Nickel INSTITUTE

NICKEL IN TOMORROW'S WORLD

Tackling Global Challenges

Content

Tackling Global Challenges

By 2050, the world's population will have increased to an estimated 9.6 billion people [1]. Providing enough food, housing, energy and water will require a concerted drive for new and improved technologies. It will be impossible to address these needs without metals such as nickel.

This publication focuses on seven key and interlinked global megatrends which will have a significant impact on individuals and societies over the coming years. These trends represent some of the greatest challenges of tomorrow that innovative technologies will help to overcome. Nickel is an essential material used in or supportive of all these technologies.

1 **United Nations, World Population Prospects, 2012. http://**esa.un.org/unpd/wpp/Documentation/pdf/WPP2012_%20KEY%20FINDINGS.pdf

Water Quality and Supply

Water is vital. One of the greatest challenges for today and tomorrow is the sustainable management of this finite resource. The World Bank calculates [2] that by 2030, water demand will exceed supply by 40%, as the growing world population demands more water for agricultural, industrial and personal use.

Food Security

The global food production system is under increasing pressure as populations increase. Industries and governments will have to find new ways of improving productivity and reducing wastage in the supply chain.

Access to Quality Healthcare

Life expectancy substantially increased during the course of the twentieth century due to advances in medicine, technology and public health. As a result, many countries around the world now have an ageing population. This presents huge challenges, including rapidly growing healthcare expenditure.

Energy Supply

Global energy demand is increasing due to the upward population trend coupled with increasing per capita consumption. Ambitious targets and concrete actions with respect to renewable energy and resource efficiency are part of the answer alongside conventional power sources. Innovation in supply and smart grids will also be important.

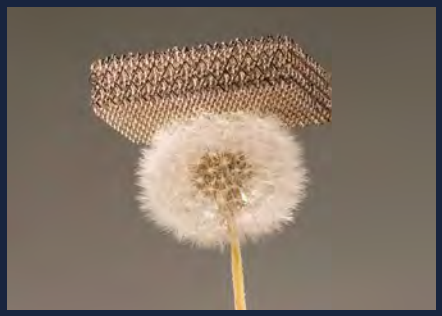
Efficient Transport and Infrastructure

Individuals and industries all rely on responsive, fast and reliable transportation. Moving people and goods around safely, economically, efficiently and with minimal impact on the environment is a key challenge. Getting transportation 'right' makes other societal goals easier to achieve.

2 **The World Bank, 2010.**
http://water.worldbank.org/publications/charting-our-water-future-economic-frameworks-inform-decision-making

Urbanisation and Quality of Life

The global population is increasingly urban[3]. By 2020, over 60% of the world's population will live in cities[4]. Rapidly expanding cities and megacities need efficient infrastructure if they are to be smarter and more sustainable – presenting significant challenges for governments and industry.



Innovation and Technology

Although quality of life is improving in many parts of the world, millions of people still live below the poverty line. Innovative technologies can help make daily lives better and more efficient, helping to address needs in both the developed and developing world.

Nickel's contribution to tackle global challenges

The best-known properties of nickel - toughness, malleability and enhanced corrosion resistance – allow superior performance in difficult environments and at extremely high temperatures. These properties are why nickel-containing materials play such an important role in providing energy, transport, food and clean water, and why they will continue to contribute to a durable and sustainable economy and society. Nickel-containing materials have the further advantage of being ideally suited for recycling because they have end-of-life value, are easily identified, and can be turned into new high quality materials with less energy. One of the best-known nickel-containing materials is stainless steel, which has now been used for over 100 years.

Less well-known properties of nickel are also being mobilised to respond to the global megatrends. Breakthroughs are increasing efficiencies and reducing emissions as well as the quantity of raw materials used to produce the goods and services we need. New applications of nickel will be in millions of parts and processes, making contributions out of all proportion to the small amounts used.

3 **United Nations Human Settlements Programme, 2009.**
http://www.unhabitat.org/downloads/docs/GRHS2009/GRHS.2009.pdf

4 **Frost & Sullivan.**
http://www.frost.com/prod/servlet/report-brochure.pag?id=M5A9-01-00-00-00

WATER Quality and Supply

Water is an intrinsic part of all our lives. Considering water globally, pictures of drought, disease, tsunamis and flooding bear witness to the power of too much or too little water to wreak havoc and destruction.

One of the greatest challenges in today's world, and indeed that of tomorrow, is the preservation of water resources. According to the UN, nearly 900 million people have no access to clean drinkable water, almost 1.8 billion live in areas where water is scarce and a further 1.6 billion live in countries which lack the infrastructure to extract water from natural sources[5].

The World Bank calculates that by 2030, water demand will exceed supply by 40%, as a growing – and increasingly urbanised - world population requires more water for agricultural, industrial and personal use [6].

'Nickel assists in virtually every step of the delivery of drinking water and making water potable.'

5
United Nations, Water scarcity, 2012.
https://www.un.org/waterforlifedecade/scarcity.shtml

6
The World Bank, 2010.
https://water.worldbank.org/publications/charting-our-water-future-economic-frameworks-inform-decision-making

Nickel & Water Supply Systems

Through its use in stainless steels and alloys for pipes, valves and pumps, nickel contributes to an efficient infrastructure providing clean water. This is vital for maintaining good health and economic productivity. Nickel's strength, toughness, castability, ease of welding and corrosion resistance are ideal for use in water treatment, transportation and distribution and make it eminently suitable in a wide variety of environments and situations.

Water treatment

Nickel-containing stainless steel has been used since 1965 for large water treatment plants with trusted performance.

As human populations increase in arid regions and in island communities with inadequate or dwindling sources of fresh water, the need for new sources of potable water intensifies. Where water is scarce, nickel-containing materials in pipes, valves and heat-exchanges help turn polluted, brackish or seawater into drinking water.

Restoration of used water to its original quality, for discharge back into the environment, or for industrial or domestic use, is another important challenge to ensure sufficient water supply to meet human needs. The use of nickel-containing materials for new facilities or refurbishing existing facilities ensures the capacity for long, reliable and low-maintenance service.

Desalination

"The use of nickel-containing materials serves people and industry as seawater is desalinated to be used as drinking water and for industrial processes"

The importance of desalination in meeting the growing demand for clean fresh water is growing. The current worldwide desalination capacity of 66.5 million cubic metres per day is projected to grow considerably by 2016[7].

The complex industrial process of turning saline water into fresh, drinkable water is used today in around 150 countries[8]. Seawater can be desalinated to provide fresh water for industrial and domestic use, either on a large scale, or on a smaller scale with reverse osmosis. The most common desalination processes use nickel-containing materials, which are recognised as the materials of choice thanks to their strength and superior corrosion resistance to seawater.

Wastewater treatment

Corrosion is a major concern at wastewater treatment plants because of the chemicals used. Thanks to the high corrosion-resistance of nickel-containing stainless steel, most, if not all, of the stainless steel pipes installed in the wastewater treatment plants built in the 1960s are still in service today.

As well as resistance to corrosion, nickel-containing stainless steel gates in treatment facilities have the advantages of lower costs throughout their entire life time, lighter weight, ease of installation and lower leakage rates. Because they weigh less than cast iron gates, the size and power of the electrical equipment needed to raise and lower them is reduced. This results in both material and energy savings.

7 **Global Water Intelligence, Top ten desalination markets, 2011.** **http://**www.globalwaterintel.com/archive/12/6/analysis/chart-month-top-ten-desalination-markets-expected-contracted-capacity.html

8 **International desalination association, 2012.** **http://**www.idadesal.org/desalination-101/desalination-by-the-numbers/

9 **SWEREA, Fighting Legionnaires' disease.** **http://**www.swerea.se/en/Start22/Press/Arkiv-Pressmeddelande/Fighting-Legionnaires-disease-with-chlorine-dioxide/

Preventing water contamination

For general distribution, pipes and valves that do not lose their integrity help maintain the quality of the water supply by preventing water loss and incursions of foreign material. This is especially important in facilities that must keep sterile environments, such as hospitals and wherever there are populations of individuals at risk. The properties of nickel-containing stainless steel allow the use of the most effective cleaning products such as chlorine dioxide and extremely high water temperatures to attain and maintain the highest hygiene and health standards. Its smooth surface also minimises the accumulation of bio-films that can become a base for bacteria such as those that lead to Legionnaires' disease [9].

Stainless steel pipes in hospitals

The Palomar Medical Center West is the largest hospital in California and one of the largest in North America.
It has very high design and construction standards. While clinical needs are foremost, the environmental and economic benefits are also significant. The project makes extensive use of stainless steel (containing an average of 60% recycled material), which was chosen for its sustainability, resistance to corrosion, and ability to maintain water integrity. Behind the walls of the hospital are over 7,300 metres of stainless steel piping, transporting both hot and cold water.

The Palomar Hospital in California shows how nickel-containing stainless steel in water distribution systems is contributing to the environmental performance of the entire structure.

'The durability and corrosion resistance of stainless steel eliminate the potential for leaks and the need for maintenance.'

Desalination plant

Water supply

The use of nickel-containing materials in distribution systems provides security to the users of water and cost-effective, efficient, low-maintenance infrastructure for water authorities, water distribution companies and building operators.

The durability and corrosion resistance of stainless steel eliminate the potential for leaks and the need for maintenance.

