycled content** is (32,509,000 - 5,396,500) + 28,700 = 27,141,200 and:

27,141,200 / 46,310,300 = 58.6%
(Post-Consumer Scrap / Total Tons Liquid Steel)

Finally, the **post-industrial recycled content** is (9,699,200 + 5,396,500) / 46,310,300 and:

15,095,700 / 46,310,300 = 32.6%
(Post-Industrial Scrap / Total Tons Liquid Steel)

The above discussion and calculations demonstrate conclusively the inherent recycled content of today's steel in North America. To buy steel is to "Buy Recycled."

Understanding the recycled content of BOF and EAF steels, one should not attempt to select one steel producer over another on the basis of a simplistic comparison of relative scrap usage or recycled content. Rather than providing an enhanced environmental benefit, such a selection could prove more costly in terms of total life cycle assessment energy consumption, transportation impact, or other variables.

Steel does not rely on “recycled content” purchasing to incorporate or drive scrap use. It already happens because of the economics. Recycled content for steel is a function of the steelmaking process itself. After its useful product life, regardless of its BOF or EAF origin, steel is recycled back into another steel product. Thus steel with almost 100 percent recycled content cannot be described as environmentally superior to steel with 30 percent recycled content. This is not contradictory because they are both complementary parts of the total interlocking infrastructure of steelmaking, product manufacture, scrap generation and recycling. The recycled content of EAF relies on the embodied energy savings of the steel created in the BOF.

Steel is truly the most recycled material.

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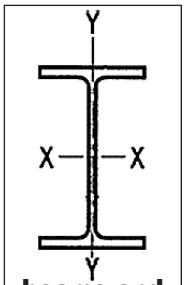
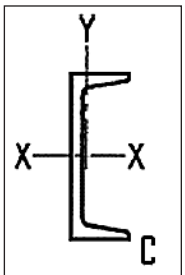
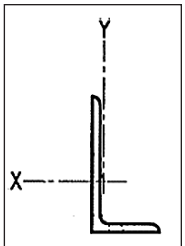
Typical EAF Products



beams and columns



channels



angles

plate

steel deck

piling

To: Architects, Engineers, Designers, and Specifiers
Re: LEED™ Version 2.1 Recycled Content Value of Steel Building Products

The U.S. Green Building Council Leadership in Energy & Environmental Design (LEED™) Green Building Rating System aims to improve occupant well-being, environmental performance and economic returns of buildings using established and innovative practices, standards and technologies.

Materials & Resources Credit 4: Recycled Content intends to increase demand for building products that incorporate recycled content materials, therefore reducing impacts resulting from extraction and processing of new virgin materials. As discussed and demonstrated below, steel building products contribute positively toward earning points under Credit 4.1 and Credit 4.2. The following is required by LEED Version 2.1:

> **Credit 4.1 (1 point)** "Use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the post-industrial content constitutes at least 5% of the total value of the materials in the project."
>
> **Credit 4.2 (1 point)** "Use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the post-industrial content constitutes at least 10% of the total value of the materials in the project."

"The value of the recycled content portion of a material or furnishing shall be determined by dividing the weight of recycled content in the item by the total weight of all material in the item, then multiplying the resulting percentage by the total value of the item." Since steel (the material) and steel (the building product) are the same, the value of the steel building product is directly multiplied by steel's recycled content, or:

Steel Recycled Content Value = (Value of Steel Product) (Post-Consumer % + ½ Post-Industrial %)

The information contained within this brochure provides post-consumer and post-industrial recycled content percentages for North American steel building products. These percentages and values of steel building products are easily entered into LEED Letter Template spreadsheet for calculation. To illustrate the application of these steel recycled content values to LEED, manual calculations are shown below for typical Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF) steel building products with nominal $10,000 purchases, using 2003 data. Steel building products include steel stud framing, structural steel framing (wide flange beams, channels, angles, etc.), rebar, roofing, siding, decking, doors and sashes, windows, ductwork, pipe, fixtures, hardware (hinges, handles, braces, screws, nails), culverts, storm drains, and manhole covers.

BOF Steel Recycled Content Value for Typical Product:
Steel Stud Framing
Value = ($10,000) (23.0 % + ½ 7.3 %) = ($10,000) (26.65 %) = $2,665
(Exceeds 5% and 10% goals)

EAF Steel Recycled Content Value for Typical Product:
Wide Flange Structural Steel Framing
Value = ($10,000) (58.6 % + ½ 32.6 %) = ($10,000) (74.90 %) = $7,490
(Exceeds 5% and 10% goals)

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