Nickel-Cobalt-Copper Opening Address

NICKEL: CRITICAL TO A SUSTAINABLE FUTURE

By

Richard Matheson

Nickel Institute, Canada

Presenter and Corresponding Author

Richard Matheson

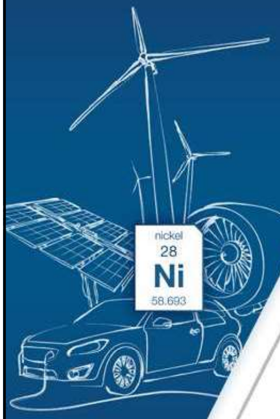
ABSTRACT

With recent announcements from the Biden Administration we now see all major economies moving to a low carbon future. Investment is rapidly changing to support low carbon policies and technologies.

Nickel has a key role to play in almost all technology moving us to renewable energy production and use. Nickel provides cost effective corrosion resistant alloys for solar and geothermal energy production. It enhances toughness and strength in alloys for wind generation and for decades has been an important component in hydropower generation at the heart of turbines. Biomass and other biofuel substances require nickel in either their manufacture, use, or both. In hydrogen production and use nickel has key functions in for instance electrolizers, storage and handling. And, of course, there are mitigating technologies like carbon capture and storage which are also rich uses of nickel.

Whether maturing or in their infancy, all these technologies are undergoing rapid development to reduce cost and extend life, typically fertile ground for increased use of nickel. In this talk we will explore how much and where nickel is currently used in the renewables sector. Importantly, many properties that nickel imparts on its own or in the alloyed or other materials being used are critical to the success of the technologies. The talk will focus on criticality and possible future applications as the needs of low carbon production drive towards lower overall cost and a more sustainable future.

Keywords: Sustainability, Low Carbon, Criticality, Renewable Energy, Batteries, Hydrogen, Carbon Capture, Nickel



Nickel INSTITUTE
knowledge for a brighter future

Nickel: Critical to a sustainable future

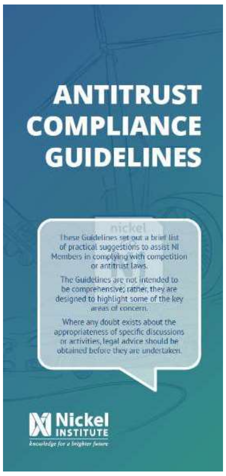
Richard Matheson
Director – Market Development
ALTA Nickel Conference, May 2022

ALTA 2022 26
20-27 May | Perth, Australia | Online

1

Antitrust

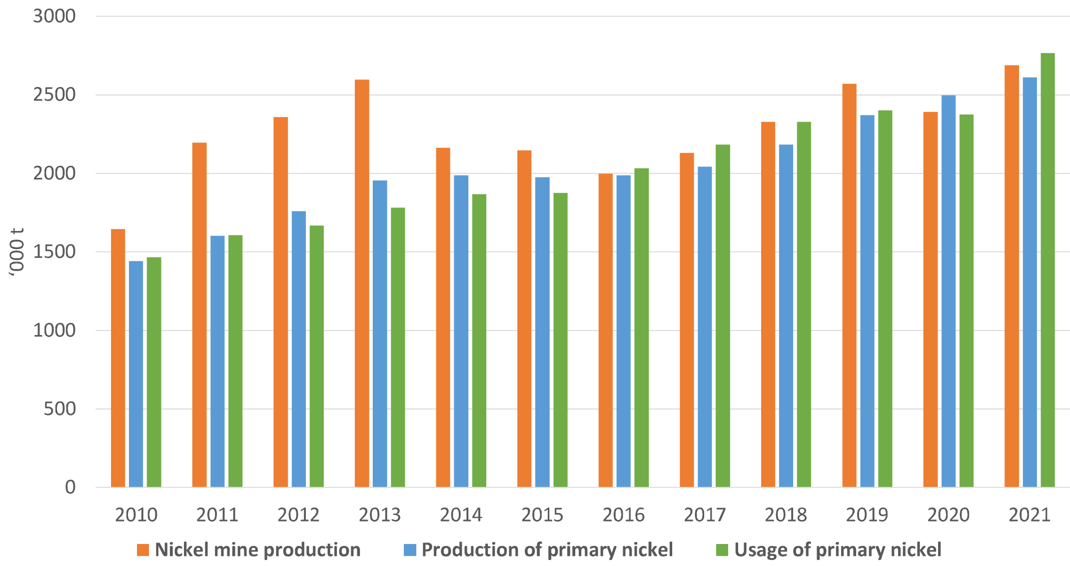
- **NI does not present forecasts or comments on nickel markets, prices, or supply/demand**
- We are committed to full compliance with the competition or antitrust laws in all jurisdictions where our members are active
- NI Guidelines (NI website) provide an overview of areas of legal risk
- All participants in NI activities share responsibility for adherence to the Guidelines
- If any doubt exists about the appropriateness of specific discussions or activities, legal advice should be obtained before they are undertaken



