Critical Raw Materials for Electric Vehicles- IEA HEV-TCP Task 40

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IEA Task 33 Battery Electric Buses
21.11.2019, Eindhoven

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IEA HEV Task 40 CRM4EV
Connecting the raw material industry with electromobility

- **Mission**
  - To supply objective information to the **Task 40 participants** & to governmental policy makers and agencies, industry decision makers and research institutes
  - To facilitate international collaboration involving shared resources from multiple countries and organisations
- **Scope**
  - Raising awareness: experts networks, workshops, publications, and communication.
  - Define supply and demand scenarios for key EV raw materials
- **Nov 2018 – Apr 2021**

Website: crm4ev.org

Task 40 participating countries and organisations

Japan is represented by JOGMEC and Western Australia by MRIWA

IEA HEV Members

Other

Agencies

British Geological Survey

ivl Svenska Miljöinstitutet

Geological Survey of Norway - NGU -

JOGMEC Japan Oil, Gas and Metals National Corporation

mriwa Minerals Research Institute of Western Australia

Office for Low Emission Vehicles

Research

Argonne National Laboratory

Birmingham Centre for Strategic Elements and Critical Materials

Institute of Process Engineering, Chinese Academy of Sciences

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center — Institute of Vehicle Concepts

IFP Energies nouvelles

IREC

JOANNEUM RESEARCH LIFE

The Faraday Institution | ReLiB Reuse & Recycling of Lithium Ion Batteries

울산대학교 University of Ulsan

Industry

AngloAmerican

AVERE The European Association for Electromobility

Cobalt Institute

Cu Copper Alliance®

Nickel Institute — knowledge for a brighter future

igo

umicore — materials for a better life

VALE

VALUAD Sustainable Future

CRM4EV Critical Raw Materials Electric Vehicles

Scope of HEV-TCP Task 40

EVs and Critical Raw Materials:

Stakeholders need reliable, transparent & up to date information on

Electric Vehicles - Demand

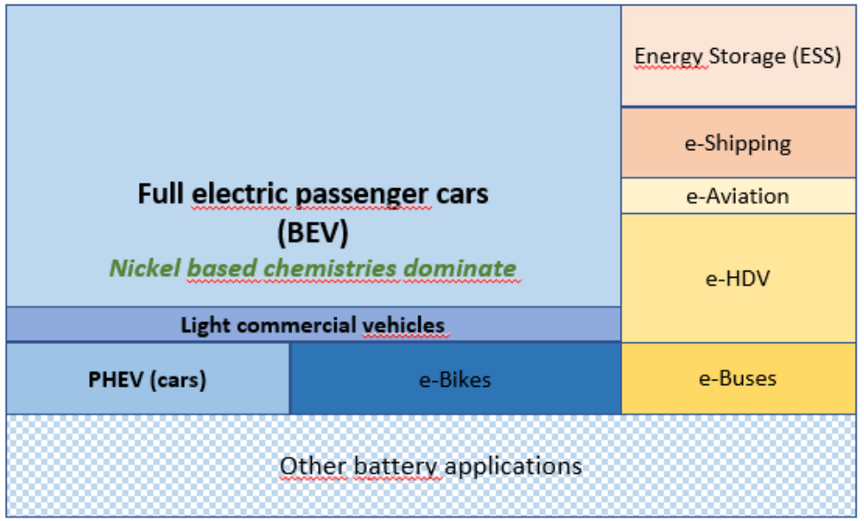
- How many, when, which type
- When and to what extend will mass deployment happen
- How EV technologies evolve: impact the type and quantity of CRMs required (per unit)

Critical Raw Materials - Supply

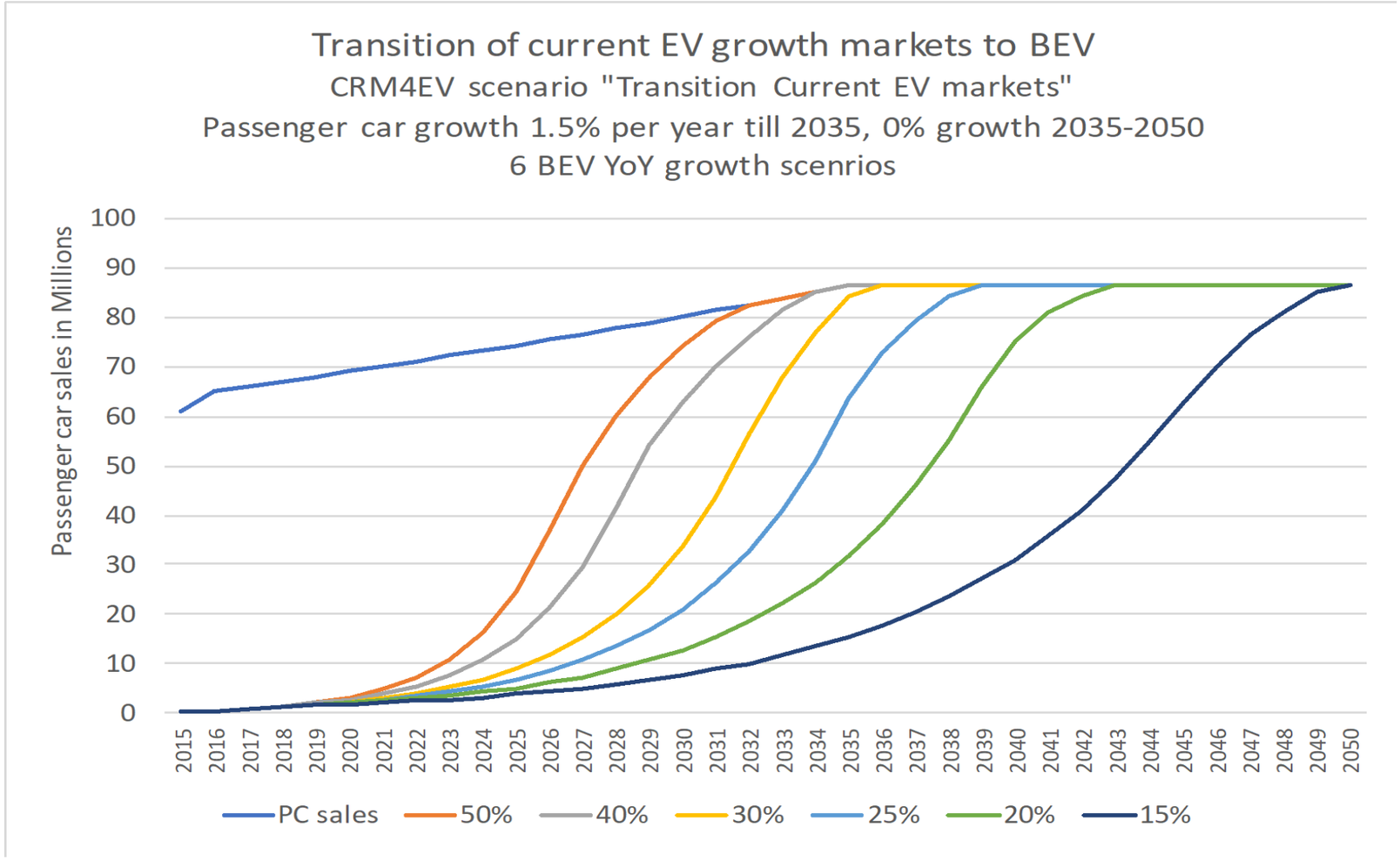
- Li – Ni – Co – Cu – Graphite – Rare Earths
- Supply risks at short and long term
- Environmental impacts - LCA
- Social impacts
- Recycling and the circular economy