Reducing losses and using existing supplies more efficiently are essential to increasing water supply. The loss of drinking water during transmission can be considerable and costly, as is replacing leaking and failing infrastructure. The use of nickel-containing materials in pipes and valves prevents loss through leakage or contamination.

In old towns, especially in Europe where water mains can be hundreds of years old, leaks in pipes result in losses of clean drinking water of up to 50%[10/11]. This in turn leads to a significant waste of money. As demand for water increases, civil engineers are faced with the challenge of how to replace obsolete pipes economically. Nickel-containing stainless steel piping is often selected because it can easily be inserted into the interior of old mains, it is strong enough to withstand ground settling and earthquakes, and has an expected life of at least 100 years.

The piping systems that deliver potable water and fire-fighting capabilities in tall buildings have unique requirements. They must be able to withstand not only high pressures but the sway motion of the building caused by seismic and wind forces. As buildings grow ever taller, engineers are turning to stainless steel piping systems to meet their needs. Such systems in high-rise buildings last longer and require fewer repairs because stainless steel has the necessary strength and resistance to corrosion, and will maintain the integrity of the system for a hundred years or more.

Industrial zone, stainless steel pipelines and valves

Taipei Financial Centre in Taiwan

The Taipei Financial Center in Taiwan, the third tallest building in the world, is a prime example of the shift to high-pressure stainless steel piping systems for essential services. This 101-storey, 509-metre-high building completed in 2004 uses a nickel-containing stainless steel system for fire protection and plumbing, with stainless steel valves and pipes for hot and cold water supply.

This system provides the flexibility to withstand any seismic activity up to the strongest earthquake in a 2,500-year cycle. Designed especially for standard or thin-wall stainless steel, the system is also less costly than traditional methods of welding, flanging or threading, because it can be installed quickly using less skilled labour, and is easy to clean and maintain.

City of Toronto

The City of Toronto is upgrading its water supply system using nickel-containing stainless steel, and doing so in a way that ensures a century or more of maintenance-free delivery of high-quality drinking water.

The durability and corrosion resistance of stainless steel eliminate the potential for leaks, increase capacity and maintain the safety and reliability of the water supply. Easily formed and welded stainless steel pipes for the vertical sections do not require any internal cement mortar lining, and resistance to corrosion from both groundwater as well as the chlorinated drinking water eliminates the need for maintenance.

10 **United Nations World Water Development, 2009.**
http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR3_Facts_and_Figures.pdf,

11 **Peter Williams, 2012.**
http://www.smartplanet.com/blog/ideas-insights/lets-use-analytics-to-plug-leaky-water-pipes/139

Tapei Tower, Taiwan

New York water supply

Projects for New York City's water supply date back to 1837. The most recent endeavour (due for completion in 2020) is a $6 billion mega–project known as Water Tunnel No. 3. The New York City Department of the Environment, which manages the project, needs valves that provide low- or no-maintenance service for 100 years under conditions of 100% relative humidity. The nickel-containing stainless steel used for this project offers the best combination of corrosion resistance, lowest maintenance and best life-cycle costs of any material suitable for carrying potable water.

Earthquake Resistance

In Japan, earthquake-resistance tests have shown that stainless steel piping systems (joined by mechanical couplings) exhibit the required air tightness and do not leak.

KEY FACTS

Worldwide investments in safe drinking water and water sanitation could lead to healthcare savings of up to US$ 7 billion per year for health agencies and US$ 340 million for individuals[12]

Nickel-containing stainless steel's corrosion-resistant properties allow the use of the most effective cleaning products and extremely high water temperatures

The use of nickel-containing materials in pipes and valves prevents losses due to leakage or contamination

12 **World Health Organization, 'Safer water , better health' 2008. http://**whqlibdoc.who.int/publications/2008/9789241596435_eng.pdf

FOOD Security

The global food production system is under increasing pressure due to a number of issues including population growth, water scarcity, soil loss and degradation, salination, deforestation and climate change.

The United Nations Food and Agriculture Organization (FAO) estimates that a third of the food produced for human consumption – 1.3 billion tonnes – is either spoiled (during harvesting, processing, storage, or transportation to market) or thrown away[13]. Whilst in the industrialised world, consumers are responsible for most food waste, in the developing world most wasted food is lost or spoiled in the early stages of production. More than 150 kilograms per person per year are lost in Africa, Asia and Latin America combined[14].

Two of the solutions the FAO advocates are: better education and co-operation among small-scale farmers; and improving access to the tools that are needed to process crops safely, cheaply and efficiently.

When food is wasted, the FAO study warns: *"huge amounts of the resources used in food production are, in effect, wasted as well."* For small-scale farmers in developing countries who already live on the margins of food insecurity, more efficient handling and processing of food will help reduce these losses.

Industries along with governments will have to find new ways to ensure good quality of life and access to food within the limits of natural resources.

'At every step of food processing, manufacturing, storage and distribution, nickel-containing stainless steels provide machinery and equipment that are robust, easily cleaned, and easily disinfected.'

13 **FAO, Global food losses and food waste, 2011. http://**www.fao.org/docrep/014/mb060e/mb060e00.pdf

14 **FAO, Global food losses and food waste, 2011. http://**www.fao.org/docrep/014/mb060e/mb060e00.pdf

Nickel & Food

Nickel in stainless steel makes the production, preparation and consumption of food and drinks safer. For over 100 years, stainless steels have been associated with food processing for the best of reasons: durability and safety.

The increasing amounts of food consumed around the world – vegetables, cereals, meat – would be inconceivable without nickel-containing stainless steels for producing, storing, processing, cooking and transporting them.

Stainless steel is an ideal material because it does not affect the taste and appearance of food products, does not easily rust, and the surfaces are easy to clean and sanitise.

Stainless steel's strength and durability, combined with sanitation measures, reduce losses and wastage caused by spills (due to pipe or equipment failure) and spoilage due to contamination.

Industrial pipelines

'The global standard material that allows the consistent quality production of safe food is nickel-containing stainless steel.'

Grain warehouse

15 **FAO, Global food losses and food waste, 2011. http://**www.fao.org/docrep/014/mb060e/mb060e00.pdf

Reduced food losses

Reducing the loss of food that currently accounts for approximately 215 kilos of food per person per year[15] globally in the food distribution system will help to reduce hunger, improve returns for farmers, and ease pressure on the land.

The flexibility of nickel-containing stainless steel allows engineers to construct increasingly more efficient food processing machinery. Because nickel-containing stainless steels and alloys can be easily shaped, cast or welded and contribute toughness, strength and enhanced corrosion resistance, industrial processes and equipment can be optimally designed and provide many years of productive use.

After harvesting or slaughter

After harvesting or slaughter, there are many ways for the producer to maximise recovery, maintain quality and add value to the raw product. This can be as simple as washing but can also include husking, sorting, drying, chopping, butchering and filleting.

At every step, basic grades of nickel-containing stainless steels provide machinery and equipment that are robust, easily cleaned, and easily disinfected.

Storage and transportation

Storage is crucial for maintaining the quality of food. Crops may be awaiting transportation and processing or may be held for release onto the market over time to assure continuous supply. During that time they are vulnerable to moisture or contamination by infestations of insects and rodents that degrade the quality of the crops. For some crops, temperature control is essential to slow down or prevent spoilage.

To tackle these concerns there are bins, coolers, tanks and tanker trucks, chutes, sieves and hundreds of other tools and pieces of equipment for which nickel-containing stainless steel is the best and often the only acceptable choice.

Food Safety

Nowadays, expectations of hygiene and health standards in food processing are understandably very high.

"It is estimated that each year food-borne disease causes approximately 76 million illnesses, 325,000 hospitalisations and 5,000 deaths in the USA alone [16].

Contamination is the enemy of food safety. However, food manufacturing and processing is an extraordinarily large and complex industry. Typically, a variety of food products are produced at the same facility. This requires strict segregation of food materials and that the machinery and vessels are perfectly clean before switching to a different food formulation production run. All this requires materials and surfaces that do not encourage colonisation by bacteria and which can be aggressively and repeatedly cleaned and sanitised. The global standard material that allows the consistent quality production of safe food is nickel-containing stainless steel.

Milk production factory, Sweden

Milk and dairy products

China has joined the front ranks of the world's dairy producers. Milk output in 2009 reached 37.4 million tonnes, making China the world's third-largest milk producing country [17]. This has resulted in a dramatic increase in the use of nickel-containing stainless steels in the handling and processing of Chinese milk and milk products throughout the entire production, storage and distribution process.

The use of stainless steels in milk production processes helps to guarantee safe and high quality products. Furthermore, increased efficiencies thanks to less spoilage have resulted in higher availability and lower overall costs for milk products. Nickel-containing stainless steels have additional advantages such as long service life, ease of sourcing and fabrication, and do not influence product flavour.

Retail and domestic use

Stainless steel water bottles were created to promote a green and sustainable option through their life cycle. They last longer and are easily recycled into new stainless steel products. These bottles are also highly popular for health and safety reasons. Stainless steel is commonly used in other food contact applications such as cutlery, cookware and commercial food processing equipment. They are easy to clean, do not leach harmful chemicals and are an inhospitable surface for bacteria.

