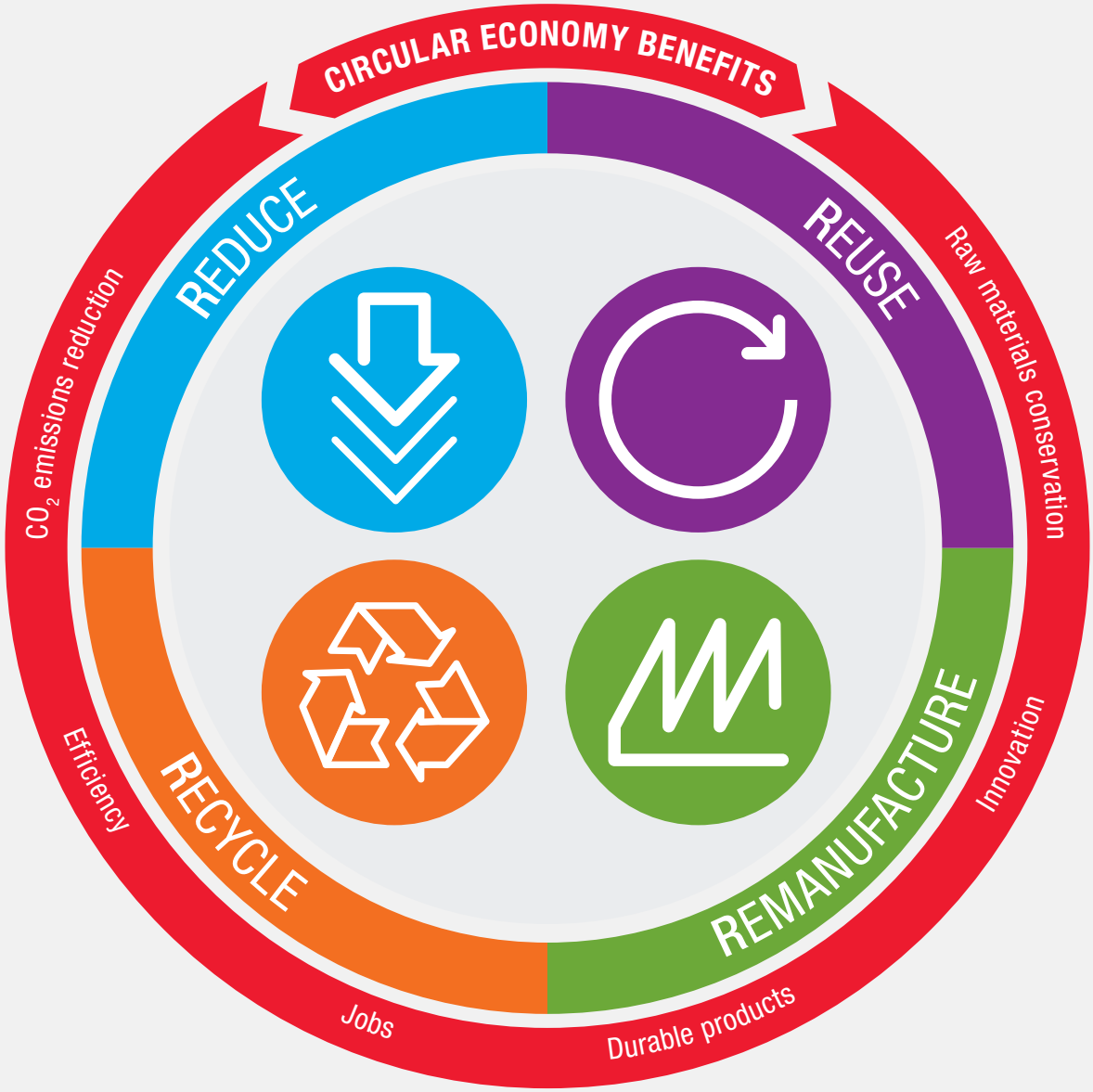
worldsteel
ASSOCIATION

STEEL - THE PERMANENT MATERIAL IN THE CIRCULAR ECONOMY



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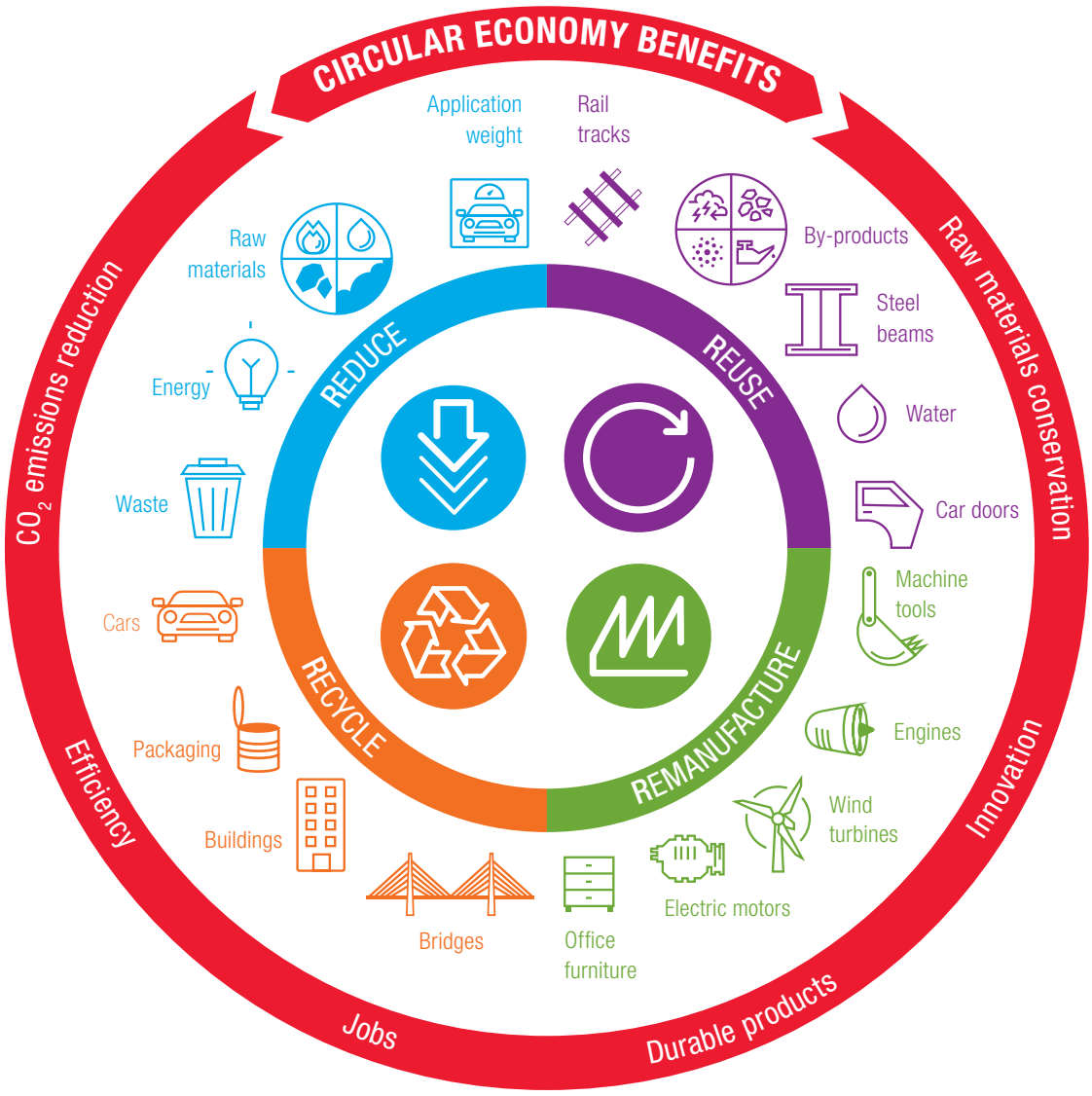
A sustainable circular economy is one in which society reduces the burden on nature by ensuring resources remain in use for as long as possible. Once the maximum value has been extracted, the resources are then recovered and reused, remanufactured, or recycled to create new products.

As a permanent material which can be recycled over and over again without losing its properties, steel is fundamental to the circular economy. The industry is