Task 40 CRM4EV: Electric vehicle scenarios

- **Scenarios for 2025, 2030, 2035 EV deployment and raw material needs**
- **Scenarios for 2050 « full transition » & « circular economy »**
- How many EVs, which type and when?
  - BEV passenger cars only
  - Battery size, lifetime?
  - Impact autonomous vehicles and shared « ownership »?
- Build in « robustness » for battery chemistry evolution
  - Different chemistries, different applications (vehicles and uses)
  - Timelines for evolving chemistries
  - Transition to solid state batteries
  - Nickel-Cobalt based developing to high nickel – low cobalt



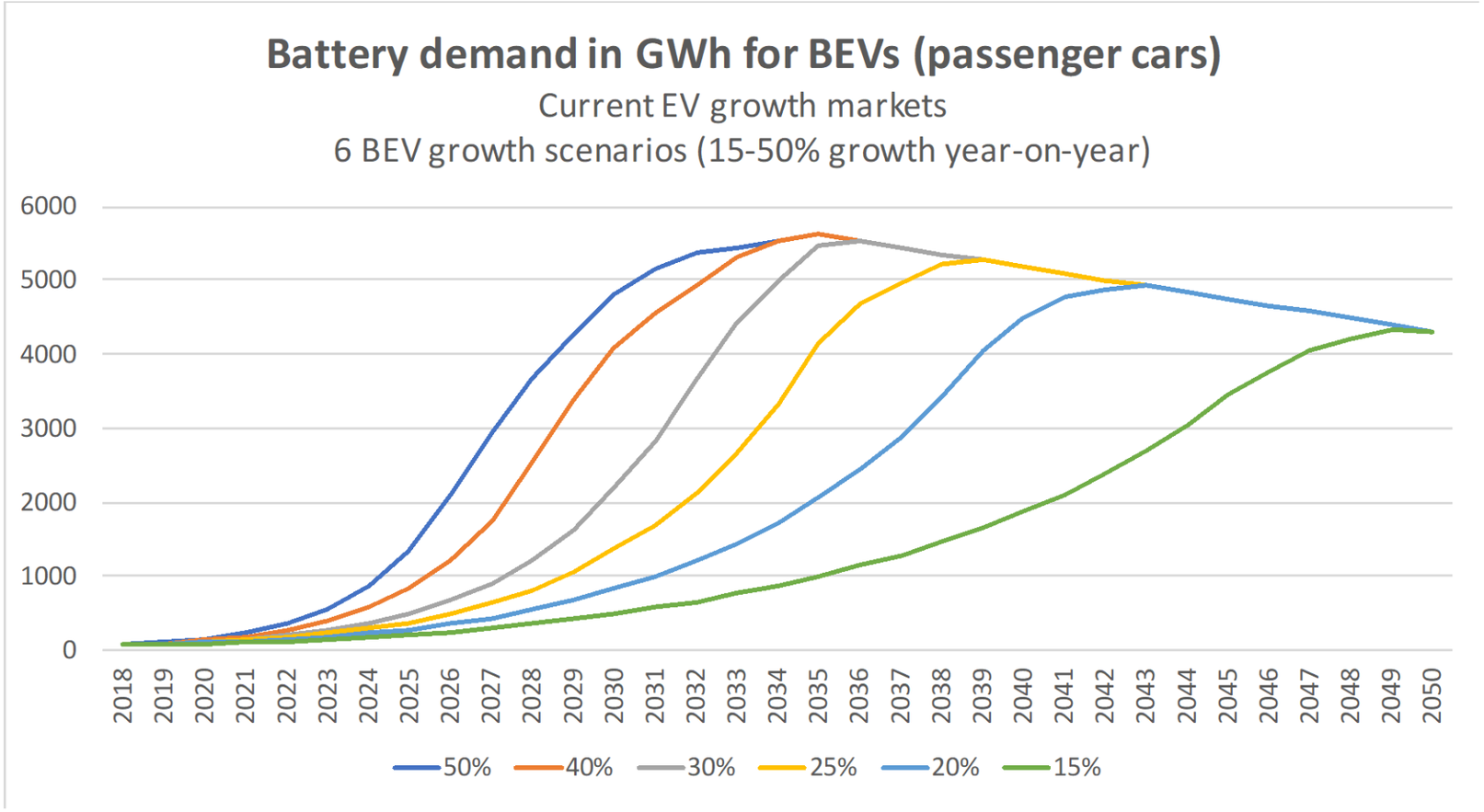
A range of BEV growth scenarios is developed
Covering all current forecasts & national / COP 21 ambitions



- Continuation of the current growth rate of 50% YoY results in a full transition by 2030
- 30-40% growth results in a transition around 2035

