Emerging Markets for Nickel and Stainless Steel in the 21st Century

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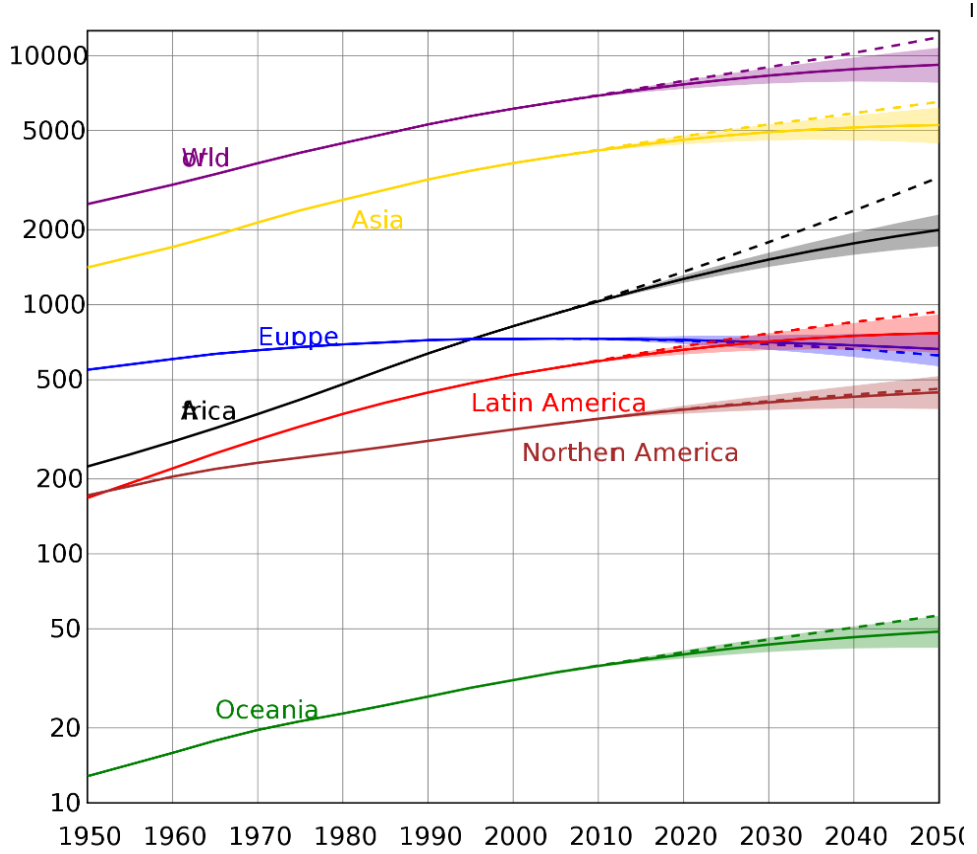
Disclaimer: The Nickel Institute does not present forecasts or comments on nickel markets, prices or supply/demand

The 21st Century – 2050 population

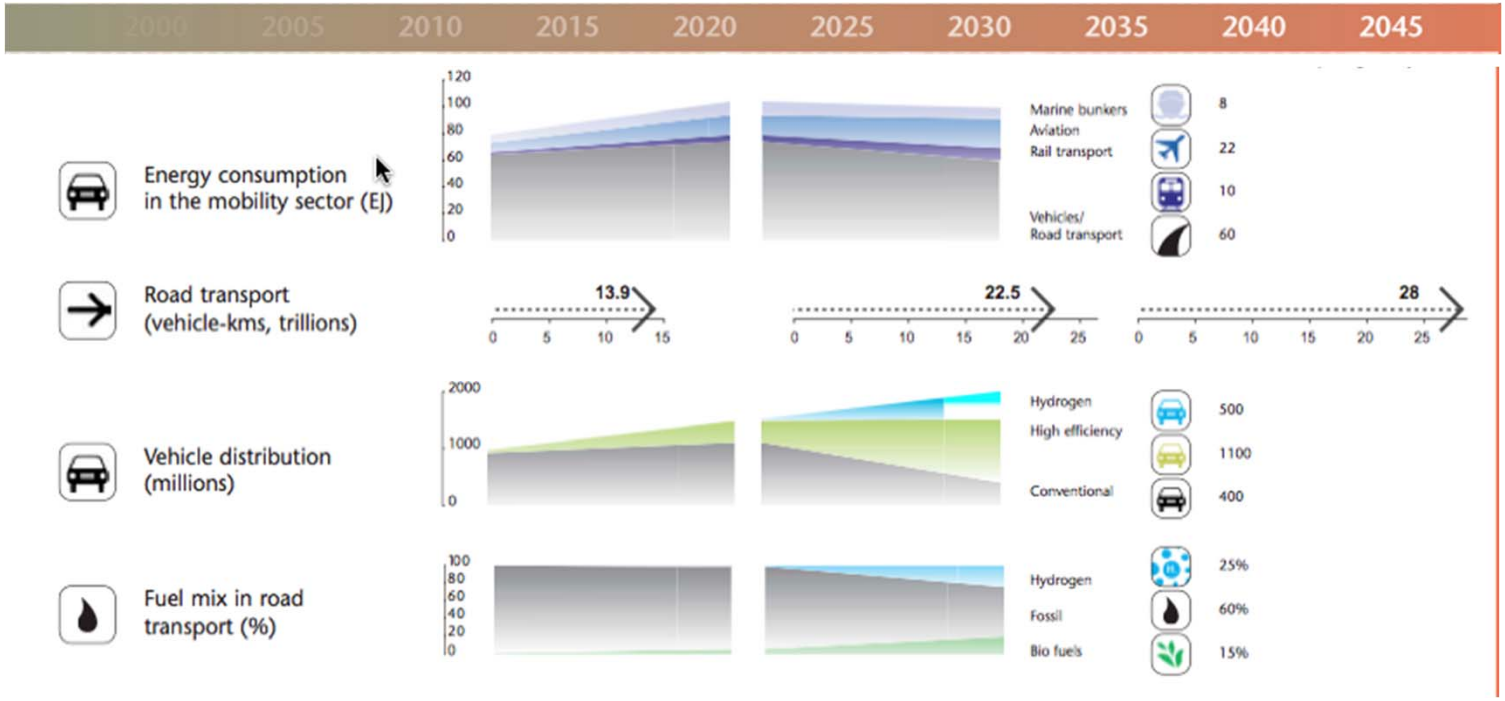
- Population growth from 6 billion to 9 or 10 billion
- Main growth in Asia and Africa
- 80% of population will be outside North America, Europe and Oceania