continuing to expand its offer of advanced high-strength steels which reduce the weight of applications, and encourage circular economy practices. For society the benefits include durable products, local jobs, reduced emissions, and the conservation of raw materials for future generations.

Steel in the circular economy: The 4Rs

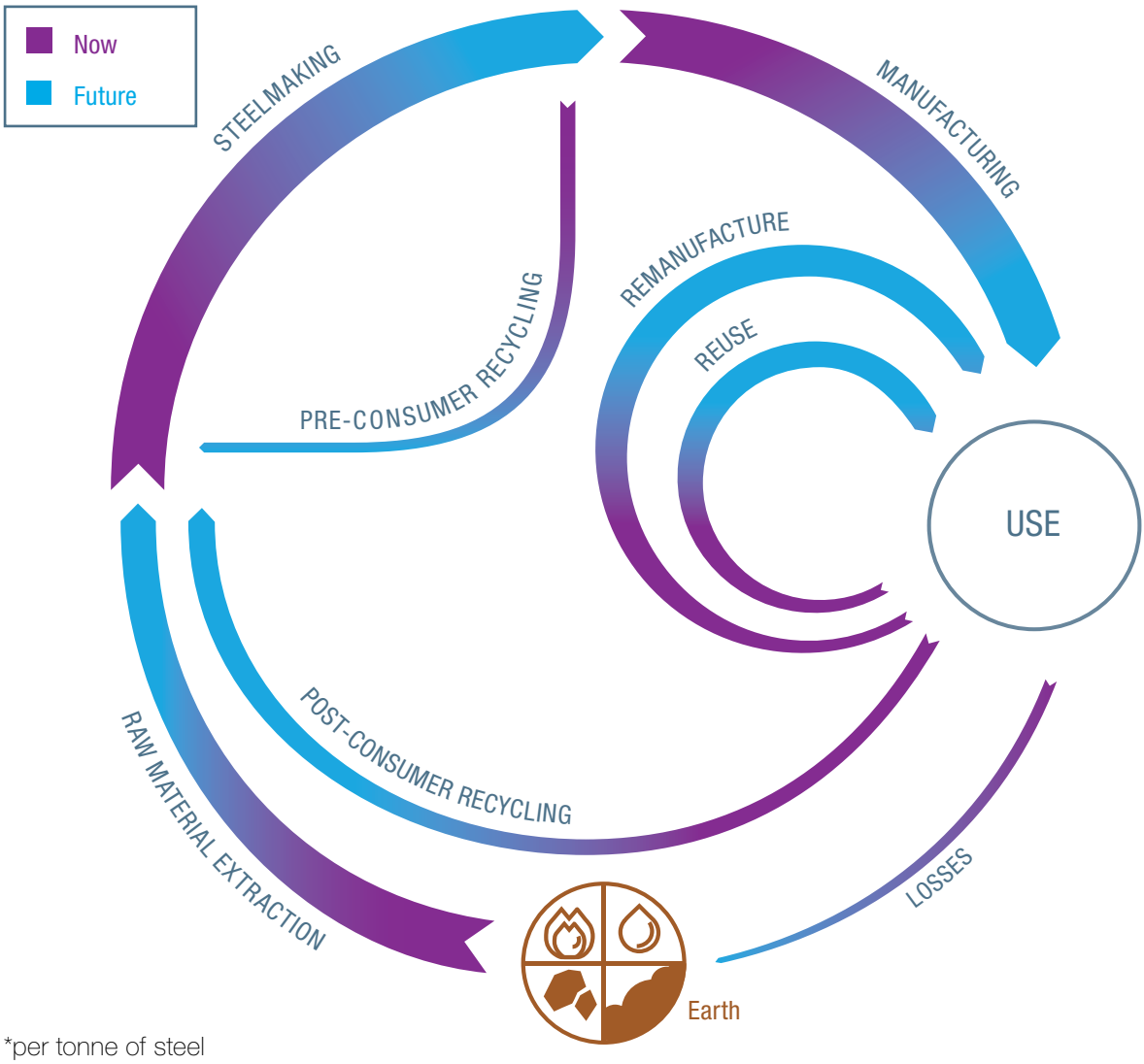


Steel is essential to the technologies and solutions that meet society's everyday needs today – and will continue to do so in the future. Whether it is for transport systems, infrastructure, housing, manufacturing, agriculture, or energy, steel is a vital material in our modern world.