16 **WHO, Foodborne disease in OECD countries, 2003.**
http://www.who.int/foodsafety/publications/foodborne_disease/oecd_fbd.pdf

17 **FAO statistics, World total milk production in 2009.**
http://www.fao.org/docrep/012/ak341e/ak341e10.htm

18 **Nickel Institute.**
http://www.nickelinstitute.org/en/NickelUseInSociety/MaterialsSelectionAndUse/FoodAndBeverage/Guidance.aspx

19 **Euro Inox, 2009.**
http://www.euro-inox.org/pdf/health/WhenHealthComesFirst_EN.pdf

Food growth and processing

Successful growth and development of green plants require nickel. The amounts required are tiny and sufficient nickel is usually available naturally in all soils. There are exceptions however, and for specific crops on certain types of soils, it is necessary to supplement the amount of nickel available to the plant through fertilisation.

Plant growth – Nickel as micro-nutrient

Some plants like the pecan tree are especially reliant on the presence of nickel. Nickel deficiency in pecan trees can produce physical deformations, reduced crop yield and reduced survivability. This can be cured by spraying a mixture with soluble nickel directly onto the foliage to maintain health and productivity.

All food producers, from the smallest fair trade farmer to the largest agri-business, are seeking to maximise their output as they help to meet the challenge of feeding the world's population. Nickel-containing stainless steel helps in mulitiple ways, including making affordable and appropriate technologies accessible to farmers, co-operatives, and small-holders in developing countries.

Cocoa beans - use and production

Cocoa production is a mainstay for an estimated 800,000 rural families in Ghana and accounts for a third of the country's exports. Researchers at the Ghana University of Mines and Technology have designed a machine that opens the tough pod that surrounds the cocoa beans, a laborious task usually done by hand with the aid of a machete or a knife.

The design specifies the use of stainless steel cutting blades to ensure hardness and corrosion resistance. The machine promises to boost quality and productivity. Moreover, it is simple and cheap to assemble, putting it within the reach of rural farmers.

Raw sugar production and export

Among South Africa's chief exports is raw sugar. Equipment to process sugarcane makes extensive use of stainless steel components to reduce downtime caused by breakdowns and worn-out parts. Stainless steel, for example, is one of the materials specified for centrifuge mesh screens and filters. Meanwhile nickel-containing materials are also used in the fabrication of entrainment screens designed to recover sugar from exhaust vapour which would otherwise be lost during processing.

KEY FACTS

Nickel-containing stainless steel has proved to be 10 times more hygienic than other food contact surfaces, such as plastics, composites and enamelled steel [18/19]

The many advantages of nickel-containing stainless steel make it an essential – and unsubstitutable – material in milk production

For decades, nickel-containing stainless steels have been the standard industrial and common domestic food contact materials for many reasons, including durability and safety

ACCESS to Quality Healthcare

Life expectancy substantially increased during the course of the twentieth century due to advances in medicine, technology and public health. As a result, many countries around the world now have an ageing population. This presents huge challenges, including rapidly growing healthcare expenditure.

Spending on healthcare is increasing in line with economic growth and will continue to rise. Some markets and sectors will represent significant opportunities for healthcare companies around the world. Manufacturers of healthcare products will have to adapt their models in order to adjust to local needs and customs and it is predicted that demand for traditionally 'western' diseases will soar in emerging markets [20].

'The qualities and high performance of nickel in nickel-containing stainless steel play a vital role in the manufacture of advanced drugs and medical materials and equipment.'

20 Peter Turner, MCI Group, Global MegaTrends, 2010. http://growglobally.org/?p=497

Nickel & healthcare

Nickel-containing materials and products are part of society's response to the enduring issue of health.

Many essential surgical materials and equipment involve nickel. Surgical materials must be easily sterilised and must not harm human health. These are key properties of nickel-containing stainless steels which can be treated repeatedly with aggressive disinfecting chemicals without suffering deterioration. This is particularly important in hospitals and medical centres where harmful organisms can and do spread easily.

Healthcare evolves continuously and nickel-containing stainless steels continue to help make medical innovation possible and medical procedures efficient.

Medical instruments

Recent medical developments have seen a rise in minimally invasive surgery, done with only a small incision or none at all. Benefits to patients include less body trauma, faster recovery times, shorter hospital stays, and lower healthcare costs. Consequently, hospitals require more instruments that are designed for these procedures. Such instruments are growing in complexity even as they shrink in size. But nickel-containing materials, including those found in various sensors, remain vital to the surgical operating theatre.

Medical instruments and all operating and human contact surfaces require stringent sterilisation and cleaning. Nickel-containing stainless steel can withstand these sterilisation processes while remaining strong and resistant to corrosion, giving costly instrumentation a longer lifespan without loss of quality.

Surgical instruments come in different shapes and forms – from simple needles used for sutures, to more complex instruments providing suction. Nickel-containing stainless steel has excellent formability and is easy to weld.

The finish of the tool's surface is also extremely important in the medical world because the finish affects biocompatibility (whether a material is suitable for use with body tissue). Finally, nickel-containing stainless steel is not magnetic and so will not interfere with any sensitive electronics.

'Nickel alloys have a long history of use in implants and have made important contributions to the quality of life of millions of people.'

Needles

Hypodermic needles are a workhorse in the medical world, delivering drugs and inoculations, drawing blood and other body fluid samples. The needle itself must be strong, sharp-tipped and sterile. The exceptional workability, strength and flexibility of stainless steel has allowed needles to be made sharper and thinner and therefore better tolerated by patients of all types and ages.

The emergency injection of a drug to counter severe allergic reactions provides one example of a lifesaving application of hypodermic needles. Epinephrine is crucial for treating life-threatening symptoms triggered by allergic reactions to certain foods, bee or wasp stings, or other allergens. An auto-injector is a form of first aid which delivers the epinephrine immediately into the muscle of the thigh, through clothing if necessary.

Stainless steel needles are reliable, safe and ready-to-use due to the durable, hygienic and corrosion-resistant properties of nickel.

Drug manufacturing

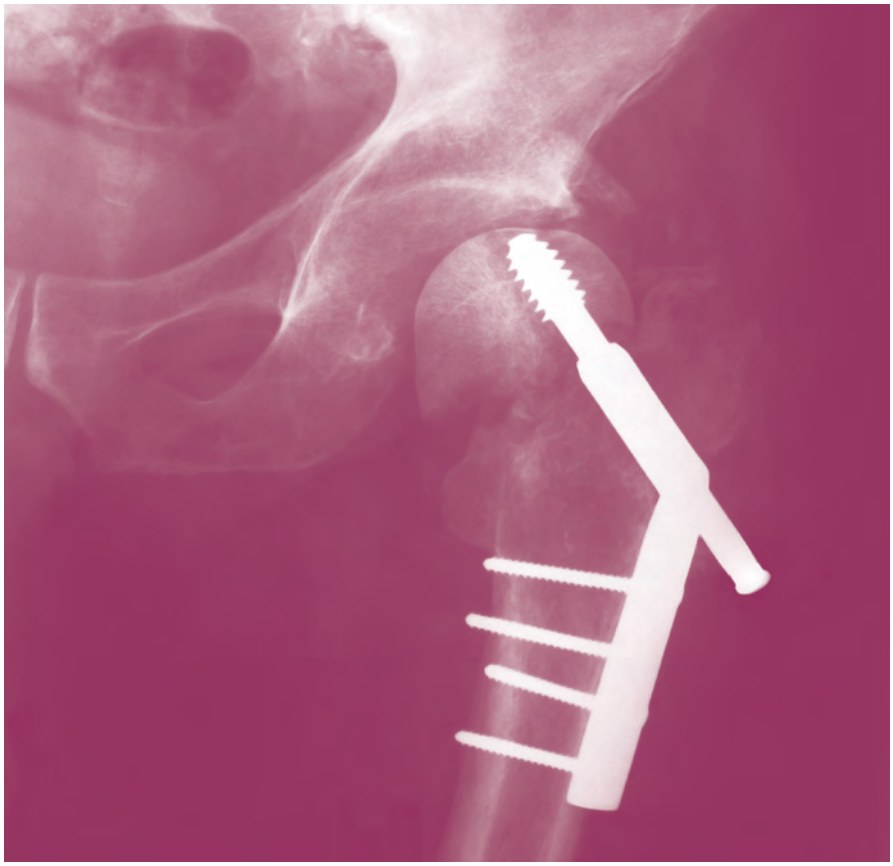
For all forms of medicine manufacturing, the safety, purity and potency of the products is essential. There are many elements that have to work together to achieve this. One of them is the use of nickel-containing stainless steel to provide machinery and tubing surfaces that are smooth, easy to clean and sanitise and, if necessary, to decontaminate. These surfaces have to be resistant to wear and erosion through contact with ingredients that can be abrasive and aggressive due to their chemical compositions. The qualities and high performances imparted by nickel in nickel-containing stainless steel play a vital role in the manufacture of high-quality drugs.

Cost effectiveness

As in any industry, choosing an alloy involves evaluating its cost-effectiveness. If an industrial batch of medicines or their chemical ingredients has to be discarded due the presence of corrosion products (such as rust) or contamination of any kind, the production cost, potential revenue and profit are all lost. Avoiding the loss of even one batch easily covers the extra capital cost of higher grade, more corrosion-resistant materials.

Medical implants

Longer human life expectancy brings an increased need for medical procedures along with an increasing need for different and complex implants. Nickel alloys have a long history of use in implants and have made important contributions to the quality of life of millions of people.



Orthopaedic implants

Orthopaedic implants such as knee, hip and other joint replacements, and the associated screws, plates and wires, are typically made from stainless steels. Long-term clinical experience with stainless steel implants confirms that it has acceptable biocompatibility with the human body. Because of this, stainless steel is one of several control materials against which new materials are compared for bio-compatibility. A very low nickel implant grade can be used by patients who have a particularly low tolerance to metal.