Demand for batteries will increase faster then the growth in BEVs

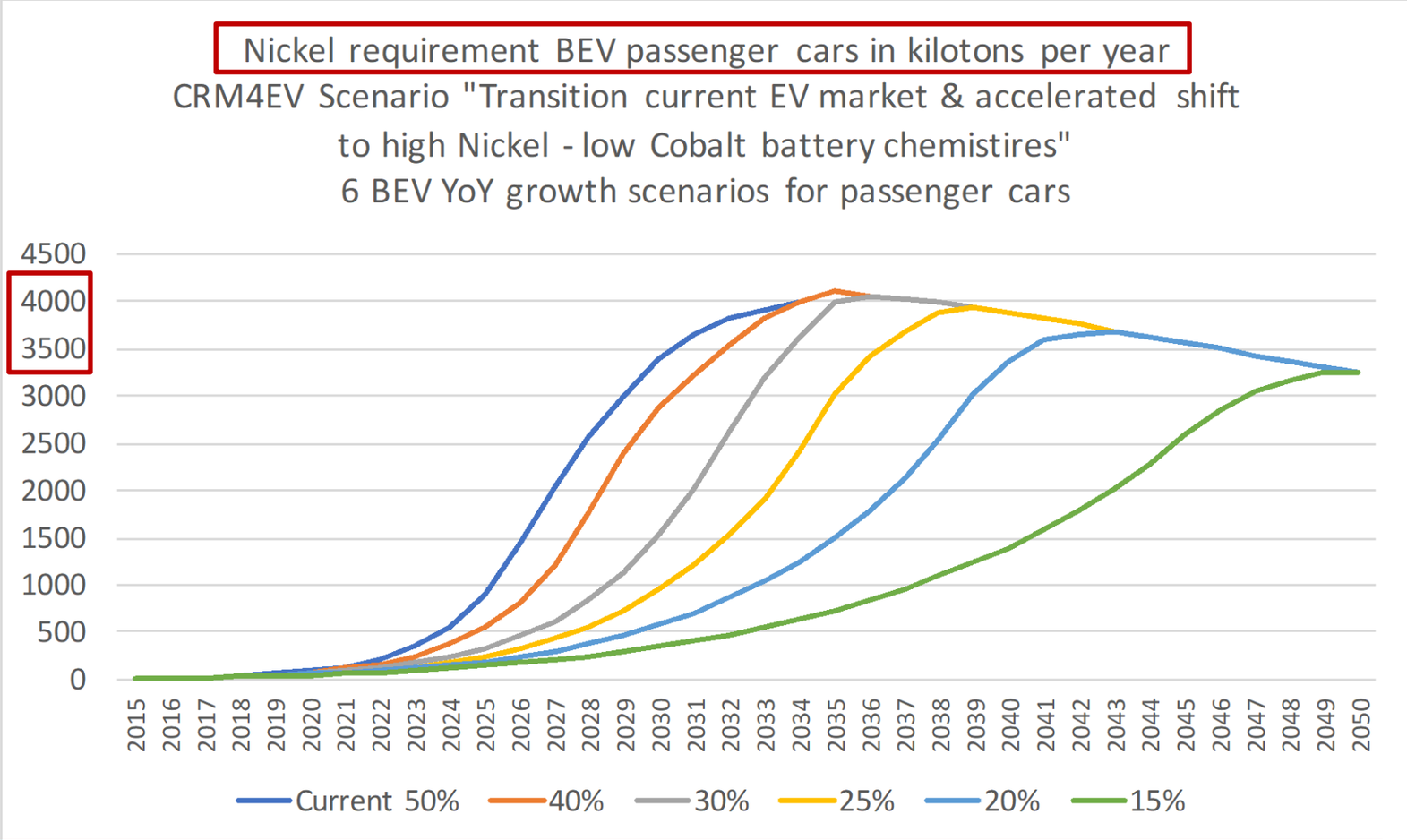
Longer battery lifetimes may impact demand substantially after 2035



- Battery size increasing to 65kWh in 2030 and gradually decreasing after 2035 to 50 kWh in 2050
  - More efficient vehicles
  - Improved charging infrastructure (+ wireless)
  - Consumer used to electric vehicles
- Overall demand decreasing with zero growth in PCs after 2035 and smaller batteries

Nickel demand for BEV (car) batteries

Longer battery lifetimes and changing chemistries may impact demand substantially after 2035



Scenario parameters:

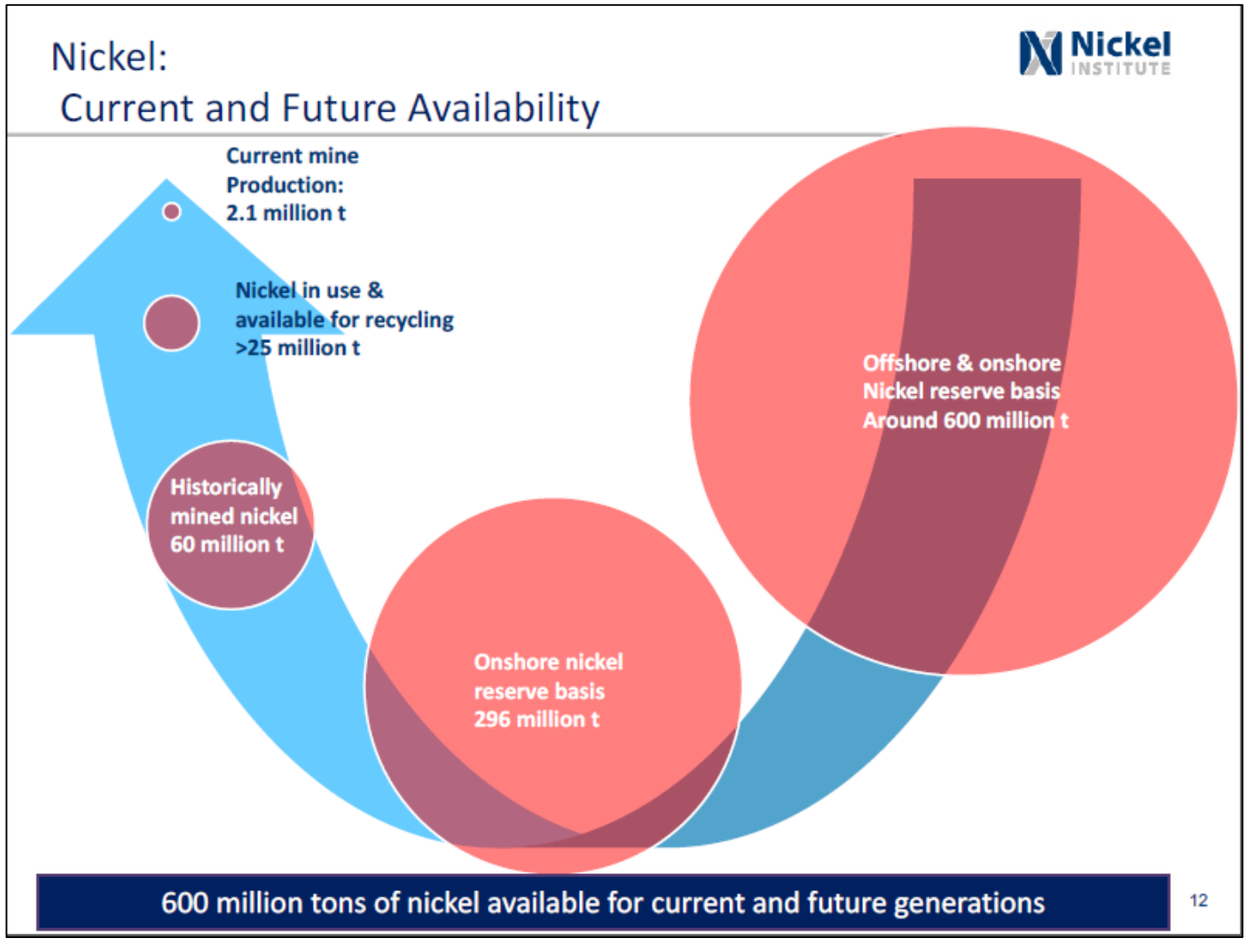
- Battery chemistry for BEV (cars) based on NMC/NCA evolving to high Nickel
- Battery size increasing to 65kWh in 2030 and gradually decreasing after 2035 to 50 kWh in 2050
- Battery lifetime is equal to vehicle lifetime: 15 years

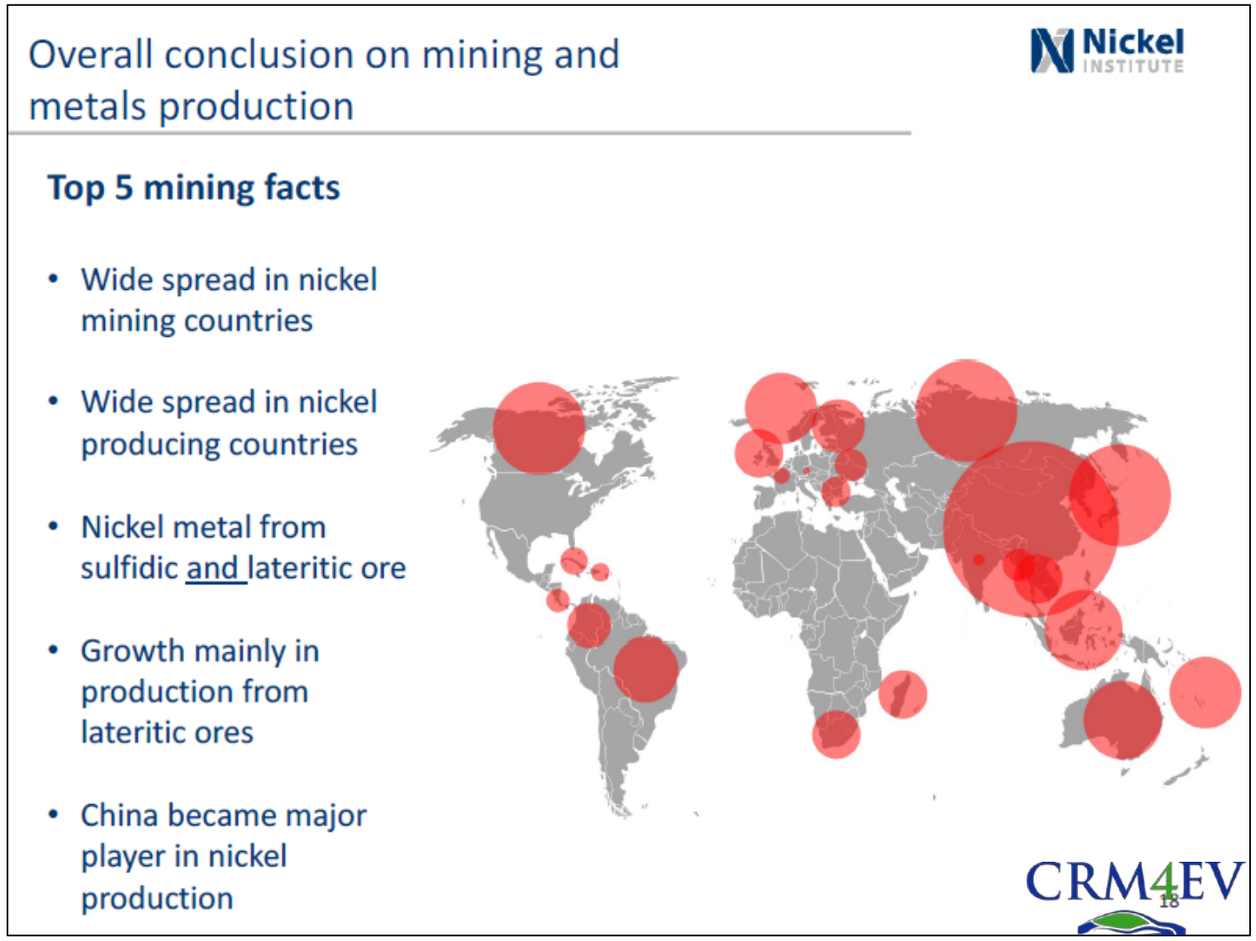
Nickel based battery chemistry is continued in this scenario till 2050; however competitive chemistries with low or without nickel may be developed