Nickel Institute is committed to antitrust compliance
- ✓ Remain vigilant and compliant with NI Antitrust Compliance Guidelines during all NI activities
- ✓ Outside NI activities remain vigilant and compliant with your own company's antitrust compliance guidelines

2

Primary nickel production and usage 2012 – 2021



Source: INSG

3

Nickel: Tackling global challenges

Megatrends population

- Food
- Water
- Energy
- Transport
- Building infrastructure

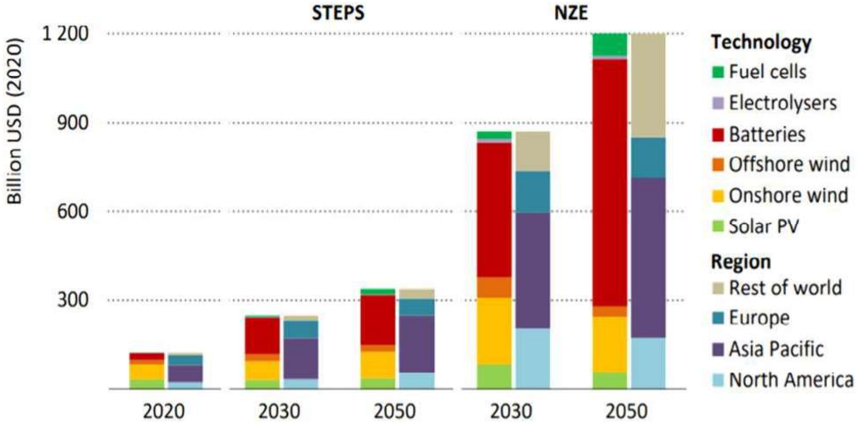
Climate change

- Decarbonisation
- Clean energy
- Reduction in fossil fuel production
- Mitigation technologies

4

Ni contribution to clean energy

ESTIMATED MARKET SIZE FOR SELECTED CLEAN ENERGY TECHNOLOGIES, BY TECHNOLOGY AND REGION, 2020 – 2050



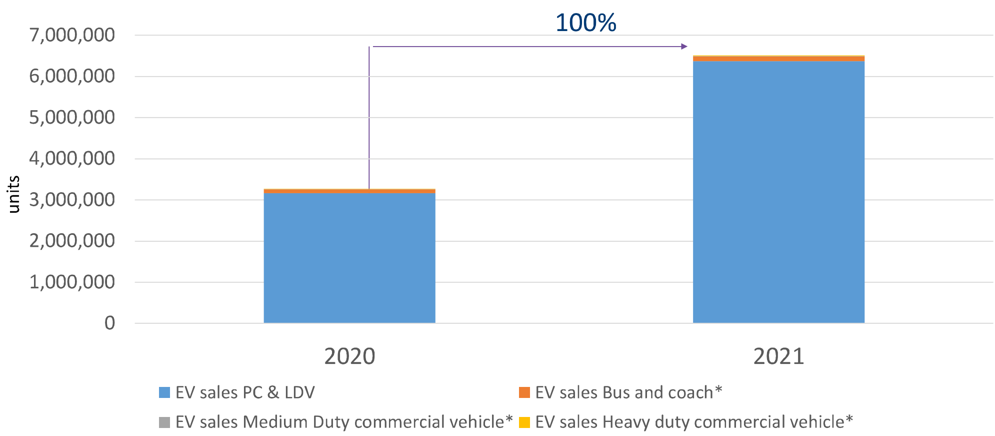
The IEA forecasts an explosive growth in clean energy technologies over the next decade under the NZE scenario, leading to the clean energy market worth a cumulative USD 27 trillion by 2050.