Vascular stents

Another common implant is a 'stent' - a small mesh tube used to keep arteries open and often used in the treatment of coronary artery blockages. These stents are made from a nickel-titanium alloy (Nitinol®), because of the alloy's shape-memory or 'superelastic' properties. Each year in the United States alone, more than one million people undergo an operation called angioplasty to treat coronary heart disease. Patients have a 90% long-term success rate when treatment includes an anti-bacterial coated Nitinol® stent. Prior to the advent of this technology, doctors performing angioplasty without stents could expect only a 60% success rate.

Magnetic fields to target tumours

Since the beginning of cancer nanotechnology, researchers have thought about using magnetic fields to increase the concentration of drug-loaded iron oxide nanoparticles that reach the tumour. However, magnetic fields drop off quickly with distance, making it almost impossible to consider such an approach for tumours located more than a few centimetres from the skin. To solve this, researchers have succeeded in using an external magnetic field and an implantable magnetisable nickel mesh. When the mesh is implanted near a tumour a strong local magnetic field is created that holds the drug-bearing nanoparticles at a specific location. Depending on the size, location and responsiveness of the tumour to drug treatment, this technique allows a less invasive surgical procedure or a more effective management of non-operable tumours.

KEY FACTS

Surgical equipment and instruments have to be reliable, safe and ready-to-use. Nickel-containing stainless steel meets these needs thanks to its durability and hygienic as well as corrosion-resistant properties

The success rate of coronary surgeries has increased from 60 to 90% with the development of a stent made out of Nitinol®, a nickel-titanium alloy

Stainless steel is one of several control materials against which new materials are compared for bio-compatibility

Shielding

Imaging tools available to medical specialists continue to increase in both power and sensitivity. Patients, machine operators and the machinery itself require protection.

Sensitive electronics can be damaged or destroyed by strong magnetic fields. Equipment has been known to malfunction or fail as a result of electromagnetic interference from cell phones and other electronic devices. As electronics proliferate and become more compact and portable, designing fool-proof shielding solutions for the healthcare sector is becoming more of a challenge.

The electromagnetic properties of nickel are used to shield sensitive medical equipment from outside sources of electromagnetic interference and prevent leakage of electromagnetic waves from medical equipment. This protects healthcare workers and patients. For low levels of protection there are nickel-containing paints and nickel-impregnated fabrics. Serious shielding for magnetic resonance imaging (MRI) machines and machines used for magnetoencephalography (brain imaging) and magnetocardiography (heart imaging) is provided by a number of nickel-iron alloys that contain up to 80% nickel.

URBANISATION and Quality of Life

Globally, and for the first time in human history, more people live in cities than in the countryside [21]. By 2020, over 60% of the world's population will live in cities [22] and by 2030, the majority of inhabitants in all developing regions including Asia and Africa are expected to live in urban areas [23].

The currently growing urban population is leading to the rapid expansion of cities and megacities, some of which have already started to change how they are organised. Integrated urban management requires a vision of the future that incorporates designs and structures that are well thought-out and reflect the realities of life in that particular city.

These transformations require extensive improvements in infrastructure including information and communication technologies as well as in building and construction.

The need for efficient infrastructure for smart, durable and sustainable cities presents challenges for governments and industry. Tensions between limited resources on the one hand, and growing needs on the other, have never been greater. In addition, existing infrastructure is crumbling because it is ageing, often poorly built and stressed by increasing loads.

'Stainless steel containing nickel allows imaginative and cost-effective architectural solutions, making it possible to build multi-functional and smarter buildings and infrastructures.'

21 **United Nations Human Settlements Programme, 2009.**
http://www.unhabitat.org/downloads/docs/GRHS2009/GRHS.2009.pdf

22 **Frost & Sullivan, 2010.**
http://www.frost.com/prod/servlet/report-brochure.pag?id=M5A9-01-00-00-00

23 **United Nations. 'State of the World's Cities', 2010.**
http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2917

Nickel & urbanisation

A 2012 report by the International Federation of Consulting Engineers, on the state of the world's infrastructure explains the increasingly complex challenges:

"Infrastructure needs to deliver its service over its lifetime, efficiently and reliably, and it needs to be adaptable and resilient to change and shock. This implies assets with a long useful life, with minimum reliance on non-renewable resources, with maximum benefit to society and the environment and which contribute to, rather than endanger, economic prosperity in the long term[24]."

Materials must be chosen according to their full life-cycle cost of construction, use, and final disposal and recycling. The use of nickel-containing materials is supportive of this holistic approach as they are strong, durable, resistant to corrosion, and easy to form in different shapes.

Stainless steel containing nickel is a pre-eminent material in building construction. It is also popular in high-traffic public transit, security and other architectural applications. It allows imaginative and cost-effective architectural solutions, making it possible to build multi-functional and smarter buildings and infrastructures.

Nickel-containing stainless steel typically contains 60% recycled material. Furthermore, at the end of the structure or infrastructure's life, more than 70% of post-consumer nickel-containing scrap is reclaimed and recycled. This high recycling rate is driven by nickel's high economic value rather than legal requirements. Overall, considerable natural resources are saved for future generations. Energy use and carbon dioxide emissions are also significantly reduced when stainless steel is re-manufactured using scrap metal.

Nickel-containing materials make our urban environments safer, attractive and durable. The many properties of nickel are enabling the technologies that will improve the quality of life of individuals and the sustainability of urban societies.

'Nickel-containing materials make our urban environments safer, attractive and durable.'

24 **International Federation of Consulting Engineers, 2012. http://**fidic.org/sites/default/files/sow2012-0822-electronic.pdf

Durable structures

The strength of nickel-containing materials allows the use of materials to be minimised at the construction stage. During the maintenance phase, nickel allows further material savings as there is no need for paint, sealants, or cleaning chemicals. There can also be significant material and financial savings when it is not necessary to refurbish prematurely or rebuild core infrastructure elements such as bridges and elevated highways.

The following projects illustrate the exceptional performance and cost-effectiveness of nickel-containing stainless steel. As an architectural design material, it is ideal for sustainable designs where long-term performance is expected.

Eastern Coast of Australia

Warm marine environments are very demanding on materials, limiting the service life of structures. For critical elements such as joint interfaces for concrete works, bolts, brackets and cleats for boardwalks, and high-use facilities like rubbish bins, nickel-containing stainless steel is the appropriate choice. The initial additional cost of stainless steel is justified over the life of the structures[25]. There is no one material that is appropriate for all uses at all times, but for structures with a design life of 19 years or more, stainless steel is the first choice in terms of capital cost alone.

Barcelona, Spain

The coastal city of Barcelona is increasing the size of its metro system by one third. For this project, nickel-containing stainless steel mesh is being used. The grade's corrosion resistance is well-suited to the city's atmospheric characteristics, keeping the maintenance requirements to a minimum.

Stainless steel mesh is aesthetically pleasing, yet is durable, strong and highly fire resistant. It is transparent enough to create a sense of lightness and open space, yet can be used to conceal unattractive features, such as concrete ceilings. The result is attractive metro stations that should retain their pleasing appearance for years to come.

Japan

Future high-rise buildings will be characterised by energy conservation, harmony with the surrounding environment, earthquake resistance, and easy maintenance. As a result, the use of long-lasting nickel-containing stainless steel in residential high-rise piping systems is being expanded throughout Japan. The piping systems in shared areas can be considered part of the 'skeleton' of the residential structure. Stainless steel valves are used because of their durability, which reduces the need for repairs and expands the life of the entire piping system. The shift toward durable piping, with the result of fewer leaks, breaks and need for replacements, will help reduce carbon dioxide emissions as well as overall energy consumption.

Architect, Eero Saarinen and structural engineer, Hannskarl Bandel revolutionised the world's concept of large sculpture with their design for the 192-metre Gateway Arch in St. Louis, Missouri, U.S.A. The Gateway Arch remains the world's tallest monument.

25 **Griffith University, 2011. http://**www.nickelinstitute.org/~/Media/Files/Magazine/Volume26/Vol26-01Jun2011.pdf

Smart buildings in liveable cities

The concept of 'liveability' is different for every citizen. The difficulty of responding to these diverse views is amplified by rapidly changing and growing demographics. Providing citizens with appropriate building infrastructures requires urban solutions using high quality materials.

For the 1964 World's Fair in Flushing Meadows Park, New York, Gilmore Clarke used nickel-containing materials to create the Unisphere, a 43-metre-tall, 370-tonne globe. It is one of the most iconic and identifiable sculptures in the world, having appeared in numerous films, TV shows and music videos.

Liveable cities are cities that may be densely populated per hectare but are easy to move around in. They have reliable supplies of water and energy. Their public institutions and facilities are not a drain on public finances because of a constant need to maintain, repair or replace infrastructure that is failing. This also avoids upheaval, dislocation, loss of time, and diversion of traffic. The qualities of nickel-containing materials – especially their strength, toughness and enhanced resistance to corrosion – reduce both the social and financial costs of the things that make city living desirable.

Quality of life: art in city environments

Over the ages, architects and sculptors have sought materials that can withstand the elements and last for generations. The 1930s-era buildings of New York City, for example, make use of the properties of stainless steel and other nickel-containing alloys. From these world-renowned structures to more modest ones found in every urban centre, stainless steel will continue to capture the public's imagination for generations to come.