In the sustainable future, new economic models will maximise the value of raw materials by encouraging practices such as reuse and remanufacturing.

The weight of many steel products will be reduced, losses will be minimised, and the already high recycling rate for steel will increase, resulting in more recycled steel to make new steel products. Pre-consumer recycling from the steelmaking and manufacturing processes will decrease due to increased process efficiencies and collaboration between steelmakers and their customers to reduce yield losses.

A sustainable future for steel*



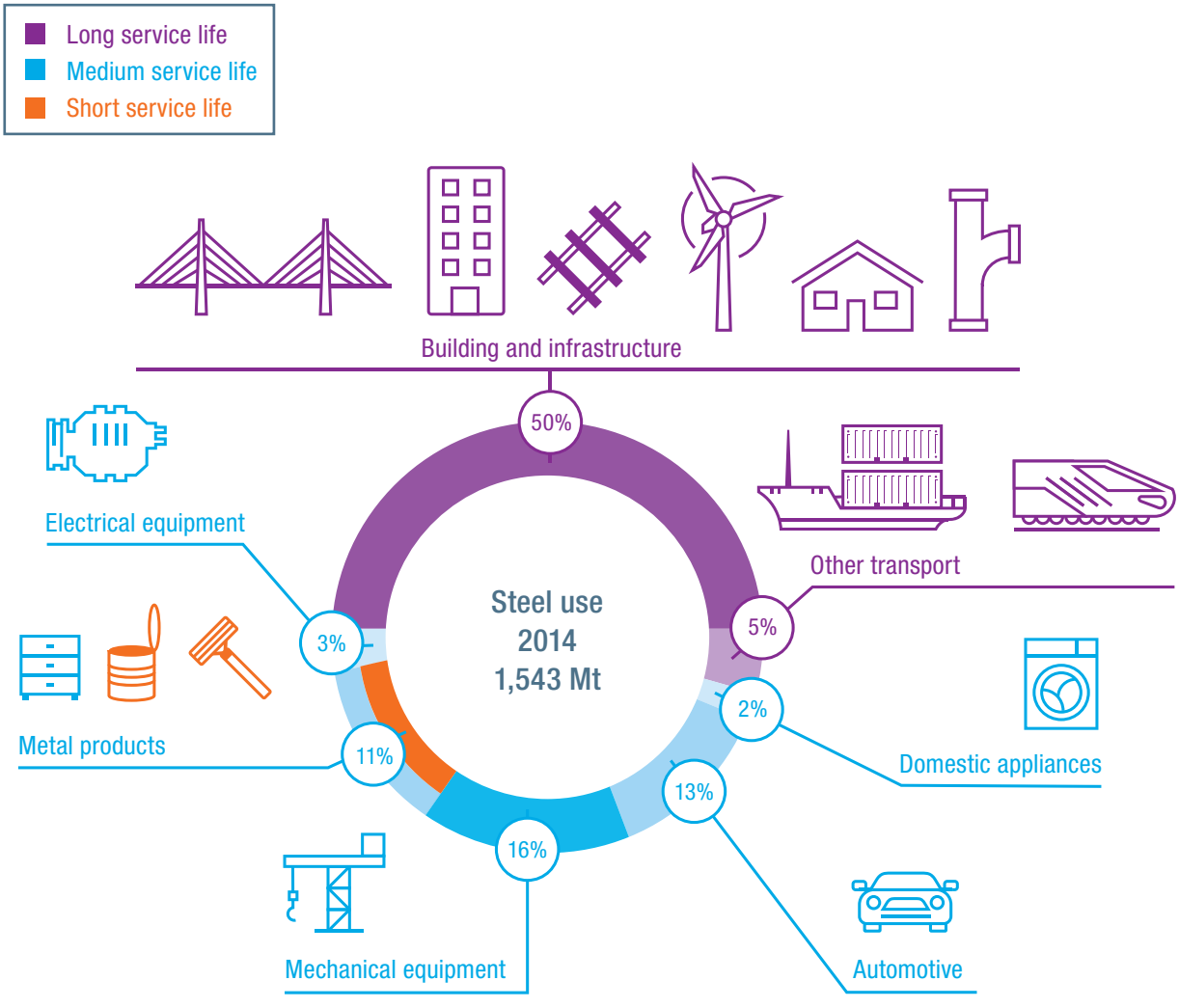
*per tonne of steel

STEEL IS ESSENTIAL TO OUR MODERN WORLD

Around 650 million tonnes of recycled steel were utilised in the past year to create new steel. But it was not enough to satisfy the world's demand for this essential metal. The main reason we still need to make steel from raw materials is the durability of steel products in combination with growth in steel demand.

Steel products are durable and simply last a long time. In applications with a long service life, such as buildings and infrastructure, we will need to wait a hundred years or more to recycle the steel they contain. But every piece of steel can eventually be recycled to meet the growing global need for new steel.

Steel markets and durability



REDUCE

Decreasing the amount of material, energy and other resources used to create steel and reducing the weight of steel used in products.

Over the past 50 years, the steel industry has invested in research and technology to create new grades of advanced and ultra-high-strength steels. These grades have reduced the weight of many steel applications by up to 40%. Optimising the weight of products is an integral part of a circular economy.