Source: http://esa.un.org/unpp/

The 21st Century – 2050 mobility and transport

- Absolute increase in energy consumption can be expected
- Road transport will increase
- Emerging vehicle technologies (hydrogen, hybrid and electric) will play an important part



Source: WBCSD Report: Pathways to 2050

The 21st Century – 2050
buidings and accommodation

- About 1/3 of global energy consumption will be related to buildings
- About 2/3 of energy used in buildings and accommodation will be related to heating (space and water)
- Lots of potential energy savings

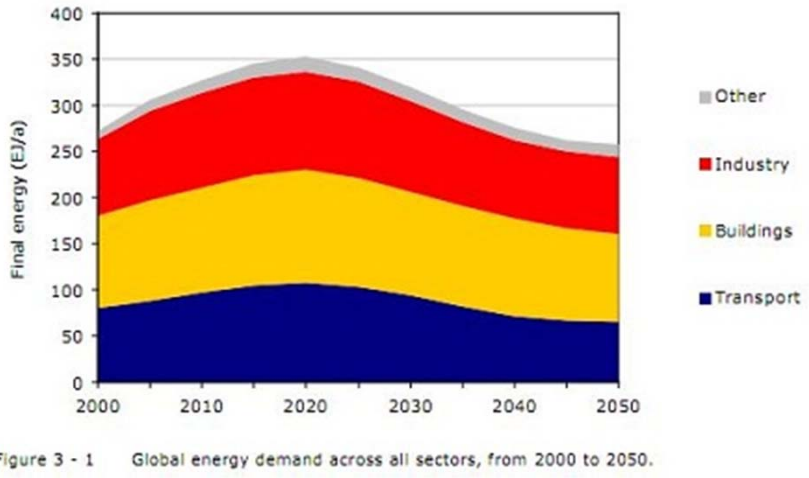
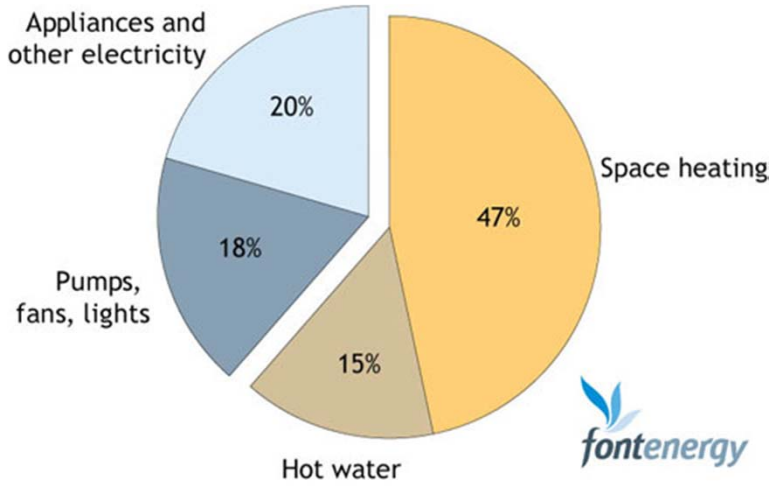


Figure 3 - 1 Global energy demand across all sectors, from 2000 to 2050.