STEPS = Stated policies scenario; NZE = Net zero emissions by 2050 scenario

Source: IEA, World Energy Outlook 2021 5

5

Global EV sales: 2021 vs 2020



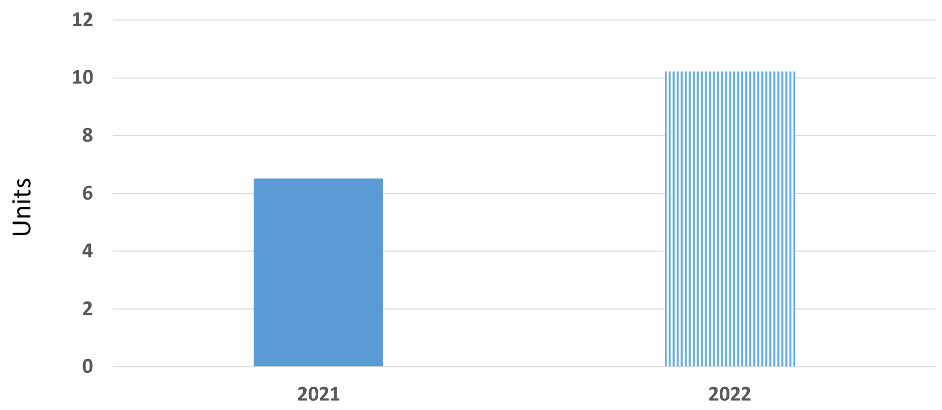
For the full year 2021, BEV & PHEV sales across all vehicle classes exceeded 6.5 million, double of what was sold in 2020 with a y-o-y increase of 100%. Electric buses, coaches as well as electric medium-duty and heavy-duty trucks are quite a small segment of the market: around 2-3%, in terms of overall sales.

Includes PC &LDVs, electric buses and coaches, medium and heavy-duty commercial vehicles

Source: Rho Motion

6

Global EV sales outlook 2022



More than 10 million EV sales expected in 2022

Sources: https://www.bloomberg.com/news/articles/2022-01-25/electric-car-sales-could-hit-10-million-globally-in-2022
https://seekingalpha.com/article/4485897-what-to-expect-in-2022-for-global-electric-vehicle-sales Rho Motion's key issues to watch in 2022 - Rho Motion

The Nickel Institute (NI) does not endorse any particular forecast or forward-looking statement. Any NI member who wants to utilize or refer to this available data from an independent third party should cite the original source (and not the NI).

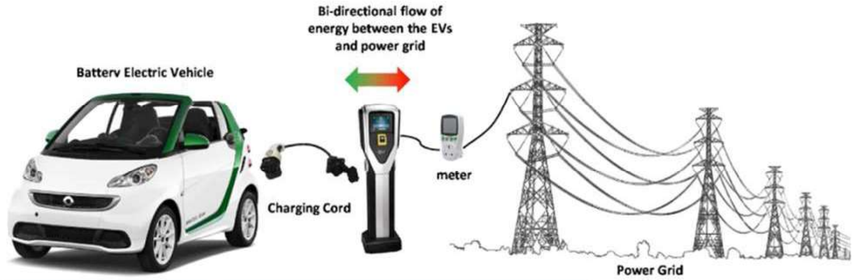
7

Nickel in four-million-mile battery

A team of researchers, led by Professor Jeff Dahn at Dalhousie University, have developed and demonstrated batteries that can last four million miles (almost six million km). Nickel-based cathode is behind this breakthrough.

Factors contributing to the cells' long lifetime include switching from polycrystalline NMC to single crystal NMC, the choice of quality artificial graphite (AG), and appropriate electrolyte additives.