By reducing weight, the amount of raw materials and energy used to create the product is decreased, reducing pressure on raw materials. Lighter weight applications which take advantage of high-strength steels, such as vehicles, also produce fewer emissions during the use phase of their life. In construction, substituting high-strength steels for regular steels can achieve a CO_2 reduction of around 30% in steel columns and around 20% in steel beams[1]. Whether it is a wind turbine, construction panel, a vehicle, or a steel can, the application of high-strength steels means that less steel is required to provide the same strength and functionality. This also has a knock-on effect by reducing the amount of other materials required, for example in foundations. In addition, the development of better coating systems results in an extended service life and hence reduced material demand.

At the same time, the steel industry has reduced its dependence on raw materials.

Since 1900 the global steel industry has recycled over 22 billion tonnes of steel. This has reduced iron ore consumption by around 28 billion tonnes, as well as cutting coal consumption by 14 billion tonnes[2].

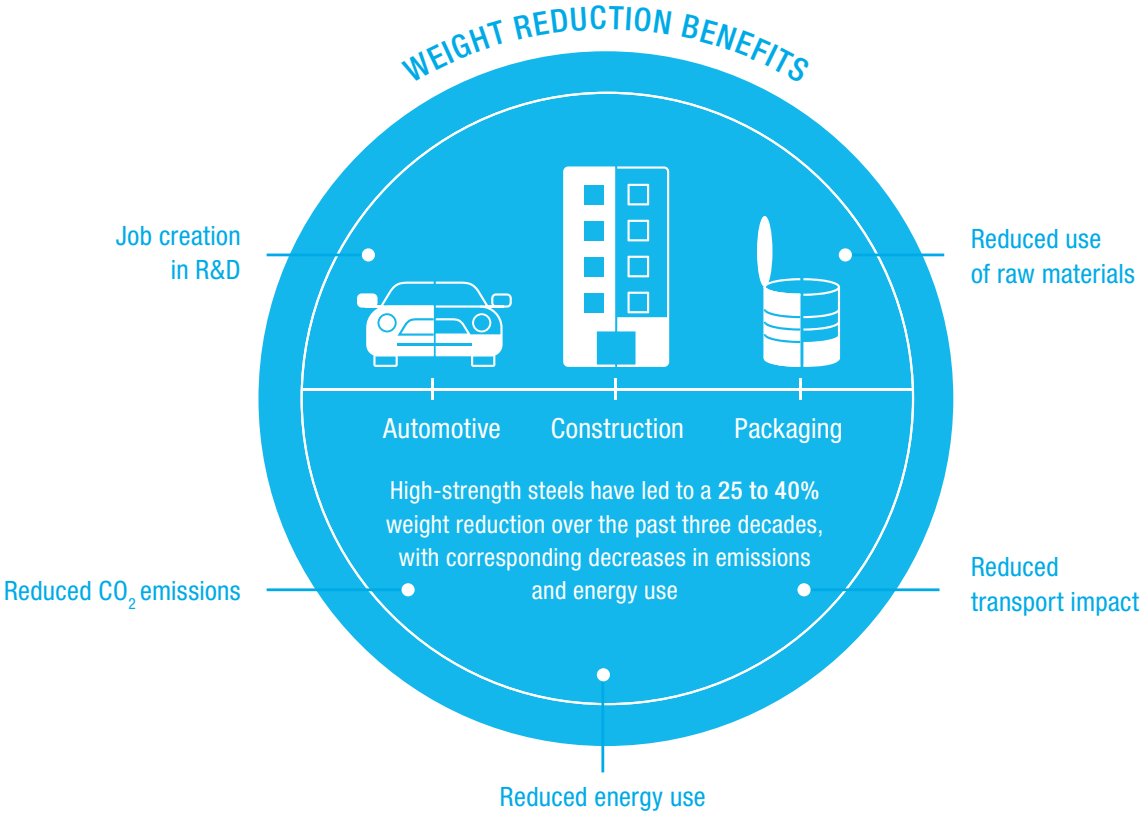
The industry has also dramatically reduced the use of energy. Producing one tonne of steel today requires just 40% of the energy it did in 1960[3]. Over the same period, steel production has increased almost five times.

Waste is another area in which the steel industry has made huge gains over the past decades. Working with external partners, the industry has been able to find markets for over 97% of its production with only a 2.7% waste stream[4].

The valuable by-products, including slag, dust, and process gases are fully utilised in other applications and industries (see page 13 for examples), avoiding the use of primary materials such as cement clinker.

One area that the steel industry and its customers are working hard to improve is reducing the yield loss in downstream manufacturing processes. A common drive to diminish the percentage of offcuts, which are then re-melted to make new steel, will lead to greater productivity as well as energy and resource savings.

Reduce in steel applications

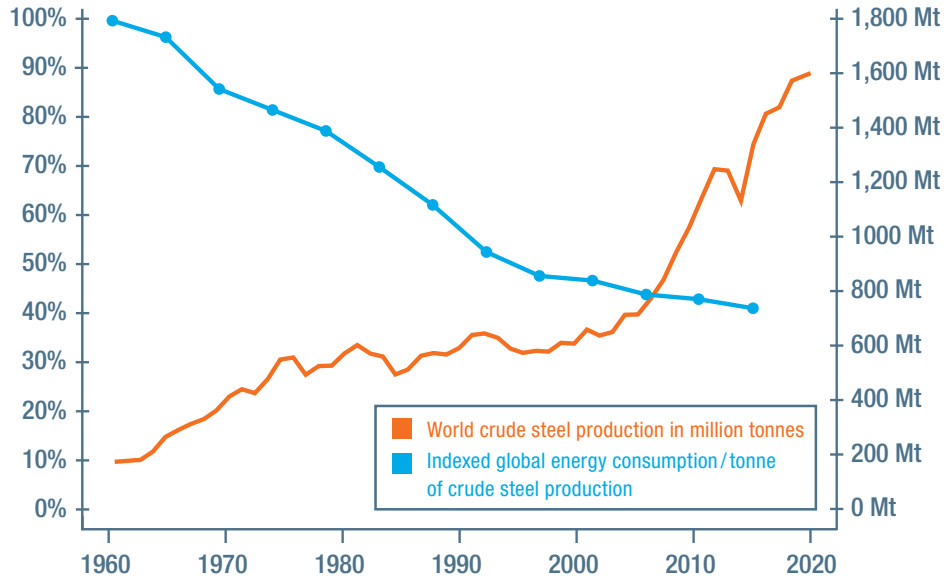


CASE STUDY › New high-strength steels allow light and sustainable structures

With the development of its HISTAR® range of steels for construction, ArcelorMittal has created structural steels which combine high yield strength with excellent toughness at low temperatures and outstanding weldability. Compared to conventional structural steels, HISTAR® beams exhibit significant weight and material cost savings.