http://www.earthtechling.com/wp-content/uploads/2011/02/wwf2050-2.jpg



http://carbonlimited.org/2009/02/05/heat-is-the-key-to-2050-co2-target/

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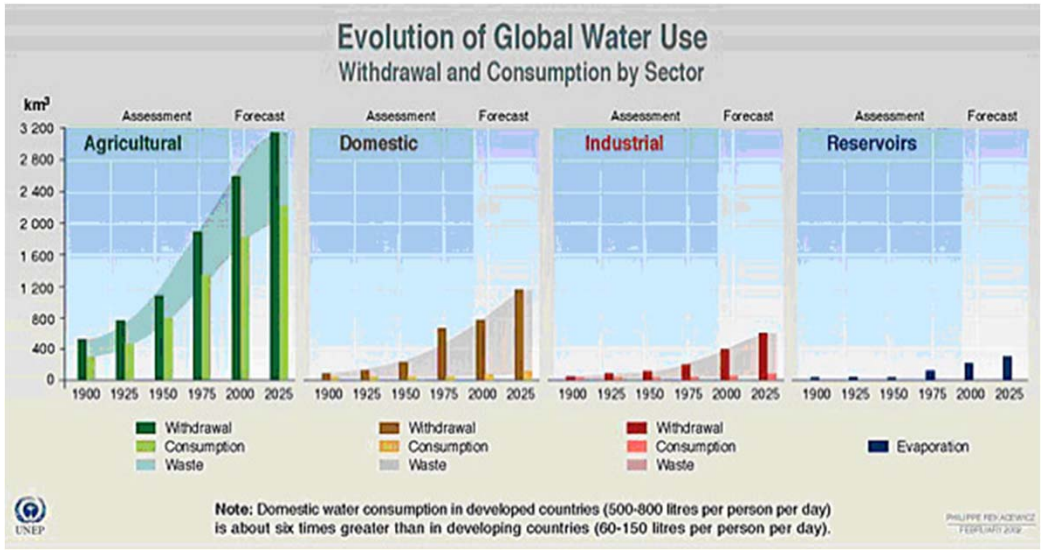
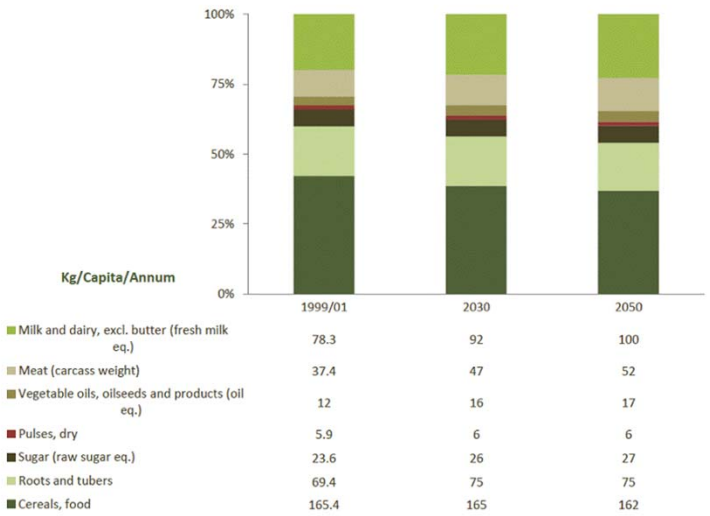
The 21st Century – 2050 food & water

- Substantial increase in water use to be expected for agriculture domestic and industrial uses
- Food consumption will not only increase in total amounts, but also food quality and processing