Current Nickel production is 2,000 kilo tons (of which 3% is for batteries) of which about half Class I, suitable for Li-ion batteries

Nickel production – reserves - resources

Reserves: ore body known and extraction viable / Resources: future expected reserves

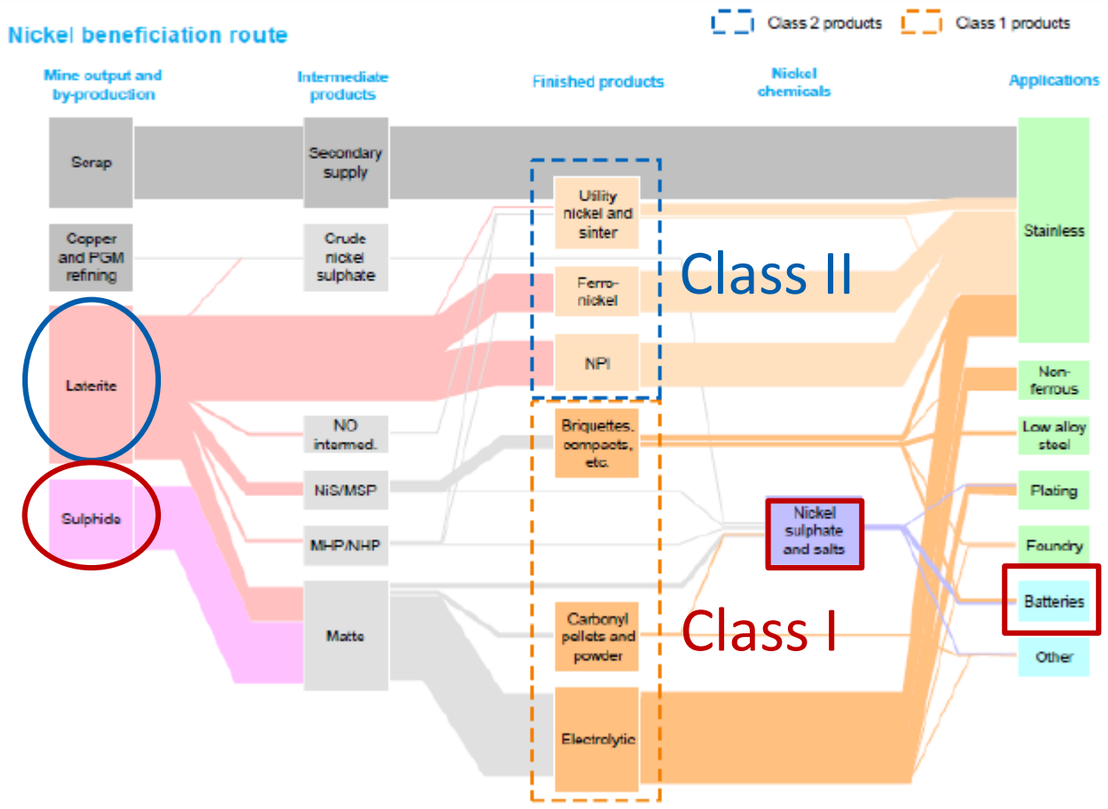




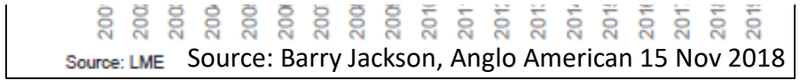
Source: Mark Mistry, Nickel Institute 15 Nov 2018

Nickel for EV-batteries

NICKEL SULPHATE IS THE PRODUCT NEEDED FOR BATTERIES



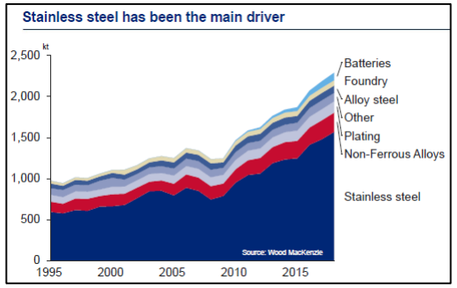
SOURCE: Roskill, McKinsey nickel team anlaysis