A HISTAR® 460 beam weighs 32% less than a standard S355 JR grade beam of the same length and thickness. Material savings are around 30%. These new steels satisfy the demands of architects and designers for materials which enable them to create light and economical structures.

Reduce during steel production



- Global steel production has increased almost fivefold since 1960
- Energy consumption has been reduced by 60% per tonne of steel in the same period

For every tonne of steel produced today, we save almost 24 GJ per tonne compared to 1960. That's enough energy to drive an average passenger vehicle 17,380 km, which is equivalent to driving across the USA and back more than twice.

CASE STUDY › Modern steelmakers use 60% less energy

The efficient use and recovery of energy has enabled steelmakers to reduce the amount of energy required to produce a tonne of steel by around 60% since 1960. To help its members measure their energy performance against other steelmakers, worldsteel has introduced a comprehensive energy benchmarking system.

Members can compare a specific process in their plant against the top performers. Using this data, the steelmaker can identify where the energy performance of their process deviates from the reference and take action.

For more examples of **Reduce**, go to the circular economy section of **worldsteel.org**

USE AND REUSE

Reuse is using an object or material again, either for its original purpose or for a similar purpose, without significantly altering the physical form of the object or material.

Steel's durability enables many products to be reused at the end of their life. As well as extending the product's life cycle, reuse avoids the need to transport and re-melt the steel, and to create new products. This has significant advantages for the environment and maximises the use of resources.

In a fully circular economy, the reuse of a manufactured product is considered in the earliest design phases of its creation. This allows both small- and large-scale products to be repurposed for another use quickly and efficiently once their initial use is fulfilled. High-speed rail tracks, for example, can be designed to wear to a certain point, at which they become suitable for reuse as low-speed tracks.

Buildings are a prime example of where designing for reuse is critical if we are to conserve resources. Modular design using steel construction methods and demountable connections (screws, bolts) allows buildings to be repurposed quickly and cost effectively without remanufacturing, as needs change. For example, a community might build a school to meet the needs of a growing population. As community needs change, the internal walls can be removed to create open spaces suitable for offices. Decades later the rooms can be re-divided to create retirement units.

Integrating reuse into the economy presents a range of new opportunities for consumers and steelmakers. In our current business model, buildings are typically constructed with new steel beams as their quality and strength is guaranteed by the steelmaker. In an economy where reuse is well established, steel companies will continue to examine new business models and may offer services such as testing and recertifying used beams before they are reused. This provides the builder with the safety guarantee they require, low-cost fast remodelling solutions for building owners, and a source of revenue for the steelmaker.

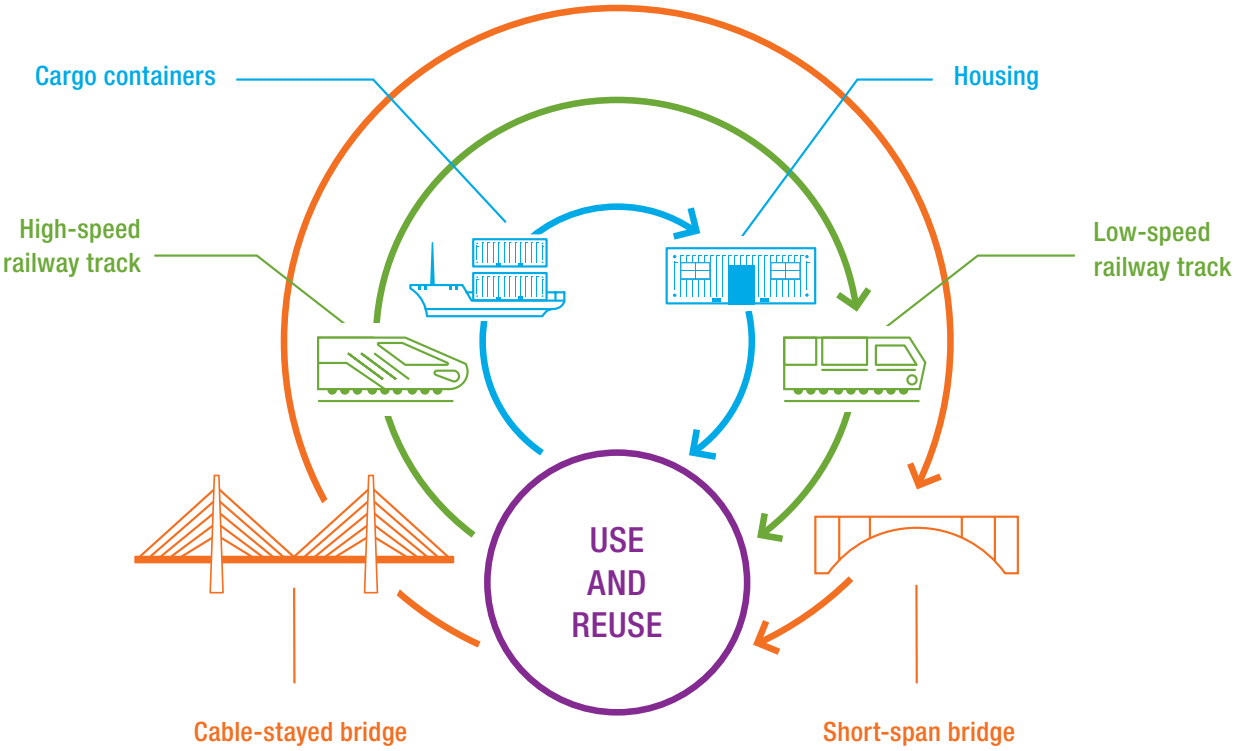
Use of by-products

Today, material efficiency is an integral part of the modern steelmaking process. Our goal is to use all raw materials to their full capacity, ensuring zero waste from steelmaking. This ambition guarantees that almost every by-product formed during steelmaking is used in new products. This approach minimises the amount of waste sent to landfill, reduces emissions, and preserves raw materials.