http://www.plastemart.com/upload/Literature/lit_images/freshwater.jpg



http://www.globalharvestinitiative.org/wp-content/uploads/2011/08/Figure2.gif

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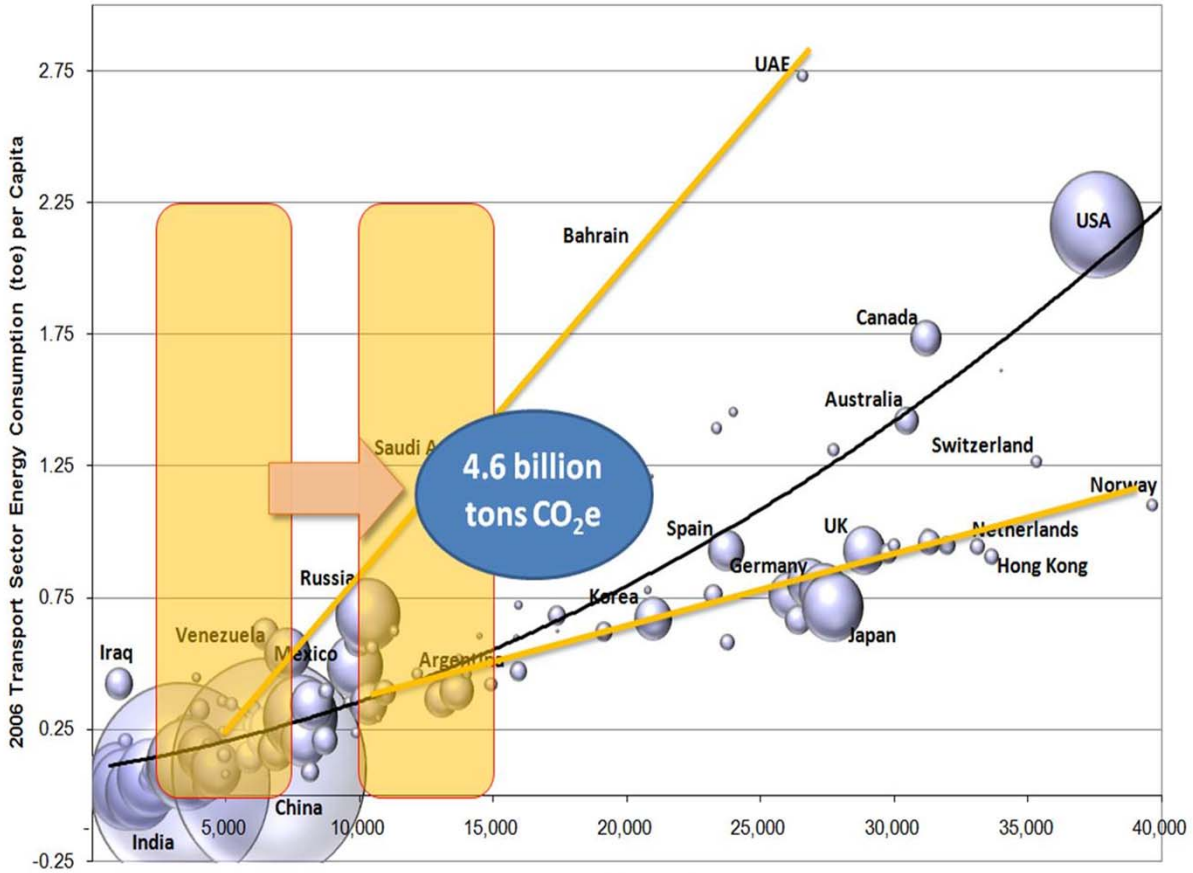
The 21st Century – 2050 energy demand

- Energy consumption of growing economies could be substantial
- If the 30 countries in 2006 with a GDP per capita between US$3000 and 7000 emitted the same tons per capita as countries with GDP per capita between US$10000 and 15000 (on average)
- Without any change in population the net impact on transport sector emissions would be an additional 4.6 billion tons CO_2 per year



http://blogs.worldbank.org/transport/global-implications-of-transport-sector-energy-consumption-in-the-developing-world-0

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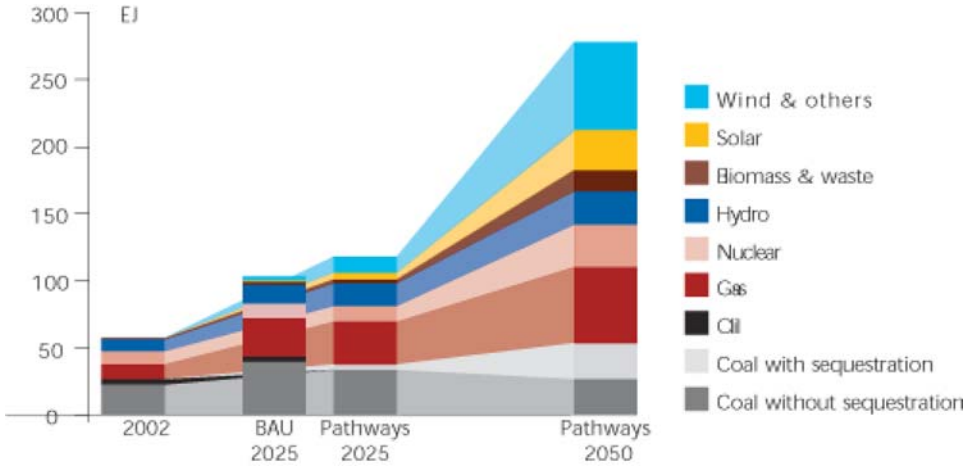
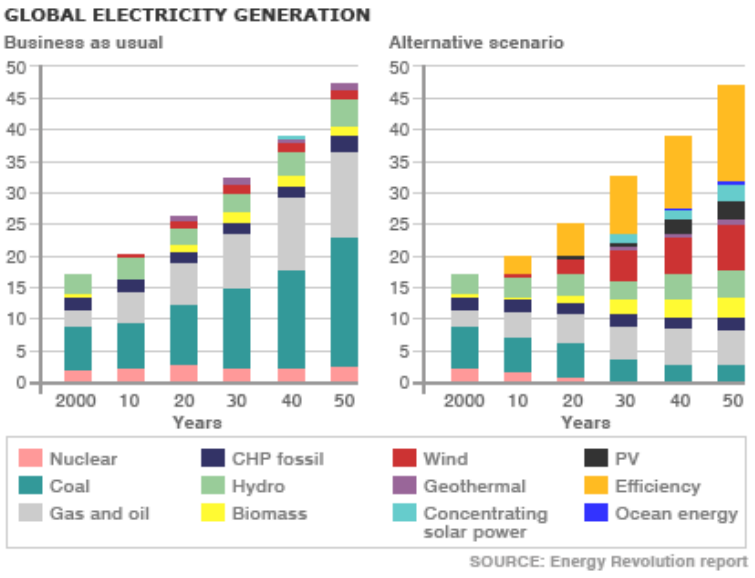
The 21st Century – 2050 energy supply