Extremely long-life cells are significant for vehicle-to-grid application and utilizing storage capacity in electric vehicle batteries for solar and wind energy.



Simplified Vehicle-to-Grid (V2G) Schematic, Ref: Bibak, B., & Tekiner-Moğulkoç, H. (2021). A comprehensive analysis of Vehicle to Grid (V2G) systems and scholarly literature on the application of such systems. Renewable Energy Focus, 36, 1-20

8

https://nickelinstitute.org/en/blog/2022/march/four-million-mile-battery-is-now-a-reality/

8

Clean energy technologies outlook

Technology	Sub technology	Current nickel intensity Ni kg/MW *(1)*	Forecast capacity by 2050 *(2)*	CAGR	Opportunities for nickel
Solar energy	CSP	940-1,800	600-800 GW *(3)*	8%	Gen3 CSP under investigation to lower cost to $0.05/KWh; temp. around 700ºC requires the use of Ni
	PV	1	8,500 GW	9%	Criticality uncertain
Wind energy	Onshore	427	5,044 GW	7%	Increasing turbine sizes; opportunities for Ni in tower, nacelle, bearings
	Offshore	427	1,000 GW	12%	
Hydropower		31	2,147 GW	2%	Upgrade work in advanced economies; growth in Asia, Latin America and Africa
Geothermal		440-1,000	227 GW	8%	Opportunities in well casings
CCS		1,145	5.6 $GtCO_2$/yr	18%	High growth market

The Nickel Institute (NI) does not endorse any particular forecast or forward-looking statement. Anyone who wants to utilize or refer to this available data from an independent third party should cite the original source (and not the NI).

- Opportunities in wind and solar
- Cost pressures likely in CCS, maturing over time

(1) Source: IEA, literature review; for Geothermal based on market findings
(2) Source: IRENA, for CCS: IEA
Global Renewables Outlook: Energy Transformation 2050 (irena.org)
(3) Sources: Several; including Clean Technica (https://cleantechnica.com/2009/05/29/concentrated-solar-power-could-generate-25-of-the-worlds-electricity-by-2050/); IRENA: Global Energy Transformation: A Roadmap to 2050 (irena.org)

9

9

Solar PV: China as an example

China PV installations use significant quantities of nickel relative to the IEA figure of 1 kg NI/MW

Galvanised carbon steel, aluminium and stainless steels are used for support structures

Ni-containing low alloy weathering steel is a recommended material and has been incorporated into many installations already for PV support

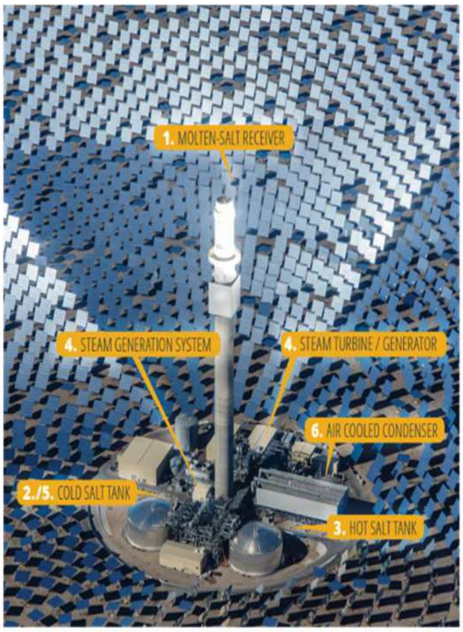
10

Nickel in concentrated solar power
Central tower systems

Receiver materials include Nickel base alloy 625 (about 61 % Ni) as a standard grade. As alternatives, alloy 800HT containing 30–34 % Ni or alloy 230 (47–65 % Ni) have been discussed, the latter being used in UAE's Noor Energy 100 MW Central Tower Power CSP project

Nickel-based alloys and nickel-containing stainless steel are playing key roles in Concentrated Solar Power (CSP). Their use has enabled solar industry to overcome challenges in heat transfer & thermal storage and is helping the industry realize its goal of lowering the LCOE

Nickel provides creep resistance, corrosion resistance, ductility and fatigue strength