Slag is used to make a range of products including cement, fertilisers, and asphalt. Process gases from iron and steelmaking are typically used within the steelmaking plant, replacing steam and electricity, or exported to the local grid. Other by-products such as dust are used for their high metallic content.

Water is recirculated within the plant, especially for cooling purposes; around 90% of the water used in steelmaking is cleaned and either reused or returned to its source[5].

Reuse in steel applications

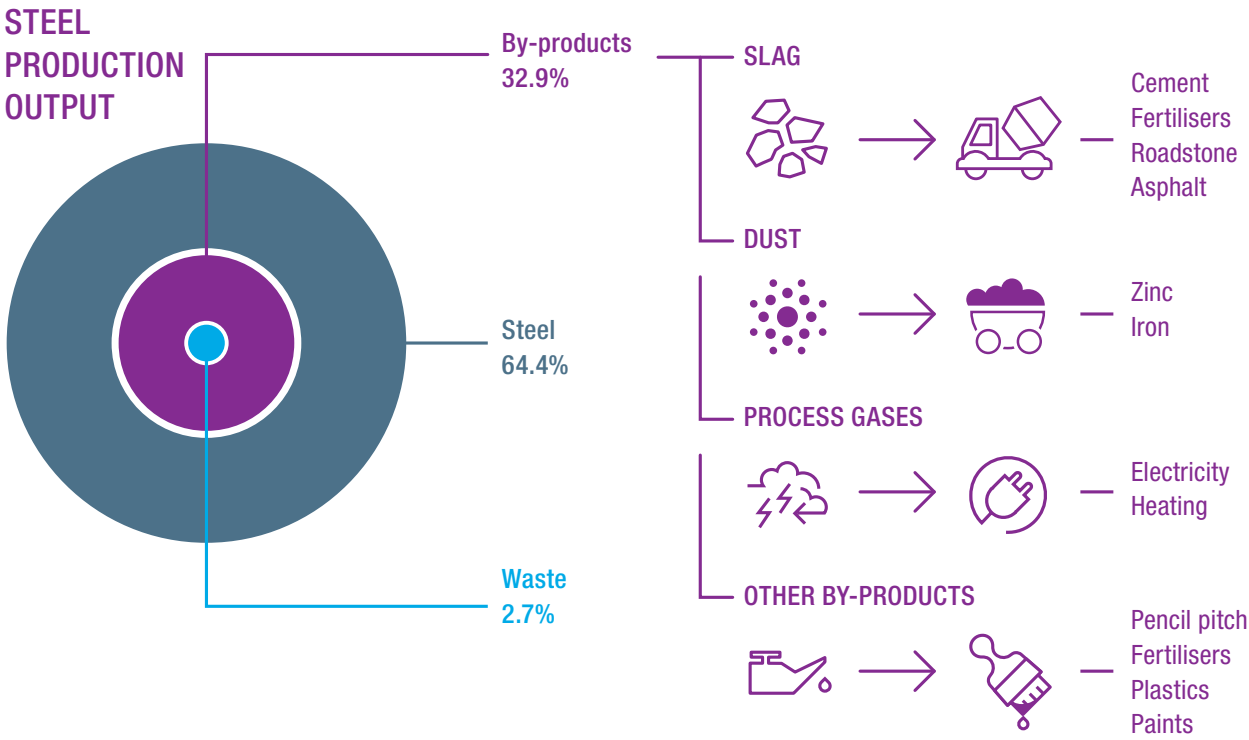


CASE STUDY › Reused steel gives old bridges an upgrade

Faced with budget cuts, the engineers office in Muskingum County, Ohio (United States) decided to use salvaged beams to replace the superstructure of the local Green Valley Road Bridge.

The team removed old attachments from the beams before cutting them to the required lengths. A mock-up of the superstructure was created with the reused beams so that new cross-frames and stiffeners could be fitted. The entire structure was then disassembled, cleaned, and painted before being transported to the bridge site. This reuse of steel beams saved over US$50,000.

Main steelmaking by-products and their uses



CASE STUDY › Steelmaking slag stimulates marine environments

Once cooled, slags have a wide variety of uses in industries ranging from cement production to road building. worldsteel members have even created products which are helping to restore marine environments.

JFE Steel markets Marine Stone® - a crushed form of slag which is used in bodies of water with poor circulation. Typically oxygen levels at the bottom of the water body are low and hydrogen sulphide is produced, both of which can harm fish and shellfish which feed on sediment. The crushed slag attracts life to the area which helps to remediate the sediment.

For more examples of **Use and Reuse**, go to the circular economy section of **worldsteel.org**

REMANUFACTURE

The process of restoring durable used steel products to as-new condition.

In a truly circular economy, products which stop working are restored to as-new condition in a process known as remanufacturing.

Remanufacture involves the disassembly of a product, during which each component is thoroughly cleaned, examined for damage, and either reconditioned to original specifications or replaced with a new or upgraded part. The product is then reassembled and tested to ensure proper operation.

The goal is to create an application which can be offered with a guarantee that is equivalent or better than that of the original product. Remanufacturing differs from repairing, which is a process limited to making the product operational as opposed to thoroughly restoring it.

Many steel products such as construction and farm machinery, truck and car engines, electrical motors, domestic appliances, and wind turbines are already remanufactured. Remanufacturing takes advantage of the durability of steel components. It guarantees that the energy used to create the components is preserved – as only the faulty or worn components are replaced or reconditioned. Once recertified, the application is then 'as-new' and can continue to be utilised for longer.

Steel applications are particularly well suited to remanufacturing. The technology needed to work with steel is widespread, and the tools needed are relatively inexpensive and readily available.