- Increase in energy demand by 2050 combined with massive reduction in GHG emissions
- Green energy from renewables will play a central role
- Fossil energy maintains its importance, but technology needs to become more efficient
- Hi tech will gain increasing importance to achieve higher efficiencies or in the further development of renewable energies





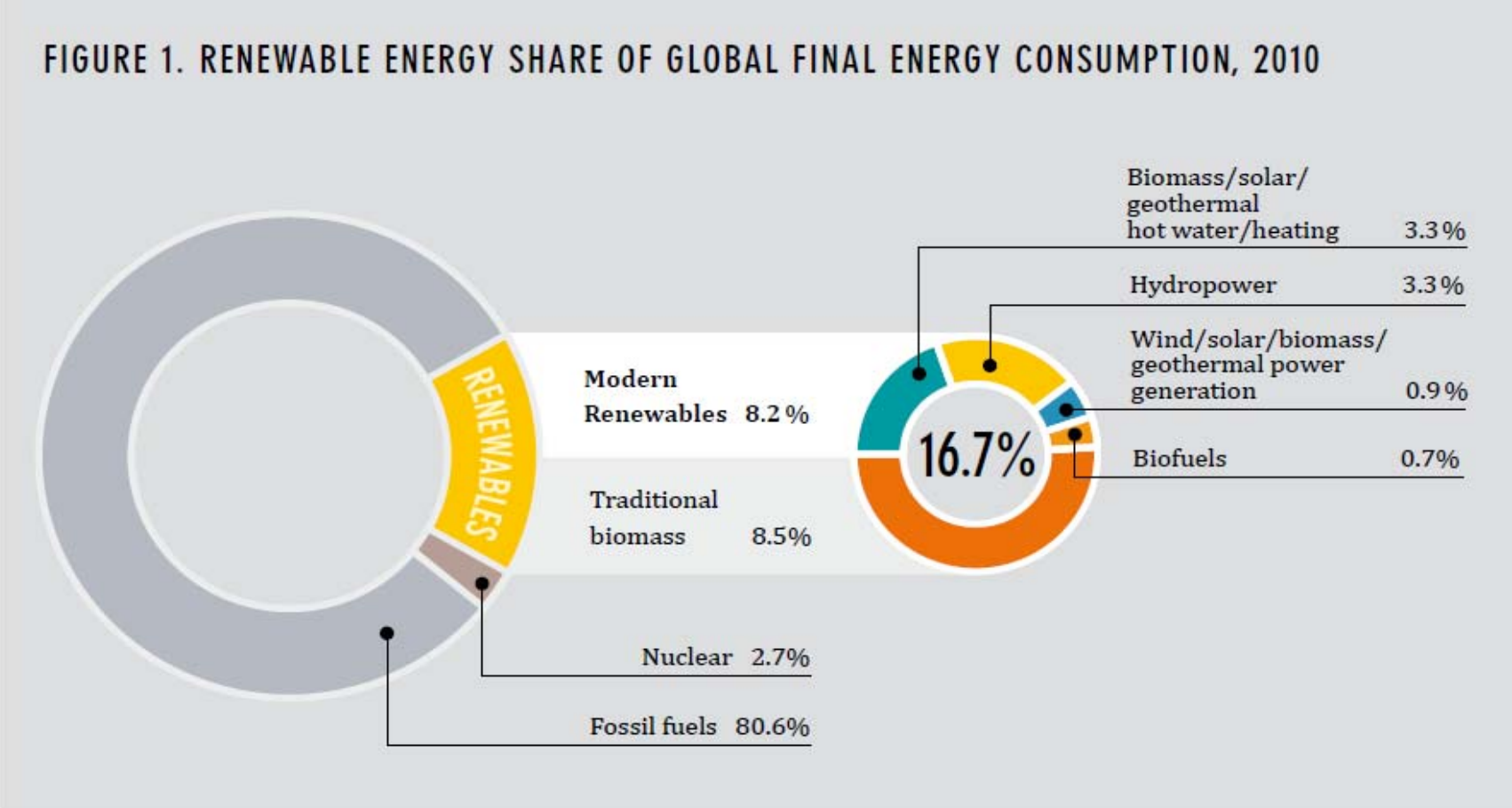
Source: WBCSD Report: Pathways to 2050

The 21st Century – 2050

- We need solutions to manage the expected demands and help us meet these challenges
- New and adapted technologies, smart solutions and energy savings will be required all based on raw materials, including stainless steel and nickel.