The amazing role of high-temperature nickel alloys and stainless steels for concentrated solar power | Nickel Institute

11

11

Summary of nickel use in wind turbines

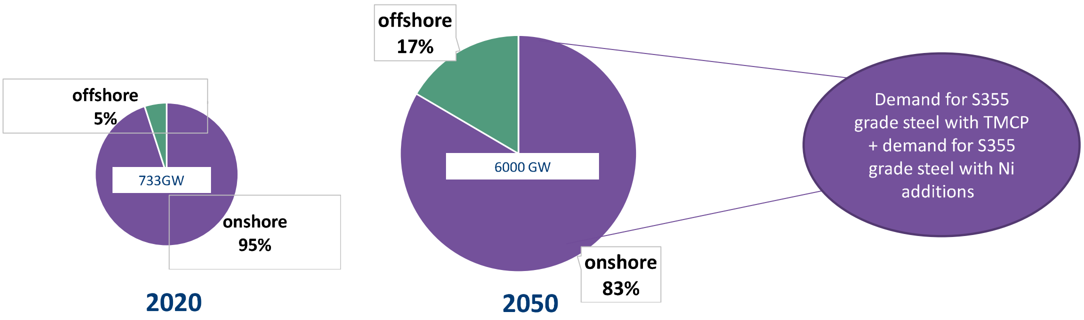
Component	Nickel benefits
Tower	Current material of construction is steel with 355MPa min yield strength, with no nickel addition. As towers get larger, nickel-containing steels with 465+ MPa min yield could allow for thinner steel plate and thus reduced material weight in the tower.
Filler metal	Ni improves weld metal toughness for towers designed for cold weather environments.
Nacelle frame	Currently fabricated from ductile cast iron or welded steel, with no nickel addition. As turbines increase in size and weight, nickel-containing steel with higher strength would reduce the weight of the nacelle.
Shafts	Ni increases hardenability of low alloy steels allowing them to "through harden" producing shafts with higher strength than steels with no nickel. This minimizes shaft diameter and shaft weight. Ni also improves toughness in comparison to those steels with no nickel, improving reliability.
Gears	Most common material used is a Ni-containing low alloy steel. Ni improves toughness and reliability critical to the application.
Bearings	Currently material of construction may or may not incorporate Ni depending on engineering house, but larger turbines could see significant Ni use in future.
Bolts	Ni improves toughness of bolt material and reliability.

12

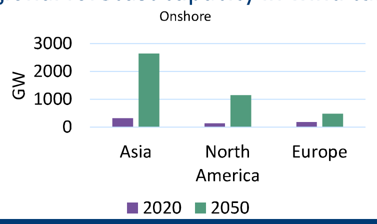
Opportunity in wind towers

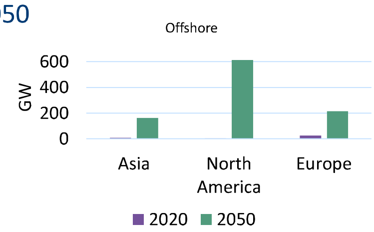
ALTA 2022 | Nickel Institute

Global wind capacity 2020 vs 2050



Regional forecast capacity in wind turbines - 2050





Source: IEA/IRENA

Global wind capacity in 2050 is expected to be 10 times the current capacity. This will have implications for steel demand.

13

Nickel in geothermal

ALTA 2022 | Nickel Institute

- Costs for geothermal becoming increasingly competitive
- Two main types of plants : dry steam / flash plants and binary plants (75/25)
- NI research with operators suggest Ni use can be estimated as follows:
  - **Between 438 and 1000kg/MW**
- Key components for nickel include turbines, condensers, heat exchangers, pumps and piping systems especially for the cooling tower – requiring a range of stainless and nickel alloys
- Local conditions determine intensity
- Nickel provides strength; also, corrosion resistance and clean surfaces for heat transfer resulting in cost-effective service
- MD opportunities include:
  - Well casings (that reach the surface) – super duplex alloy 2507
  - High temperature fluid wells drilled for research - Ni-base alloys may be suitable