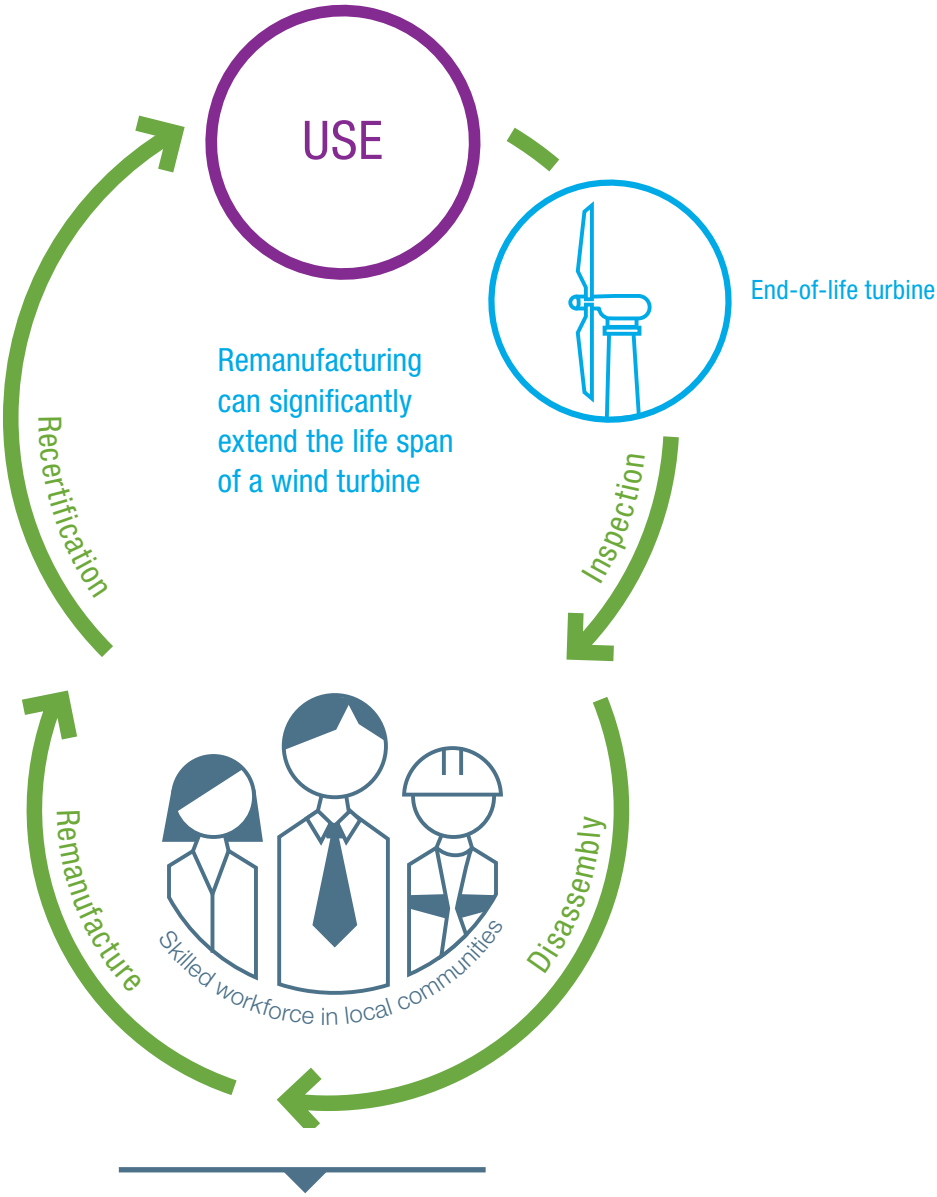
The process of restoring durable, used steel products to as-new condition also helps to create jobs in communities.

A key limitation to the success of remanufacturing is consumer behaviour. Consumers who are used to the 'make, use and dispose' linear economic model – common in developed economies – are the most reluctant to adopt remanufactured goods.

But in emerging economies, remanufacturing is a normal concept which provides many families with access to labour-saving devices that might otherwise be out of their economic reach.

The steel industry encourages manufacturers to design their products with dismantling and remanufacturing in mind. Ensuring that components are modular, standard, and easy to remove means that they are more likely to be repaired or remanufactured.

Remanufacture of steel applications: Wind turbine



BENEFITS

- Return on investment is increased significantly
- 25 to 50% cheaper for the customer
- 80% energy saving
- Substantial conservation of raw materials

CASE STUDY › Breathing new life into wind turbines

Wind power is one of the fastest-growing sources of renewable energy in the world. But demand for wind turbines is growing so rapidly that it can take up to two years for manufacturers to fulfil orders. By contrast, existing wind turbines can be remanufactured and delivered in as little as four months.

Remanufactured turbines can keep wind farms at peak capacity, long beyond their designed lifetime. In fact, remanufacturing can almost double the return on the original investment by extending turbine life by up to 20 years.

Around 80% of a typical wind turbine is made up of steel components. Various parts can be remanufactured to meet or exceed the original specifications including gearboxes, generators, bearings, and rotors.

CASE STUDY › Remanufacturing: a way of life for industrial machinery

The world's leading suppliers of machinery and equipment for construction and mining typically design their products with remanufacturing in mind. Frequently remanufactured components include engines, drive trains, hydraulics, and the tracks which move vehicles such as bulldozers.

Customers return a used component to the OEM and receive a remanufactured product in return. This product has the same guarantee as the original and is immediately available to minimise machine downtime.

Returning end-of-life components to as-new condition reduces waste and minimises the need for raw materials to produce new parts.