Emerging Demand for Nickel In Renewable Energy

Renewable Energy Status



Source: Renewables 2012 Global Status Report

Use of Stainless Steel and Nickel Alloys in Coal-Fired Power Plants

- **Type 304 SS for coal chutes and handling equipment** (better wear resistance than carbon steel or ferritic SS)
- **High temperature applications – burners, tube shields, etc.** (Type 310, special high temperature SS and Ni alloys)
- **Largest potential application is in the boiler tubes to achieve even higher steam temperatures. The higher the steam temperature, the more efficient the fuel use.** (Currently using 9% Cr / 1% Mo VNb, experimenting with 12% Cr steels, but need for even better materials with higher creep strength and oxidation resistance as steam temperatures reach 600^{o}C and higher.)

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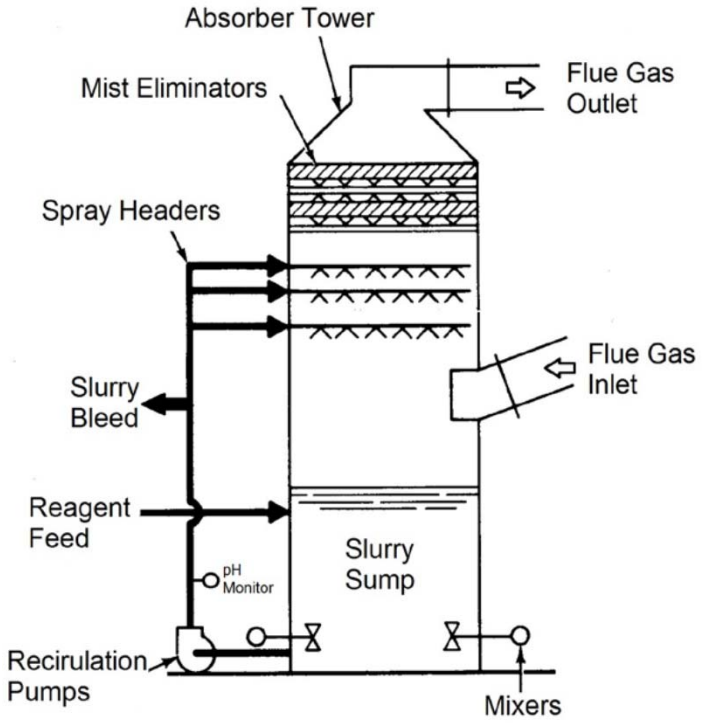
Use of Stainless Steel and Nickel Alloys in FGD (Flue Gas Desulphurization) systems of coal-fired power plants

- Most common design involves using a calcium carbonate slurry to react with the acidic sulphur dioxide gases to form calcium sulphate (gypsum).
- Chlorides build up in the acidic slurry, causing pitting of lower alloyed stainless steels.
- In the last 10 years, the process has been modified to add air (oxygen) to the slurry to produce a saleable gypsum product, but has made the process even more corrosive.
- Today, 6%Mo SS, superduplex, or nickel-based C-alloys are needed.



Mercury removal is also possible

Demand for Stainless Steel and Nickel In Non-Renewable Energy

Non-renewable resources

Nuclear – original designs called for a life of 25 years, but most plants have had extended lives. New designs use more SS and nickel alloys than older designs. Similarly, storage on-site is most often done using SS. Reprocessing of fuel requires extensive use of SS.

If and when fusion reactors ever become commercial, they will use much SS.

Oil and gas – more difficult oil and gas production requires more use of high alloy materials including SS & nickel alloys, both on-shore and offshore.

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Emerging Demand for Nickel In Renewable Energy

Demand for renewable energy grows despite:

- Uncertainty of policy in many countries
- Reduction of price of some fossil fuels in some markets

Growth in renewable electricity production in 2011

- Nearly half of the estimated 208GW of new capacity was from renewable sources
- 8% increase in renewable power capacity (over 2010), but a 24% increase in non-hydro capacity
- 20.3% of global electricity was produced from renewable energy

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Conventional Hydroelectric

- 3% increase in installed capacity worldwide in 2011.
- Large projects as well as small-scale hydroelectric installations.
- Increased efficiency of turbines in existing installations.

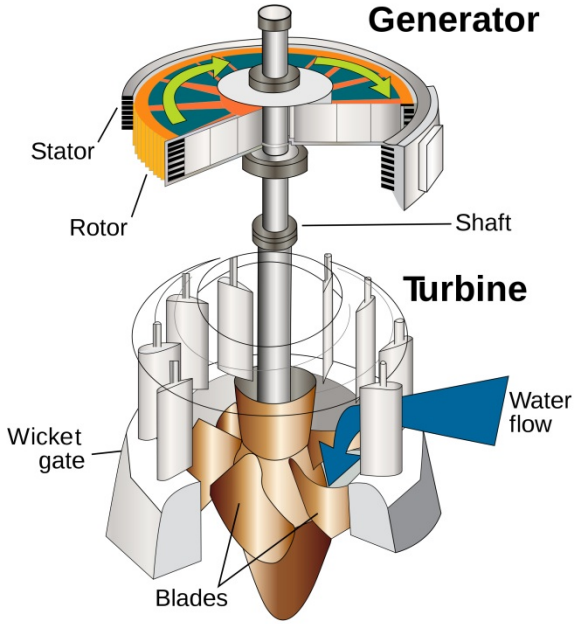
Xiangjiaba Hydro Generating Station will be China's fourth-largest hydro-generating facility when completed in 2015