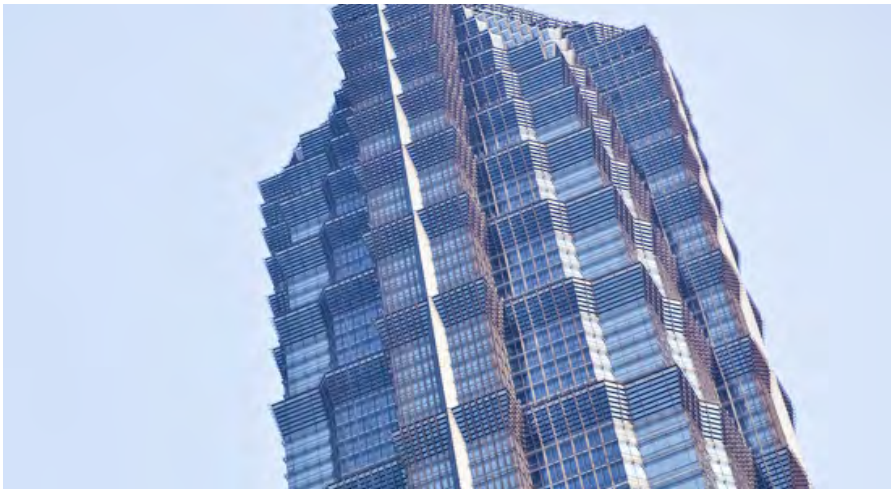
'The qualities of nickel-containing materials – especially their strength, toughness and enhanced resistance to corrosion – reduce both the social and financial costs of the things that make city living desirable.'

Quality of life : effective use of land

Nickel-containing materials have the potential to allow the use of a space that would otherwise be unavailable because of environmental considerations. The opening of Haneda Airport's 'D' runway in October 2010 has ensured the continued success of this airport, now ranked the second busiest in Asia and the fifth busiest in the world. The new runway was built at the mouth of the Tama River in Tokyo Bay. There were concerns about erosion or deposition if the river course were changed. To minimise its effect on water and tidal flows, a third of the runway is a steel pier that allows the free movement of the river and Tokyo Bay waters. Nickel was chosen as a core material to help protect a large amount of structural steel from corrosion, using methods that do not require difficult and expensive repairs. As part of the design phase of the project, a life cycle cost evaluation was undertaken that showed the need to use very thin stainless steel sheets with high quality welding. Not only did this contribute to capital cost savings, it will also ensure long-term durability.

The expansion of the existing airport facilities saved money and brought economic benefits to the city. The expansion maintained the liveability of the city and surrounding communities by avoiding the social, political and financial impacts of having to build another airport.

Nickel-containing stainless steel is also used in two of the tallest towers in the world, the Petronas Twin Towers in Kuala Lumpur and the Jin Mao building in Shanghai. Its strength and versatility is absolutely essential in both the internal and external construction of these architectural masterpieces.



Jin Mao building in Shanghai.

KEY FACTS

60% of all nickel is used to make stainless steel [26] and more than 70% of all stainless steel is currently recycled [27]

The strength of nickel-containing materials allows a minimum of material use at the construction stage

For structures with a long design life in demanding environments, stainless steel is the first choice in terms of capital cost alone

26 **Nickel Institute.** **http://**www.nickelinstitute.org/en/NickelUseInSociety/MaterialsSelectionAndUse/Ni-ContainingMaterialsProperties/StainlessSteels.aspx

27 **Center for Industrial Ecology, Yale University, 2010.** **http://**www.worldstainless.org/Files/issf/non-image-files/PDF/2010_Global_stainless_steel_cycle_exemplifies_Chinas_rise_to_metal_dominance.pdf

ENERGY Supply

Global energy demand is rising due to population growth and increased per capita use of energy. Demand for all sources of energy is forecast to escalate significantly by 2035[28]. At the same time, the geographical pattern of energy consumption is shifting.

As a result, fossil fuel prices are likely to become even more volatile and unpredictable. It will take time before renewable energies can make a significant contribution to world energy use, even though their use is growing rapidly [29]. Ambitious targets and concrete actions for energy, including renewable energies, and resource efficiency are needed.

The rise in energy consumption will certainly lead to a global increase in carbon emissions. In the long term, emissions could cause an average global temperature increase of 3.5°C [30].

Climate change directly impacts all the other megatrends discussed here. More sustainable lifestyles, renewing and restoring damaged ecosystems, smart cities and information and communication technology innovations will be key to addressing this issue.

The innovations required to meet the challenges of climate change and increasing demand for energy also bring business opportunities. Responses to global warming include shifting patterns of energy production, and new ways to achieve greater efficiency in the production, transmission and use of energy. Not yet widespread but emerging is the question of storage of energy between periods of peak production and periods of peak demand. The International Energy Agency anticipates that investments in energy supply infrastructure will approach some US$38 trillion, with two-thirds of this expenditure occurring in the developing world [31].

'Nickel plays a crucial role in the production of renewable energy, enabling such technologies to be a central part of the world's efforts to respond to climate change.'

28 **International Energy Agency, World Energy Outlook.**
http://www.iea.org/publications/freepublications/publication/English.pdf

29 **CSIRO, Our Future World, 2010.**
http://www.csiro.au/en/Portals/Partner/Futures/Our-Future-World-report.aspx

30 **International Energy Agency, World Energy Outlook, 2011.**
http://www.iea.org/publications/freepublications/publication/English.pdf,

31 **KPMG, Sustainable Insight, 2012.**
http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/sustainable-insight/Pages/sustainable-insight-expect-the-unexpected.aspx

Nickel & Energy

Nickel and nickel alloys are crucial to all aspects of the global energy economy. Over the past century stainless steels have played a key role in the extraction and generation of fuels and electricity, and are increasingly needed to produce 'greener' energy. It is clear that society's future depends on innovative and renewable energy sources. Transfer of existing knowledge and technologies to new energy sectors will become increasingly important. Nickel-containing alloys, with their combination of strength and corrosion resistance, will play a key role in this demanding environment, regardless of the technology used.

Renewable fuel technologies require more metal. According to a study by Leiden University [32], the provision of raw materials including nickel "would have to be scaled up considerably in order to fulfil the demand for photovoltaic solar panels, biomass and wind".

High-efficiency heating systems

Approximately 60% of the energy required to run an average modern home in advanced economies is used for heating and cooling. The need to save energy and ensure that homes are as energy-efficient as possible is now universally accepted.

Condensing furnaces and boilers

The highest efficiency furnaces and boilers on the market today are those called 'condensing'. These systems use 35% less energy than a standard model. Condensing furnaces and boilers feature additional advanced heat exchanger designs to extract more heat from the flue gases before they are emitted from the chimney. These heat exchangers are often made from nickel-containing stainless steel to withstand the corrosive nature of the acidic gas and liquid condensation. This ensures that heating systems are not only energy-efficient, but also low-maintenance.

Renewable energies

Nickel and nickel alloys play a crucial role in the production of renewable energy, enabling clean power to be a central part of the world's efforts to respond to climate change.

Wind power

Horizontal-axis wind turbines operate by capturing the wind's kinetic energy and turning it into mechanical energy. Most of the components of modern wind turbines – the shafts, rotor hubs, gears and base plates – are cast in ductile iron. Nickel is added in the casting process to ensure that the turbine can resist low temperatures, which sometimes reach minus 20°C. Nickel is one of the few elements that strengthens the iron casting without simultaneously making it brittle. A single turbine, composed of 45 tonnes of iron castings, generally contains close to half a tonne of nickel. Wind energy has a promising future and nickel alloy steel castings help to make this future a reality.

Solar Power Station, USA

32 **René Kleijn et al., Metal requirement of low-carbon power generation, 2011.**
http://static.euractiv.com/sites/all/euractiv/files/Material_Requirements_Low_Carbon_Power_Kleijn.pdf

Solar power

Solar energy is becoming more widely used around the world. But two key challenges remain: how to store the energy created during the day so it can be used through the night; and how to dispatch the energy to where it is needed. Both of these problems can be solved by coupling concentrated solar power with molten salt, using nickel-containing stainless steel. This type of solar power technology concentrates the sun's power to create steam, which turns a turbine to make electricity. Molten salt is a heat storage medium that retains thermal energy very effectively over time. It remains in a liquid state throughout the plant's operating cycle, even at temperatures greater than 500 °C (the temperature reached by the most efficient steam turbines). Nickel-containing stainless steel tubes, valves and vessels are used throughout the process because their properties ensure that the equipment can withstand high operating temperatures and the corrosive properties of salt.

Hydro-Electric Power

The Xiangjiaba Hydro Generating Station will be China's fourth-largest hydro-generating facility when completed in 2015. The use of nickel-containing materials has made possible the engineering advances that support such large-scale efficiency.

The runners that sit on top of the generators receive water from penstocks and give the flow water its initial critical spin. Nickel-containing stainless steels allow runners to be designed and manufactured to the highest tolerances as each runner is built to maximise the flow rates and pressures specific to the installation. Only in this way are the highest efficiencies achieved and the best use made of the kinetic power of the water flow. In addition, the toughness of the alloys minimises erosion and prolongs the life of optimum angles and curves of the runners.