For more examples of **Remanufacture**, go to the circular economy section of **worldsteel.org**

RECYCLE

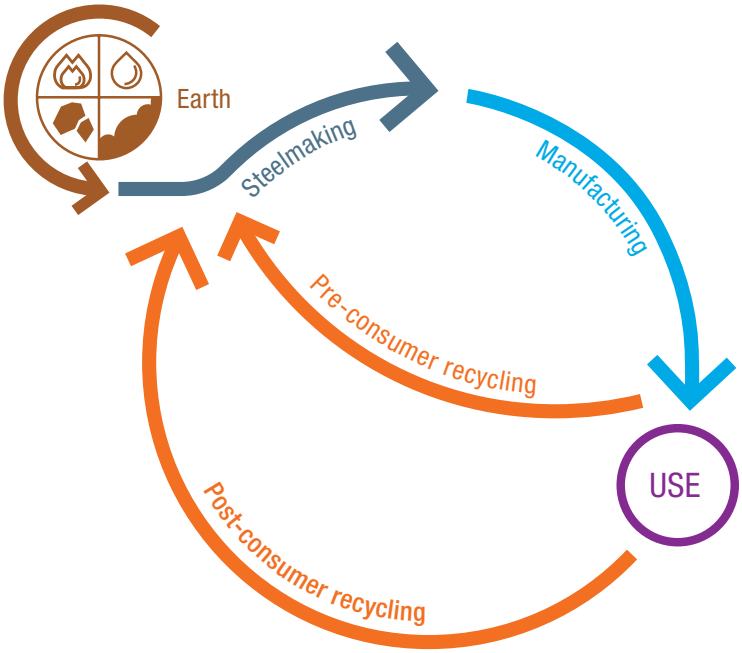
Melting steel products at the end of their useful life to create new steels. Recycling alters the physical form of the steel object so that a new application can be created from the recycled material.

Steel has been recycled ever since it was first made. All available steel scrap is recycled, over and over again to create new steel products in a closed material loop. Recycled steel maintains the inherent properties of the original steel. These properties can be modified during the steelmaking process or through mechanical processes to create the many thousands of advanced and commodity steel grades available. The quality of the steel product can also be improved on recycling.

The high value of steel scrap ensures the economic viability of recycling. With its inherent magnetism, steel is easy and affordable to recover from almost any waste stream. This is why steel is the most recycled material in the world. Around 650 million tonnes (Mt) of steel are recycled annually, avoiding over 900 Mt of CO_2 emissions[6]. This includes pre-consumer scrap from manufacturing and post-consumer scrap from steel products at the end of their useful life.

Although all available steel scrap is recycled, there is not enough scrap available to meet demand for new steel products. While many steel products such as packaging and vehicles have a short to medium service life, large-scale products such as buildings and bridges are designed to last for decades or centuries. In the future all of this material will be recycled to meet our ever-growing need for steel.

Steel recycling: Attributes and benefits



TODAY
650 million tonnes of steel are recycled every year

Steel attributes — Benefits of steel recycling

Steel attributes

- Infinite recycling without loss of properties
- Permanent material
- Easy magnetic separation and recovery

Benefits of steel recycling

- Raw materials conservation
  One tonne of steel recycled saves on average:
  1,400 kg iron ore
  740 kg coal
  120 kg limestone
- 70% Energy saving
  Recycling a single steel can saves:
  1 laundry load, or
  1 hour TV, or
  4 hours lighting (60 watt bulb)
- Job creation
  Jobs required for scrap collection, separation and recycling

CASE STUDY › Abandoned ships lead to new industry in Morocco

Over 70 disused ships are temporarily moored at Moroccan ports, hampering trade and posing an environmental hazard. With such a large stock of unused steel floating in harbours, ArcelorMittal's Sonasid site began to explore the option of establishing a local ship-breaking industry.

Beginning with a pilot project to dismantle a vessel in 2012, Sonasid was able to instill international social and environmental standards in the local industry from the start.

Sonasid's use of scrap as a raw material is expected to reduce carbon emissions by 0.8 tonnes for every tonne of steel produced. By limiting the distance the scrap needs to be transported, another 3,000 tonnes of CO_2 will be saved each year.

The dismantling process will ensure the development of an environmentally positive solution for end-of-life ships. The project also has economic benefits for Morocco, and widespread social benefits to local communities.

CASE STUDY › Gerdau improves sustainability in the scrap supply chain

South American steelmaker Gerdau began its Base of the Pyramid (BOP) project in 2007 in partnership with public sector and non-profit organisations. Through BOP, Gerdau aimed to formalise scrap recycling activities in Brazil, Chile, Peru, and Uruguay. In these countries, scrap collectors have traditionally worked independently, in poor conditions, and without access to protective equipment or social security.

During the project, over 1,200 scrap collectors received training to develop their technical and management skills. The BOP team also strengthened cooperation and communication between the different recycling stakeholders and contributed to public policy debates at both the local and national levels.

In the cities where BOP was implemented, approximately 1,630 tonnes of scrap are now correctly processed and made available for new steel production each year. The economic, social, and environmental benefits speak for themselves. Between 2011 and 2013, scrap collection grew by 228% a year while the average income of the scrap collectors rose by 155%.

For more examples of **Recycle**, go to the circular economy section of **worldsteel.org**

END NOTES

1. http://luxembourg.arcelormittal.com/Innovation/Around-the-world/
2. worldsteel estimate
3. worldsteel fact sheet: Energy use in the steel industry, October 2014
4. Sustainable Steel: Policy and Indicators 2015, worldsteel
5. Position paper: Water management in the steel industry, worldsteel 2015
6. Estimate according to BIR Global facts and Figures: Ferrous Metals: World Steel Recycling in Figures 2009 – 2013

About the World Steel Association

The World Steel Association (worldsteel) is one of the largest and most dynamic industry associations in the world. worldsteel represents approximately 150 steel producers (including 9 of the world's 10 largest steel companies), national and regional steel industry associations, and steel research institutes. worldsteel members represent around 85% of world steel production. worldsteel's mission is to act as the focal point for the steel industry, providing global leadership on all major strategic issues affecting the industry, particularly focusing on economic, environmental and social sustainability.

Steel - The permanent material in the circular economy.

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Page 10: Shipping container homes by CreativeNature_nl

Page 14: V112-3.3 MW, Denmark, courtesy of Vestas Wind Systems A/S

Page 18: Recycling bales by Matt Brown

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