Emerging Demand for Nickel In Renewable Energy

Conventional Hydroelectric

- Stainless steel use in turbines (CA15, 410NiMo, EN1.4418).
- Stainless steel in dam gates and rollers (410, 17-4PH, EN1.4418).
- Misc. other equipment in the water, above grades but also 304L and 316L.

The runner or rotor of a small scale water turbine
(Wikipedia)



Cut-away view of a Kaplan turbine and generator
(Wikipedia)

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Biofuels

- Main liquid biofuels are biodiesel and ethanol

- worldwide production in 2013 expected to be 127 billion litres, with 6% growth predicted to 2023. (Navigant Research)

- feedstock today for ethanol production is mainly corn (NA) and sugar cane (Brazil); for biodiesel, main feedstock is vegetable oils (Europe).

- new large-scale technologies coming on-stream, including cellulosic biofuels.

- alternative feedstocks include wood, grasses, sorghum, algae, waste organic matter, jatropha, etc.

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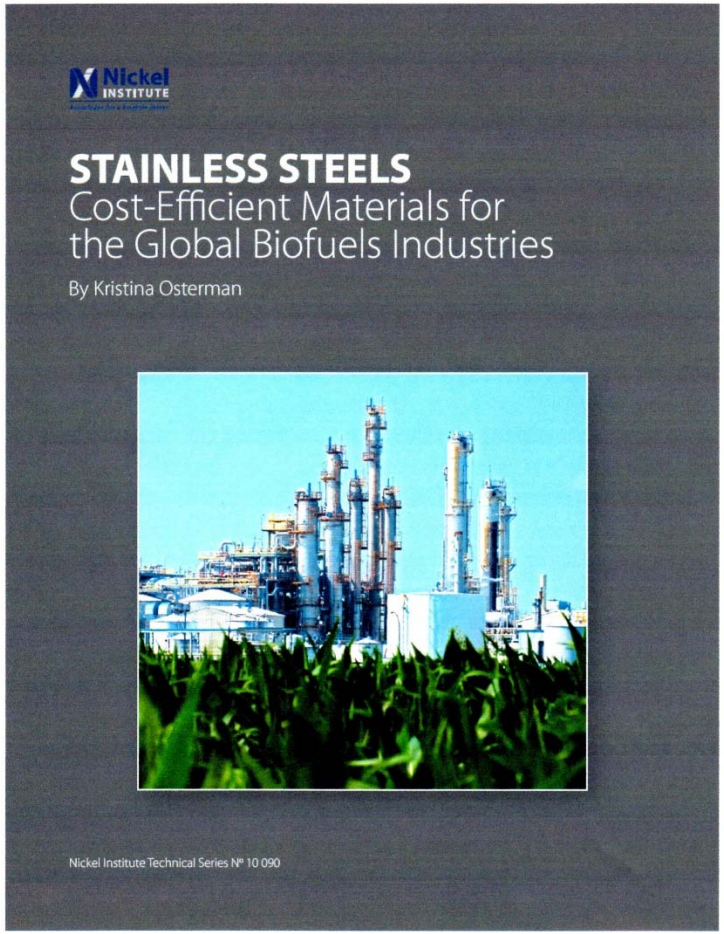
Liquid biofuels

- For ethanol from starch and biofuels, mostly 304L and some 316L, with a small use of higher alloyed stainless steel and nickel alloys. In Brazil, more use of ferritic (non-nickel-containing) stainless steels.
- For cellulosic ethanol plants, they are more like a conventional petro-chemical plant, with high temperature nickel-containing alloys, corrosion-resisting stainless steels.



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Liquid biofuels

- In North America 2005 which was a peak year for construction of ethanol plants, an estimated 150-200k tonnes of stainless used (~14-18k tonnes of nickel).
- In Europe for biodiesel expansion during 2008/2009 (5 billion litres/year), an estimated 25-30k tonnes of stainless steel were used (2-2.5k tonnes of nickel).

Pumps selling 100% ethanol and gasoline in Brazil (Wikipedia)

In some countries, biodiesel is less expensive that diesel. (Wikipedia)

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Biogas

- mostly from anaerobic digestion of sewage and organic wastes including landfill sites.
- large scale production involves some nickel-containing stainless steels, mostly 304L and 316L.