Ethanol production

Renewable ethanol is an increasingly used alternative to conventional fuels. One particular second-generation biofuel called cellulosic ethanol can be produced from any plant material including grain, straw, grasses and trees – even municipal waste. Cellulosic ethanol is particularly popular because it reduces green-house gases by more than 85% compared with petroleum-based fuels.

However, these plant materials require pre-treatment processing before they can be converted into a useful form of ethanol. Many of these processes involve harsh environments and corrosive materials – a common pre-treating agent is sulphuric acid. The production equipment that handles this processing must therefore be extremely durable and corrosion-resistant. Nickel-containing stainless steels and higher nickel-containing alloys are the preferred materials.

Hydrogen

Hydrogen and fuel cells are innovative alternative sources of energy. Effective production of hydrogen through electrolysis of water relies on platinum that acts as a catalyst. But platinum is extremely rare and expensive. In order to meet energy and environmental challenges, researchers have developed a promising replacement catalyst formulation containing nickel, which delivers performance similar to platinum.

The rotor of the 1st generating unit of the Xiangjiaba Hydro-electric dam is made of 2100 tonnes of martensitic stainless steel
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Nuclear power

Nickel-containing stainless steel and nickel-base alloys are used primarily for their strength and resistance to corrosion in nuclear power plants. A typical reactor uses up to 20 different nickel alloys for components such as the internal elements of the reactor, tubes in the steam generator, and piping for coolants and heated water.

Cooling towers of nuclear power plant

New generation nuclear reactors

Some original nuclear reactors used carbon steel piping in their construction and these reactors are now suffering from corrosion. The new generation of nuclear reactors will benefit from the lessons learned from past experiences when it comes to choosing materials that are appropriate to the application and operating environments.

Clean coal

Burning coal is one of the largest sources of air pollution and carbon dioxide emissions. New technologies are in place to ensure coal power plants emit the lowest possible levels of sulphur dioxide, carbon dioxide and particulates. Stainless steel and nickel alloys are used, for example, in 'wet scrubbers' for coal-fired power plants to capture the mercury present in the coal which is released when the coal is burnt. Most wet scrubbers are constructed using nickel-containing alloys because of their strength and resistance to corrosion in the hot and acidic atmospheres of chimneys.

Carbon capture and storage

Considerable research and development is being put into carbon capture and storage (CCS) technology in order to capture and fix in solid form the carbon that would otherwise be added to the atmosphere. The action of "fixing" the carbon – mineral carbonation – can involve corrosive high pressure atmospheres and temperatures higher than prevailing in chimneys. These conditions are best managed through the use of high nickel alloys.

'Nickel plays a crucial role in the production of renewable energy, enabling clean power to be a central part of the world's efforts to tackle climate change.'

Batteries

The chemistries of rechargeable batteries are evolving quickly, with different battery technologies emerging including lithium ion, metal hydride and sodium-based, among others. Most contain nickel in some form and are used in applications such as cordless equipment, mobile phones, laptops and digital cameras, cars and as back-up power units.

Rechargeable nickel metal hydride batteries tend to last much longer than standard alkaline batteries and can be re-used hundreds of times, saving money over the long run and helping to protect the environment.

In addition to often being an active part of the battery chemistry, nickel is also a critical component of circuit breakers, which are the safety mechanism in these batteries. A combination of nickel and resin forms a small sheet used in the circuit breaker. The circuit breaker maintains safe levels of voltage and current during charging and discharging.

Emerging storage batteries technologies

Sodium-metal halide batteries were first invented in the 1940s. Now, with nickel as the active metal, this battery chemistry is being perfected and proving to be safe, energy dense, scalable in size and voltage, rechargeable over thousands of cycles and is entirely recyclable at end-of-life. It is likely to find many industrial applications and especially useful in capturing and storing energy produced through wind, solar, tidal and other such power generation sources, a development that will make such non-carbon energy sources more viable and desirable.

Recycling batteries

At the battery's 'end-of-life,' it is important that it be recycled. Recycling batteries allows important materials such as nickel to be re-used and reduces the demand for new mined materials. This not only reduces demand for resources, it also helps to conserve energy.

KEY FACTS

A large wind turbine generally contains 500 kg of nickel.

Nickel is used in new energy solutions such as fuel cells, concentrating solar power, and cellulosing ethanol.

High efficiency heating systems depend on the corrosion-resistant properties of nickel containing stainless steel.

Sulphuric acid production

Sulphuric acid is produced in larger volumes than any other chemical in the world. In fact, the industrial strength of a nation is often gauged by its per capita use of sulphuric acid because it is so widely used in industry.

The past thirty years have witnessed major changes in sulphuric acid manufacture and today it is closely tied to environmental protection. Sulphur is naturally present in all oil and gas deposits, and so, as a result, combustion of these fossil fuels produces sulphur dioxide gas. When this gas is emitted, it reacts in the atmosphere to produce acid rain. In the 1980s, governments started regulating sulphur dioxide emissions. Since then, industry has responded by installing technology made with nickel-containing stainless steel to recover the sulphur during the combustion process and produce sulphuric acid instead.

The corrosion-resisting properties of nickel-containing stainless steel, particularly at high acid concentrations and high temperatures, makes it essential for the piping, storage and cooling tanks required in this important chemical process. Thanks in part to nickel, sulphur recycling now produces 70% of all sulphur used, drastically reducing the need to mine new sulphur. Most importantly, emissions of sulphur dioxide have been halved, enabling many lakes and forests to return to health.

EFFICIENT Transport and Infrastructure

Individuals and industries rely on responsive, fast and reliable transportation. Moving people and goods around safely, economically, efficiently and with minimal impact on the environment, touches all the megatrends. Progress in transportation makes other societal goals easier to achieve.

Transportation capacity issues can occur everywhere: on roadways, railways, airways, and waterways. Land transport in particular is facing a huge increase in congestion and environmental problems related, inter alia, to excessive car use. These problems are more severe at times of high demand. To encourage commuters to use public transport, investments in infrastructure to allow additional capacity at peak times and to guarantee a safer and more reliable service are necessary [33/34/35].

With increased globalisation, several areas in the world are affected by industrial transportation capacity limitations. According to a report [36] by the U.S. Chamber of Commerce, by the year 2020 *"every major U.S. container port is projected to at least double the volume of cargo it is expected to handle."*

'Nickel enables safe and sustainable transport.'

33 **CSIRO, Our Future World, 2010.**
http://www.csiro.au/en/Portals/Partner/Futures/Our-Future-World-report.aspx

34 **KPMG, Sustainable Insight, 2012.**
http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/sustainable-insight/Pages/sustainable-insight-expect-the-unexpected.aspx

35 **Theodore Stank, Global Transportation Management Trends, 2007.**
http://www.industryweek.com/regulations/global-transportation-management-trends

36 **http://**www.uschamber.com/sites/default/files/reports/portstudy_toc_0304.pdf

Delhi metro coach – 301L

Nickel & transportation and infrastructure

The world never stops moving and nickel plays a key role in many of the various modes of transportation. Be it nickel alloys in the batteries of hybrid cars and in the turbines of jet engines, or nickel-containing stainless steel in passenger trains and subways, nickel is a crucial element in enabling movement from place to place. The qualities of nickel-containing materials provide enhanced corrosion resistance, and reliable and efficient electrical and spark systems. Nickel helps ensure that the bodies of railroad cars and trucks are strong, durable, and absorb impact (by crumpling rather than fracturing) in collisions. Nickel-containing materials also support the infrastructure for all this movement: airports and train stations, bridges and fly-overs.

Today, nickel-containing stainless steel is used for numerous internal parts in standard automobiles, from exhaust systems to fuel systems. Aware of the energy-absorbing properties of stainless steels, some car companies are now looking to design stainless steel car frames.

Stainless steel tanks have been used for the road transportation of chemicals and of food and food-grade ingredients for many years.

Bringing Sustainable Transport to Urban Life

Rail transportation is a long-established, reliable, energy efficient and economical way to move people, whether for inter-city travel or shorter commuter journeys. Many highly populated developing countries, such as India and China, understand the connection between their rail infrastructure and their successful economic development.

'Many railway operators use nickel-containing stainless steel carriages for their strength, durability and corrosion resistance.'

Train carriages

Many railway operators use nickel-containing stainless steel carriages for their strength, durability and corrosion resistance. Nickel-containing stainless steel is chosen over alternative materials, such as carbon steel or aluminium, because of its specific safety-related benefits: high energy-absorption at impact and a great level of fire resistance.

The combination of properties of nickel-containing stainless steel makes it an ideal material for use in the end-sections of railroad cars – often called 'crumple-zones.' In the event of a crash or a derailment, these zones are designed to collapse in a controlled way to absorb much of the impact energy, protecting passengers in the main section of the railroad car. In Beijing, new subway cars will be made from nickel-containing stainless steel because it is lighter in weight than carbon steel and has superior safety advantages over aluminium.

Durable and easy maintenance passenger carriages

India is a country with ambitious plans to expand its people-moving systems considerably over the next decade. Nickel-containing stainless steel has been chosen by Indian Railways for new commuter systems in Mumbai, New Delhi and Bangalore. Responsible for transporting seven billion passengers a year, India Railways needs the durability and easy maintenance this material offers. In contrast to plain carbon steel and low-alloy weathering steels, the nickel-containing stainless steels have superior atmospheric corrosion resistance and their surfaces remain free of stains. These alloys perform better than competing materials in more corrosive locations, such as high-humidity environments, and stand up well to constant daily wear.