Source: Barry Jackson, Anglo American 15 Nov 2018

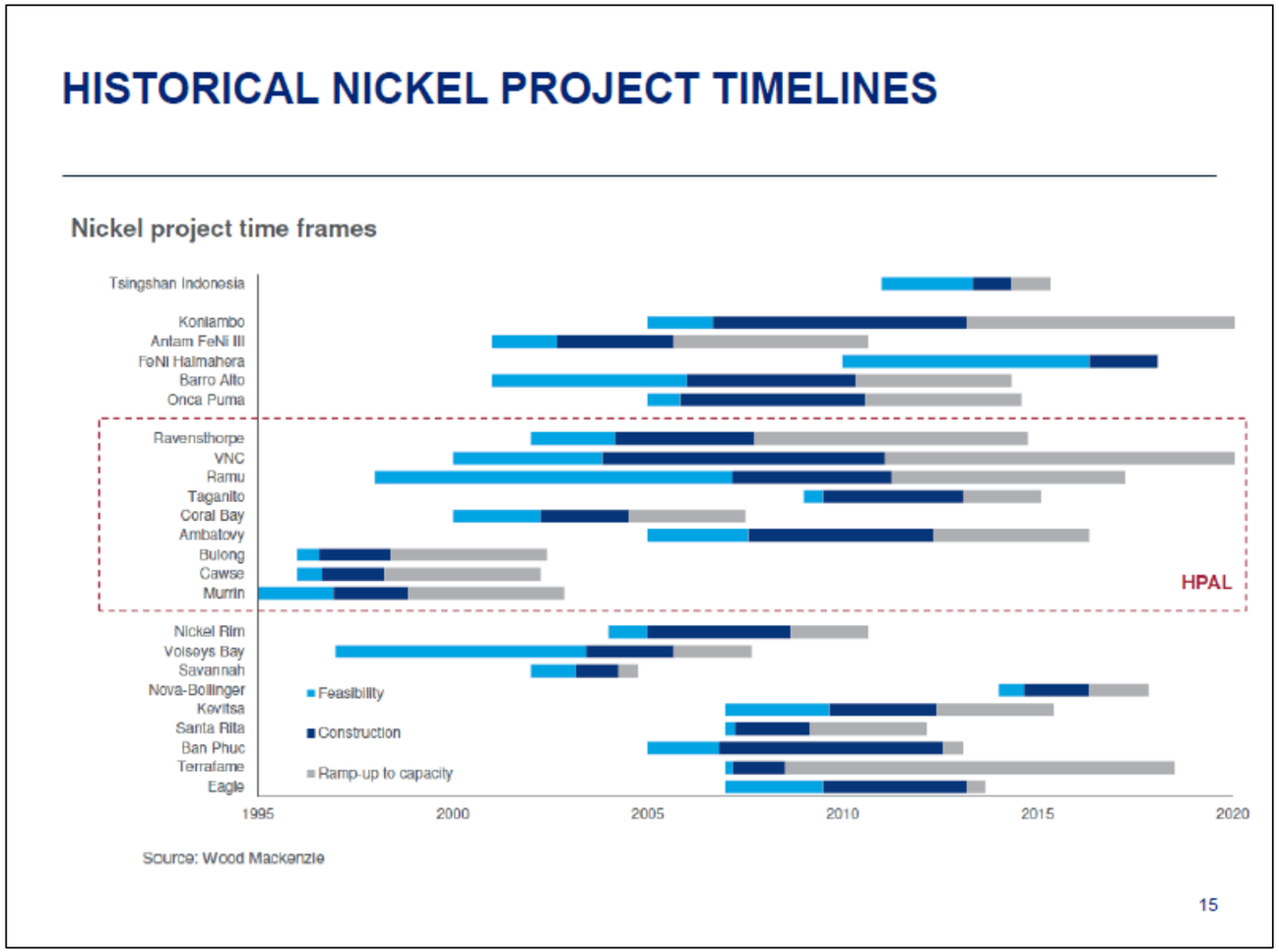
With economics limiting suitability of some nickel products

Source: Frank Nikolic, Vale, 15 Nov 2018



Raw materials for Li-ion batteries: key points

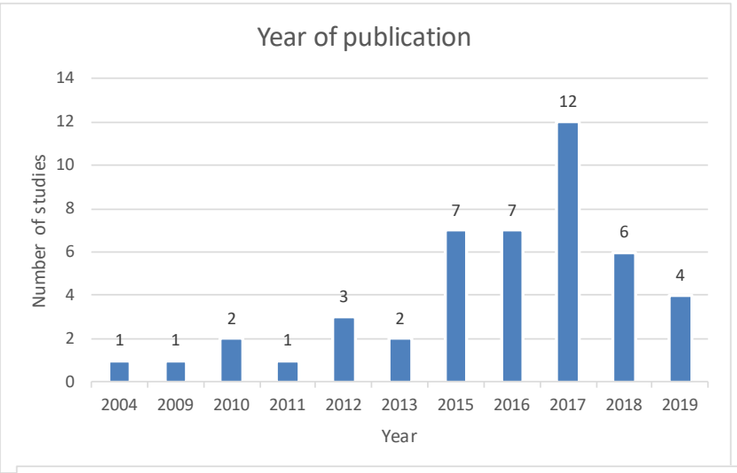
- « Expert » forecasts underestimating the developments within automotive companies and national administrations?!
- Task 40 demand scenarios point to probable (much) higher demand for raw materials then (commonly) foreseen
- Supply scenarios are needed « how fast could supply grow » ?
- Mining / refining possibly structural bottleneck, NOT the production of cells and battery packs with factory expansions lead-times of 1 year (China)

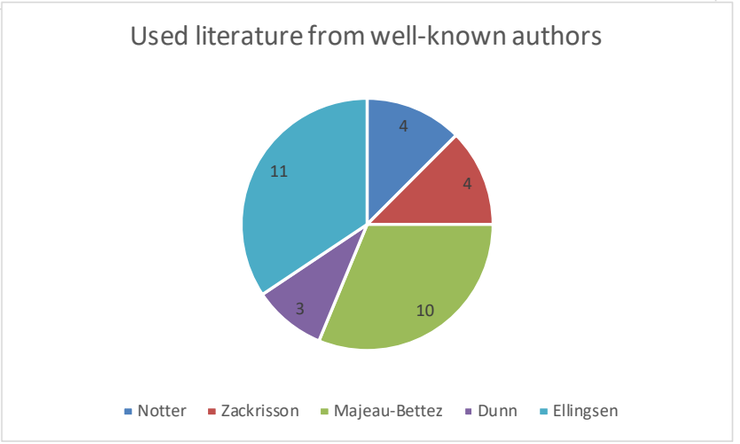


Life cycle assessment in Task 40 CMR4EV

- Covers entire EV lifecycle
- Focus on raw material mining and refining, battery production and recycling, with data from Task 40 partners
- GWP & primary energy demand, other impact categories depending on available primary data
- Leveraging existing LCA studies and expertise of Task partners (Argonne, ivl, ifp, Joanneum Research, raw material institutes, …)
- Most LCA studies show data gaps for primary material production and battery recycling - CRM4EV contribution to fill that gap
- Harmonization of methodologies in existing CRM-LCA studies (Ni, Co, Cu-Institutes)
- Current / future battery chemistries to consider in LCA

46 EV-LCA studies reviewed





Source: Christian Aichberger, Thesis, Joanneum Research 2019

Energy demand of raw material mining & refining

Raw materials and their relevance in view of primary energy demand

Nickel INSTITUTE

(A) Cumulative Energy Demand (MJ-eq / kg)