249kw Biogas site in Bauernhof, Germany (Wikipedia)

Pipes carrying biogas, natural gas and condensate (Wikipedia)

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Wind

- Largest sector within the new renewable power industry.
- In 2011, 40 GW of capacity added to bring the total to 238 GW.
- Largest use of nickel is in ductile iron castings in rotor hubs, gearbox housings, base plates, gears, shafts
  - especially important in cold climates.
  - estimate of about 28k tonnes of nickel used up to end of 2011.
- On-shore: Minor use of stainless steel for fasteners, misc. hardware.
- Offshore: Slightly more use of stainless steel due to marine atmosphere.

Wind turbines both on-shore (left) and offshore (right)
(iStock)

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Solar

Three types

- Hot water heating / cooling
- Photovoltaic (PV)
- Concentrating Solar Power (CSP)

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Solar – thermal heating /cooling systems

- Direct thermal heating is by far the largest use of solar, increasing nearly 50% to 238 GW_{th} from 2009 to 2011.
- China is by far the largest user of such systems, for both domestic hot water and for heating (often augmented by gas or electric heaters in winter). Many systems use SS, including some 300 series.
- Some use in Europe, including for cooling purposes. These include the 300 series, 400 series and duplex SS.

Solar Water Heater in China
(Wikipedia)

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Solar – Photovoltaic (PV)

- Growth of over 200% to 70 GW capacity from 2009 to 2011
- Price of PV systems have dropped considerably, and are simple to use
- Major region is Europe
- Some use of 200 series, 300 series SS, as well as 400 series. (Total SS about 10kT per year.) Fasteners are sometimes stainless steel even when other materials are used in the frames.

Solar PV Panel (iStock)

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Solar – Concentrating Solar Power (CSP)

- CSP is still in the demonstration phase, with only 1.8 GW of commercial electrical generation. Largest user is Spain.
- Large use of SS and some nickel alloys, for molten salt systems, receiver tubes, steam generators, etc. Potential use in reflectors, etc.
- Some parts are coated (black nickel).

Dish Stirling
(Wikipedia)

Solucar PS10 CSP Tower, Spain
(Wikipedia)

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Geothermal

- 2/3 as direct heat, 1/3 for electricity generation.
- Small sector, only about 11.2 GW in electricity (2011).
- Direct heating bathing/swimming pools (1/4 of total), district heating (1/6), remainder agricultural & misc. uses.
- Wide range of materials depending on water from carbon steel to stainless steel to high nickel alloys and titanium.

Geothermal plant
(Ren21)

Emerging Demand for Nickel In Renewable Energy

Geothermal

- A new 100 MW Cal Energy (California) plant would require about 2000T of duplex and superduplex SS pipe, fittings and plate + other stainless components. That translates to min. 20T/MW of stainless, or perhaps average 2T of nickel per MW.
- 2 GW new capacity per year (estimated over this decade) means 4kT of nickel per year. Not a huge amount, but necessary for geothermal to become commercial.

Puhaga Geothermal Plant, Philippines
Wikipedia

Emerging Demand for Nickel In Renewable Energy

Wave, tidal, ocean currents

- Still in early development, pilot plant or small demonstration unit stages.
- UK is in the forefront of wave generation.
- Represent a huge potential for energy generation.
- All have potential environmental issues.
- All represent an opportunity for SS

First commercial grid-connected tidal stream generator, Strangford Loch, U.K.

Emerging Demand for Nickel In Renewable Energy

Nickel and the Low Carbon Economy

- We are heavily reliant on fossil fuels for generation of electricity, and will continue to be in the near future.
- Power generation accounts for > 40% of global CO_2 emissions, and is the focus of efforts to reduce emissions because they are principally point sources.
- Carbon capture and storage (CCS) techniques will need to be applied to power plants to meet established targets.

Emerging Demand for Nickel In Renewable Energy

Nickel and the Low Carbon Economy

- Recent LCA-based study by University of Leiden[1] in The Netherlands provides some striking projections on nickel metal requirements to meet IPCC[2] targets for CO_2 reductions:

Power generation	Iron (% increase)	Ni (% increase)	Comment
CCS - Coal-fired	30	75	
CCS - Gas-fired	40	150	Due to additional infrastructure (e.g. Pipelines)
Wind	50	50 - 250	Depends on the energy production mix; biomass is particularly metal intensive
Solar	40		
Biomass	80		

[1] Kleijn R, et al., Metal requirements of low carbon power generation, Energy (2011*), doi:1016/j. energy*. 2011.07.003 (In Press)

[2] Intergovernmental Panel on Climate Change

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Emerging Demand for Nickel In Renewable Energy

Conclusions

- Growth in new renewable energy production facilities continues at a high rate.
- Each of the renewable energy generation processes uses stainless steel, some to a greater extent than others.
- The Nickel Institute is actively promoting as well as cooperating with other organizations to show the benefits of nickel-containing materials (SS, Ni-alloys, Cu-Ni, plating, etc.)
- There is an vast opportunity for stainless steels to be a solution to the world's growing energy demand and other needs.
- The Nickel Institute looks forward to our continued relationship with ISSDA and individuals in India to develop markets in all these sectors and to support stainless steel.

THANK YOU
FOR YOUR INTEREST