Personal transportation

The transport sector accounts for approximately 20% of global carbon dioxide emissions [37]. In an effort to reduce greenhouse gases, hybrid and electric cars have increased in popularity.

Nickel battery for hybrid cars

Nickel metal hydride battery (NiMH) packs first entered the consumer market in 1989 and are the first choice for the majority of mass-produced hybrid and electric cars. They have high discharge rates, are resistant to harsh environments and fluctuating temperatures, and are relatively inexpensive. Each year, the technology of NiMH batteries continues to improve. Hybrid cars produce 50% less pollutants and greenhouse gases than comparable gasoline cars.

Thanks in part to nickel, this reduction translates to fewer airborne pollutants and a less polluted earth. Today, the latest and most efficient battery technologies, such as lithium based technologies, contain between 3 and 15% nickel. And because of its value, nickel is an important economic driver for collecting and recycling non-nickel based batteries that might otherwise not be recycled.

37 **iIEA Statistics, co2 emissions from fuel combustion, 2012. http://**www.iea.org/publications/freepublications/publication/CO2emissionfromfuelcombustionHIGHLIGHTS.pdf

Air Transportation

Over the past 80 years, aircraft and aero engine technologies have evolved enormously and have enabled plane travel to become another form of mass transit. And as airlines fly more and more miles, they continually strive to burn less fuel and become more efficient.

Aircraft manufacturers go to great lengths to ensure that their products are safe, that the strength of airframes is robust and that corrosion is anticipated and managed efficiently. For aircraft turbine manufacturers, it is all about fuel efficiency and reliability.

Turbines

The advantages of nickel in aircraft engine turbines include high-temperature strength, toughness, durability and castability.

Fuel efficiency

The unique properties of nickel alloys contribute to fuel efficiency in two ways. First, nickel alloys have increased the efficiency of jet engines because they allow for increased operating temperatures. This allows more complete combustion, more thrust achieved per litre of fuel burned, and reduced production of pollutants.

Secondly, the lighter an airplane the more fuel efficient it is. Newer planes are increasingly made from composites of carbon fibre and industrial fabric, bound together with epoxy resin. The production of composite parts depends on a 36% nickel alloy called Invar. Due to its exceptional stability, Invar is the material of choice for the construction of aircraft moulds because it ensures that composite parts maintain precise tolerances while being cured in a high pressure, high-temperature autoclave.

Gears

The comparatively small wheels and landing gear of aircraft cope with taking off at speed and the impact of landing thanks to nickel-cobalt low-carbon steels which have a very desirable combination of properties – extreme strength, high resistance to damage, and easy weldability.

Nickel is also used in gears because of its strength, durability and resistance to corrosion. Its properties ensure that gears are highly resistant to cracking, chipping or fracturing.

Material transportation

For trucks, ruggedness and durability are essential. To help meet these and other demands, manufacturers are turning to nickel-containing stainless steel for truck cabs because of its higher yield strength, excellent weldability, toughness and formability. These properties ensure a long and reliable working life.

Transport infrastructure

The use of stainless steel reinforcing bars (rebar) as a partial or total replacement for normal steel reinforcing bars is a common solution for structures that are vulnerable to corrosion in aggressive environments, especially those exposed to wind-blown spray or road de-icing salts.

Container pier

An example is the container pier in Progreso, Mexico – a concrete structure reinforced with nickel-containing stainless steel that remains in excellent condition after more than 65 years of use. Its 6.5 kilometre length is in constant use as a container and cruise ship port. Thirty years later, a second pier was constructed using ordinary iron reinforcing bar. It quickly suffered deterioration and, instead of refurbishment at considerable economic, material and environmental cost, was partially dismantled and the remainder allowed to crumble. The original pier remains in service and is an example of the life-cycle cost effectiveness of using appropriate nickel-containing materials in the original construction.

Elevators

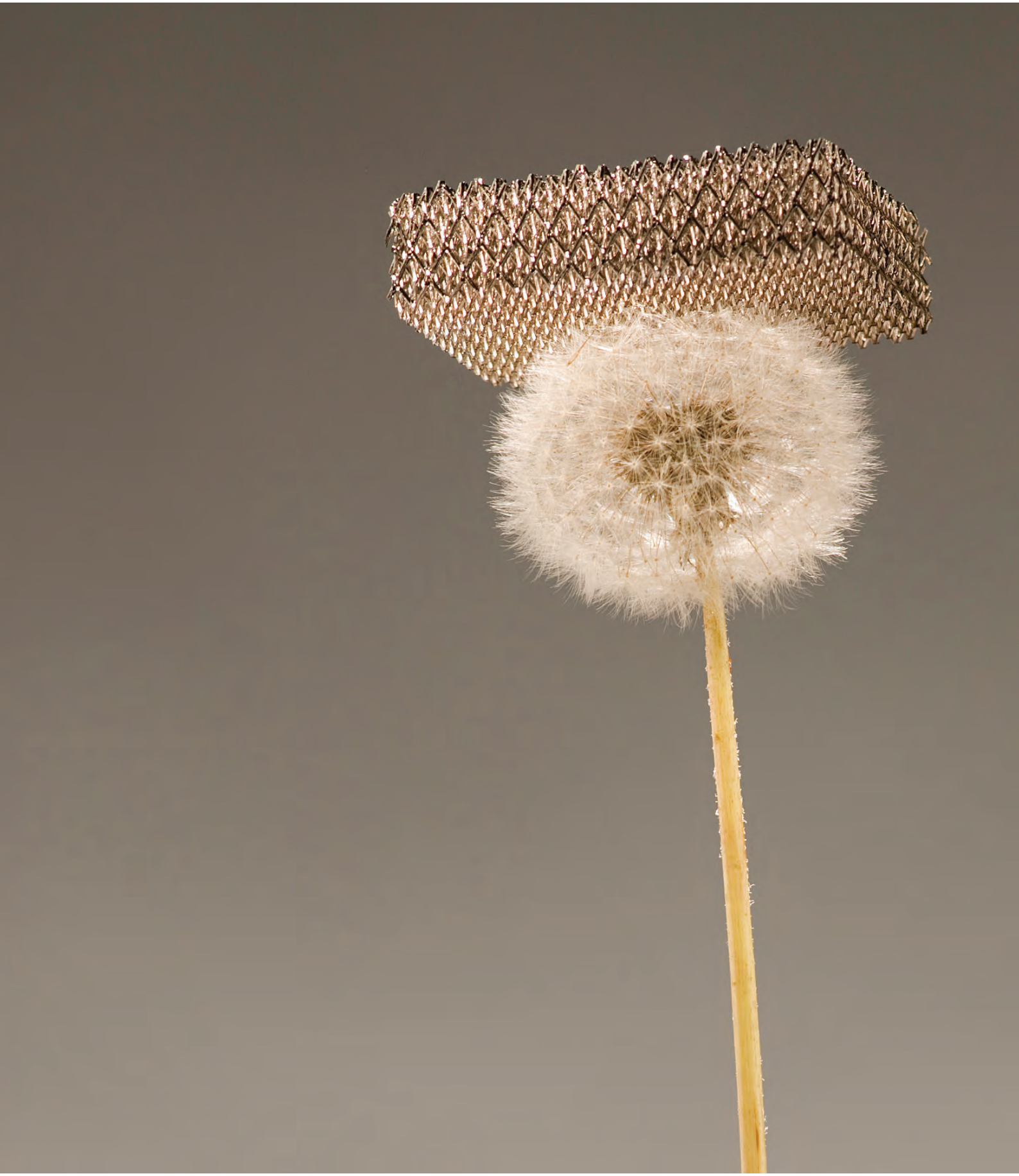
Many modern elevators, escalators and handrails use nickel-containing stainless steel because of its ideal characteristics – strength, durability and aesthetic possibilities. It is nickel's formability that allows the tough stainless steel to be moulded in a wave-like form that is also resistant to graffiti.

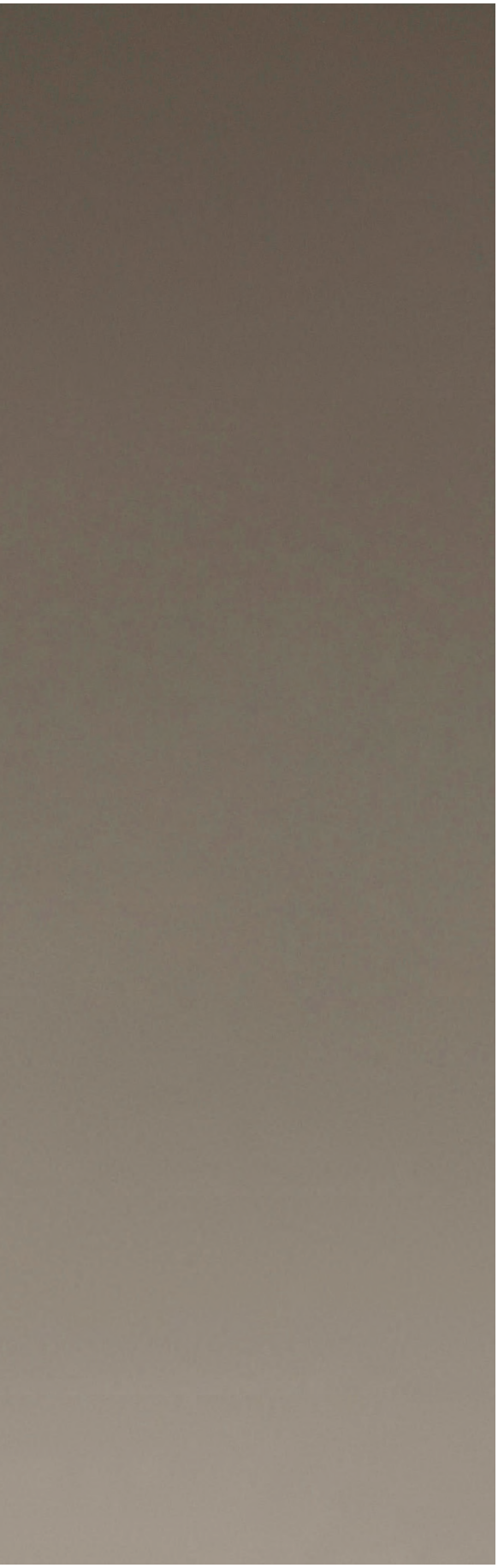
KEY FACTS

Every year, nickel makes it possible for approximately two billion people and 34 million tonnes of cargo to be flown from one place to another