Lowest — Highest

H																He 67.5
Li 125	Be 1,720											B 27.3	C	N	O	F	Ne
Na	Mg 18.8											Al 131	Si	P	S	Cl	Ar
K	Ca 5.8	Sc 97,200	Ti 115	V 516	Cr 40.2	Mn 23.7	Fe 23.1	Co 128	Ni 111	Cu 53.7	Zn 52.9	Ga 3,030	Ge 2,890	As 5.0	Se 65.5	Br	Kr
Rb	Sr 48.8	Y 295	Zr 19.9	Nb 172	Mo 117	Tc	Ru 41,100	Rh 681,000	Pd 72,700	Ag 3,280	Cd 53.0	In 1,720	Sn 321	Sb 141	Te 435	I	Xe
Cs	Ba 4.0	La-Lu*	Hf 3,510	Ta 4,360	W 133	Re 9,040	Os 85,000	Ir 169,000	Pt 243,000	Au 208,000	Hg 179	Tl 5,160	Pb 18.9	Bi 697	Po	At	Rn
Fr	Ra	Ac-Lr**	Rf	Db	Sg	Bh	Hs	Mt									

Nuss P. & Eckelmann M., Life Cycle Assessment of Metals: A Scientific Synthesis. PLoS One. 2014 Jul 7;9(7):e101298. doi: 10.1371/journal.pone.0101298. eCollection 2014.

*Group of Lanthanide	La 215	Ce 252	Pr 376	Nd 344	Pm	Sm 1,160	Eu 7,750	Gd 914	Tb 5,820	Dy 1,170	Ho 4,400	Er 954	Tm 12,700	Yb 2,450	Lu 17,600
**Group of Actinide	Ac	Th[a] 1,260	Pa	U[a] 1,270	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Metals production and primary energy demand for main metals (after Nuss and Eckelmann 2014)

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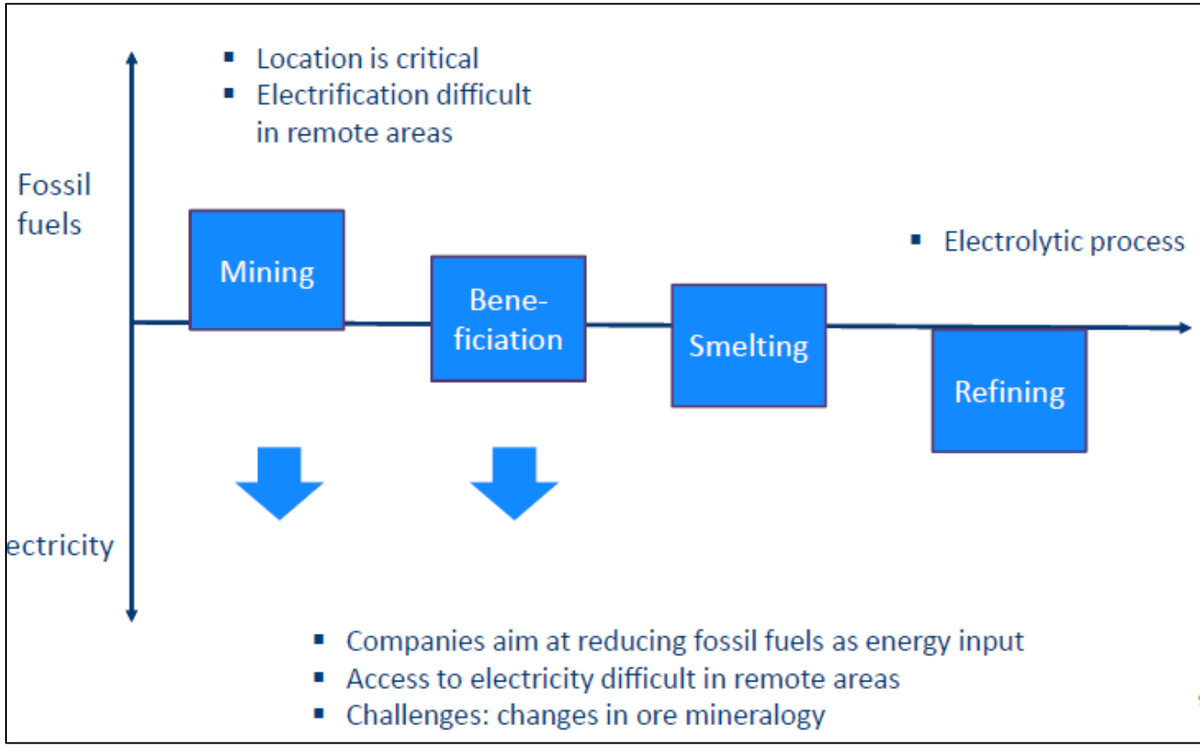
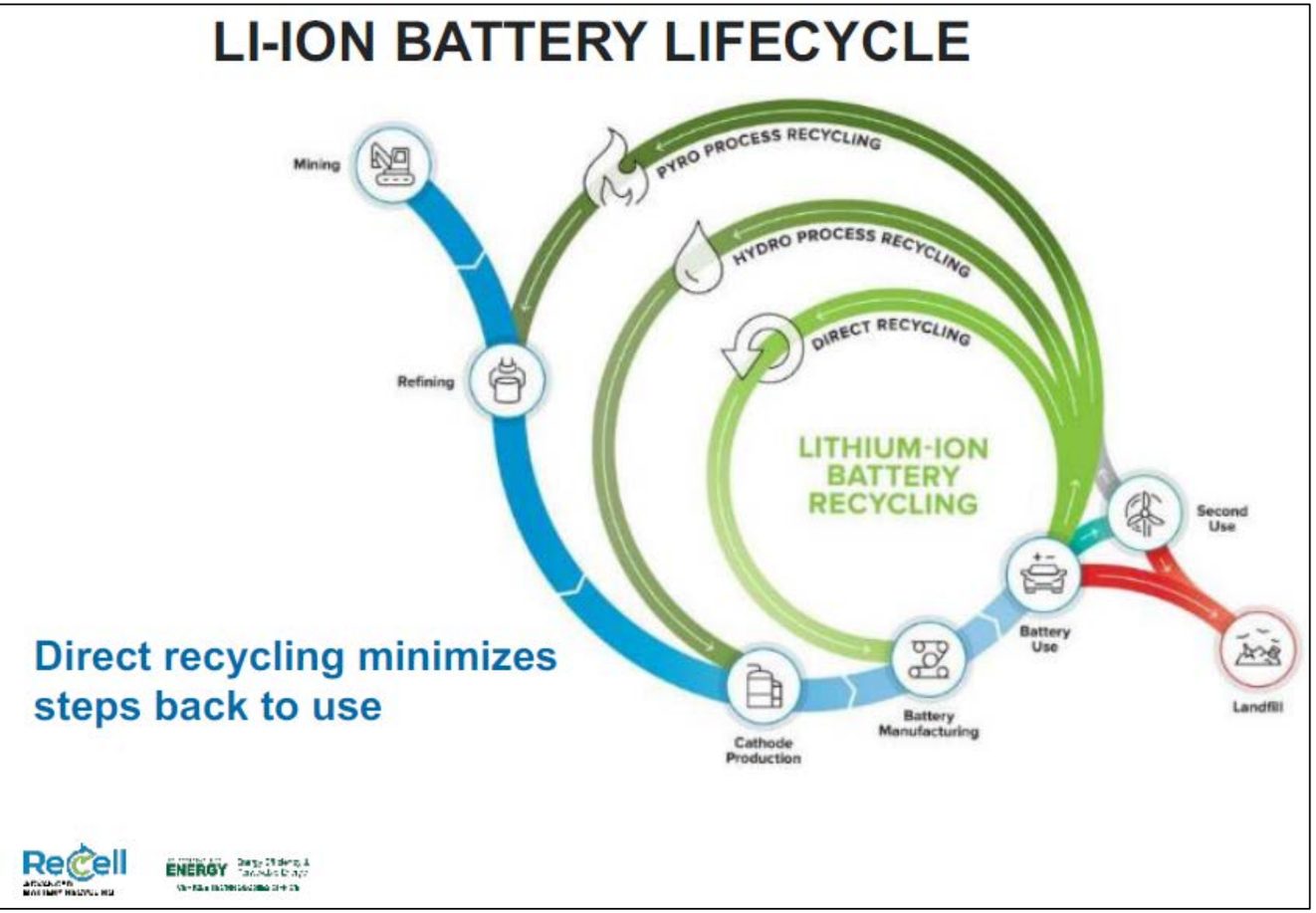