14

Nickel in carbon capture, transport and storage

Majority of CO2 **capture processes** contain water originating from combustion. Nickel-containing stainless steels are a requirement for a majority of mature CCS processes

CO2 cargo tanks for **shipping** are designed for temperature and pressure necessary for liquid CO2. These must operate between -54°C / 6 bar to -50°C / 7 bar. Pressure vessel low alloyed steel for pressurized tanks has 2.5% Ni in it, essential for strength and toughness

For **storage**, long-term injection well design necessitates the use of nickel-containing materials to prevent the risk of corrosion. Onshore storage tanks are made of 0.80% Ni low alloyed steel

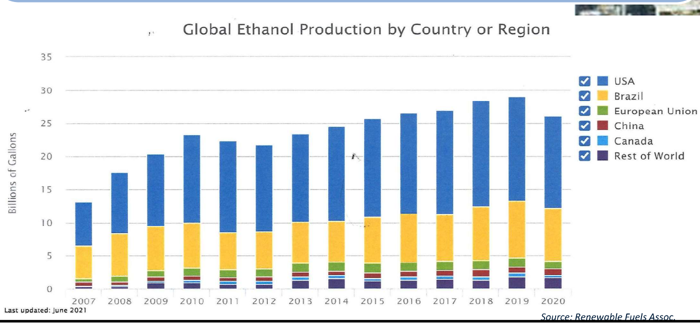
https://nickelinstitute.org/media/8d96b99d813f06b/nickelvol36no2summer2021_eng_spreads.pdf

15

Nickel in biofuels

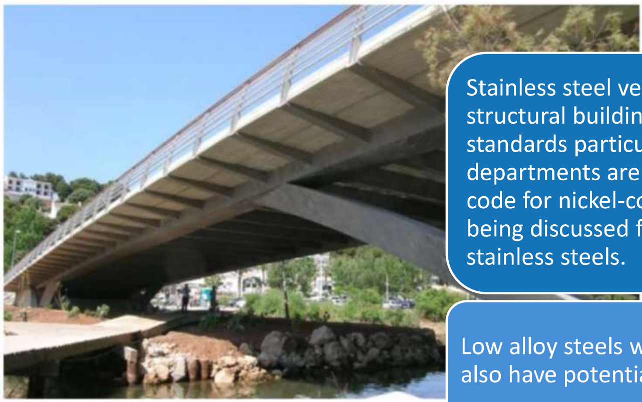
India recently announced plans to bring forward 20% ethanol blending by 2025 and not 2030. The government is speeding up the process of establishing food grain-based distilleries as well as setting up **modern technology plants** to make ethanol from agricultural waste

The use of stainless steels go hand in hand with sustainable and cost-efficient modern commercial scale ethanol plants



16

Nickel in infrastructure



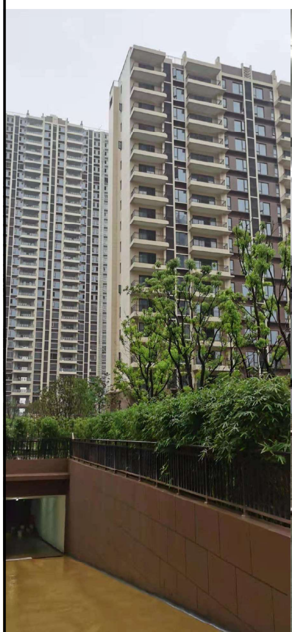
Stainless steel vehicular bridges: New US stainless steel structural building standards is encouraging new bridge standards particularly for duplex alloys. Transport departments are meeting to establish a new bridge code for nickel-containing materials. Mandates are being discussed for road and rail bridges in India using stainless steels.

Low alloy steels with through hardenability quality, may also have potential for bridges and tall cranes.

Vehicular bridge construction and renewal is shaping as a major potential market for nickel. EG 600,000 bridge structures in North America and a similar number in Japan up for renovation. Moving people and goods in India, for example, is a key market for rail and road bridges especially in coastal regions.

17

Nickel in water infrastructure



Source:Zhejiang Zhengtong Pipe Industry Co., Ltd.