Concrete structures made with stainless steel rebar survive at least twice as long as those made with carbon steel rebar

Over their life-time, hybrid cars with nickel metal hydride batteries produce 50% less pollution and greenhouse gases than comparable gasoline cars





INNOVATION and technology

Although quality of life is improving in many parts of the world, millions of people still live below the poverty line. Innovative technologies can help make daily lives better and more efficient, helping to address needs in both the developed and developing world. In order to stay competitive, manufacturers will have to be innovative in creating products and services that improve the experience of the user.

At the same time, moral and ethical dimensions are becoming more and more important to consumers, as evidenced by the rising demand for product labels with environmental and social information.

Digital communication through mobile phones, laptops, handheld devices and other wireless gadgets that continue to appear on the market in faster and savvier models will be a significant part of the future.

'Shape-memory, electrochemical and magnetic properties of nickel enable innovation and breakthroughs in science.'

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Photo: Dan Little Photography

Nickel & Innovation

There are numerous qualities associated with nickel that will continue to provide the basis of innovation and breakthroughs in science and sustainability in the decades and centuries ahead. Nickel enables innovation directly because of its shape-memory, electrochemical and magnetism properties. Nickel also supports the use of other elements and materials in innovative applications, via the well-known properties of nickel alloys.

Future decades will see continuous progress in the design of processes and products so that materials can be easily identified, separated and recovered at end of life. Designing for the environment is a growing discipline and will have extraordinary impacts on how products are developed. This increasing emphasis on design reflects not only the way products are used, but also how they are managed at the end of their useful lives. Ever higher percentages of materials in products, including the nickel contained in batteries, electrical systems, phones, fasteners and hundreds of other consumer products, will be diverted from landfills and recovered for recycling. Because of the economic value of nickel and its ability to be restored to its original properties, there will be financial as well as regulatory and ethical reasons for making the effort to recover this most talented of metallic elements.

New materials

Nickel lattice

Researchers have created a lattice whose design suggests a small-scale version of the Eiffel Tower, i.e., strong but consisting mostly of air. The structure consists entirely of hollow tubes of nickel. The creation of this shock-absorbing nickel lattice of extremely low density is expected to benefit various industrial sectors, including vehicles, aircraft and batteries. It is in fact the world's lightest material, with a density of only 0.9 milligram per cubic centimetre. The so-called 'micro-lattice' was designed chiefly to absorb sound, vibration and shock but other possible uses include applications involving lithium-ion batteries, air-cooling devices for computers, and the manufacture of cars, airplanes and spacecraft which require lightweight metals.

Shape memory alloys

Nickel-titanium shape memory alloy is a 'smart metal' which 'remembers' its shape, and can be returned to that shape after being deformed, by applying heat.

'Because of the economic value of nickel and its ability to be restored to its original properties, there will be financial as well as regulatory and ethical reasons for making the effort to recover this most talented of metallic elements.'

Bridges

Bridges in earthquake-prone regions may one day benefit from the super-elastic qualities of shape memory alloys made of nickel and titanium. During earthquakes, bridges swing back and forth and, in many cases, end up having a permanent side-sway with the whole bridge tilted to one side. New research suggests that by integrating memory alloys made of nickel and titanium into bridge columns, civil engineers can reduce the damage to bridges caused by earthquakes.

Skin-like polymer

Chemical engineers have explored the potential of self-healing polymers in epidermal electronics. In the course of their research, they have come up against the fact that all the self-healing polymers developed to date have very low electrical conductivities and are therefore of little use in electrical sensors. The researchers have therefore been looking into increasing the polymer's conductivity by adding nickel atoms to move between the metal atoms. As a result, the electrical resistance of the polymer has been modified and it now allows forces like pressure and torsion to be reflected in the behaviour of the polymer.

This material is like a synthetic version of human skin: flexible, sensitive, it also conducts electricity and is self-healing.

Tokyo Gate Bridge

New greener technologies

Electro-chemical properties

Finding a way of efficiently converting heat from waste sources into useful electricity has been a long and continuing quest. One of the promising paths involves a multi-ferroic alloy containing 45% nickel that permits just such a conversion. Ferroic alloys are materials that, at a specific temperature, undergo a sudden phase change which in turn produces a significant change in their ferromagnetic, ferroelectric or ferroelastic properties. There are many possible sources of waste heat that could be used by this process to generate electricity.

These include heat from automotive exhaust systems, heat from electronic equipment (including computers), and heat from power plants and industrial plants that today either goes up a stack or passes through a heat exchanger into the lakes or oceans. Electro-chemical properties of nickel hold the promise of generating carbon-free energy from heat that is currently wasted.

Communication technologies

Nickel is central to the communication technologies of today.

Mobile Phones

Nickel is vital to mobile phones' batteries and the electronic functioning of the device. It is an essential part of the electronic circuitry of a mobile phone: the capacitor. Layers of ultrafine nickel powder are used in the new generation of capacitors to replace an older and more expensive technology that required precious metals, such as gold and palladium. In reducing the cost of components, nickel helps to make mobile phone technology accessible to more people while reducing the demand for elements that are rare in nature and expensive in financial and environmental terms to produce.

Hard disc

Over the past decades, computers and laptops have become smaller and smaller in size and yet their storage, operational and high-speed capacity continues to grow. When the first computer disc storage system was invented, the discs were twice the size of old vinyl records (150 cm diameter) and could store 100 kilobytes. Today's hard disc drives can be smaller than 1 cm wide, and hold upwards of 400 gigabytes – a 60 million-fold improvement in performance.

Evolution in the computer technology field can be attributed in part to advancements in the magnetic heads that are used to read and write data. Today's most advanced read-and-write heads use thin-film technology. Nickel is a critical component of this technology with two parts of the film heads being magnetic alloy layers consisting of 81% nickel. The introduction of thin film heads in computers has permitted the storage density of magnetic recording to increase ten-fold every eight years since 1979.

This advancement has allowed the use of hard disc drives to be expanded into a large number of consumer applications such as smartphones, MP3 devices and video game consoles.

Copper-nickel nano wire

A nano wire material made of copper and nickel has been synthesised, which could potentially lower the cost of printing on electronics such as electronic paper, 'smart packaging,' and clothing with built-in interactive features. These and other expanding applications, such as flat-panel TVs, e-readers, smart phones and the like, require a layer of film that allows for conductivity without blocking the transmission of light. Copper nano wire films can be deposited from a liquid in a process that is both fast and affordable. Not only are these conductive films more flexible than the current used film; copper is 1,000 times more abundant and 100 times less expensive than indium. Coating copper nano wires with nickel makes the nano wire films 1,000 times more resistant to oxidation than films of copper nano wires and 100 times more resistant to oxidation than silver nanowire films. All these factors make copper-nickel nanowires highly desirable for the creation of transparent conductive films in printable electronic devices.

KEY FACTS

Nickel is a key component in modern hard disc drives which can be smaller than 1 cm wide, and hold upwards of 400 gigabytes

Although nickel makes up less than 1% of the weight of a mobile phone, it is vital to its functioning

By modifying the electrical resistance of a polymer using nickel, scientists have been able to create material that is like a synthetic version of human skin: flexible, sensitive, and self-healing

About the Nickel Institute

The Nickel Institute is a non-profit organisation that represents the interests of more than 20 companies which together produce about 75% of the world's annual nickel output. On behalf of its members, the Institute promotes the production, use and re-use of nickel in a socially and environmentally responsible manner.

This is achieved through: promoting the appropriate use of nickel, in all its forms, globally; advocating for the appropriate application of health and environment regulation based on good science; advancing the knowledge of nickel health and environment issues with scientific research.

The Nickel Institute provides a responsible, united voice for the global industry and works with other international, regional and national metals associations as well as the International and national stainless steel development associations to develop and promote the safe use of nickel around the world.

It pursues market development through a worldwide network of highly qualified specialists, offering technical knowledge about nickel, its properties and uses, to ensure optimum performance, safe handling and use. The Institute actively initiates and funds scientific research programmes to examine the role of nickel in human health and the environment. It is committed to supporting scientifically rigorous research and promoting general awareness of the care required in the production, handling, use, and disposal of nickel. The Nickel Institute shares its knowledge about nickel freely and strives to ensure that rigorous scientific research is used as the basis for regulation of the nickel industry and the industries which use nickel globally.

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www.nickelinstitute.org