Source: Mark Mistry, Nickel Institute

Recycling of EV batteries – current key issues



Source: Linda Gaines, Argonne

- Pyro- and hydrometallurgical processes available, but need Economy of Scale
- Direct recycling technology is still R&D topic
- Battery collection
  - Poor collection of portable Li-ion batteries < 10%!
  - Reverse logistics EV-batteries
  - Retired and damaged batteries; hazardous waste
- Business case for recycling
  - depends on: batt chemistries, economies of scale, recycling technologies
  - Currently main source = battery production scrap
  - Who owns the battery after EoL? Car user? OEM? Recycling company?
  - For the next 10-15 years contribution of recycled materials as raw material source for battery production is expected to be rather limited.

CRM4EV

CRITICAL RAW MATERIALS
ELECTRIC VEHICLES

Task 40 in China
November 2019

Questions related to Task 40 CRM4EV or interest to join Task 40?

Visit our website or contact:

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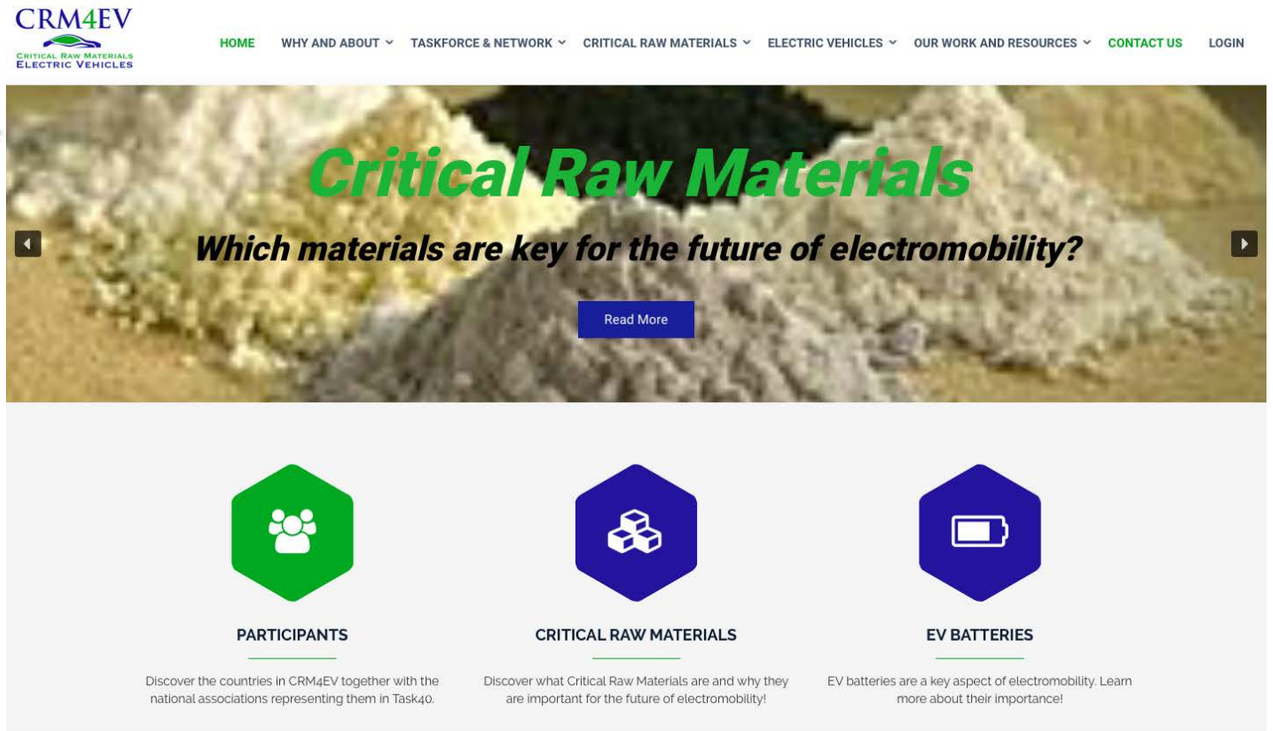

Thank you for your attention!

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