Stainless steel China's secondary water systems (eg the systems in high-rise buildings): In 2020 after 6 years of work, provincial mandates for the use of nickel-containing stainless steels began to appear. The uptake is likely to affect 200 million households in China and deliver lasting infrastructure and improved water quality across most Chinese cities with about 5 million tonnes of stainless steel.

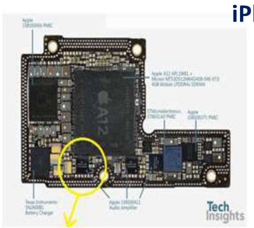
The need to reduce water losses globally is imperative to a sustainable future. Average losses are 25% and processing and pumping lost water is costing about 1% of the world's energy. Nickel containing stainless steels offer a durable and clean solution to water distribution problems, eliminating leakage without detriment to quality. Many cities in Asia use nickel to distribute their water.

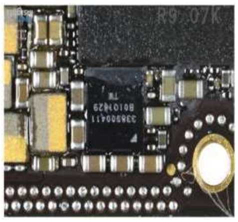
18

Nickel in electronics

- Nickel allows MLCCs to shrink in size by reducing the thickness of the dielectric layer, while maintaining the same capacitance values
- Nickel is a material of choice for manufacturing Multi Layer Ceramic Capacitors (MLCCs)
- An iPhone has more than a thousand miniature capacitors. In 2020, 4,800 t of nickel powder were used to make MLCCs, which can be as small as a grain of sand
- Nickel-containing MLCCs are found in smart phones, wearable electronics, aerospace systems, smart cars, particularly cars with Advanced Driver Assistance Systems (ADAS)

iPhone X





nickelvol36no3sfall2021_eng_fb.pdf (nickelinstitute.org)

19

19

Nickel in space applications

The economics of space exploration is changing with use of fully recyclable and reusable spacecrafts. Falcon 9 is a reusable, two-stage rocket designed and manufactured by SpaceX. It is the engines that cost, and it is where nickel makes its essential contribution.

Falcon 9 has ten Merlin engines. Dry weight of one Merlin is designed to weigh approx. 1500kg. There will be several nickel alloys – depending on the operational parameters– in the make up of the Merlin but our best estimate is that each Merlin will contain at least 125kg of nickel alloys.

Merlin Illustration Courtesy of Brian Haeger, renderspeed.com

20

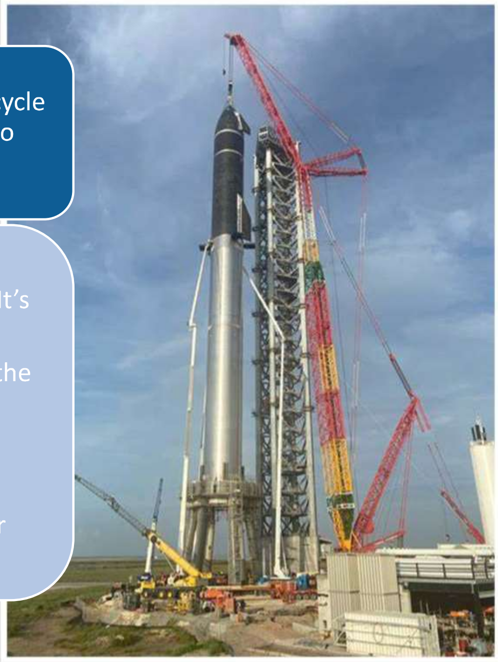
20

Nickel in space applications

Rocket motors on Starship are full flow stage cycle "raptors" - 42 in total, similar in construction to the Merlin.

The rocket's body is made of 304 nickel-containing stainless steel, like a kitchen sink. It's cheap and strong, simple to fabricate.

It can survive in the operational envelope of the vehicle with much reduced insulation on the windward side of the payload vehicle itself, making it cost effective and durable. No brittleness in the cold of space and reliable strength in the temperatures of re-entry, over and over again.



21

Nickel INSTITUTE

knowledge for a brighter future

Richard Matheson

rmatheson@nickelinstitute.org

ALTA 2022 26

20-27 May | Perth, Australia | Online

22