The circular economy, electric vehicles and the impact on cobalt supplies

UK Energy Storage Conference, 2019

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- The trouble with cobalt – three key issues
- The 2017 cobalt supply chain
- Future circular economy scenarios
- Conclusion and outlook

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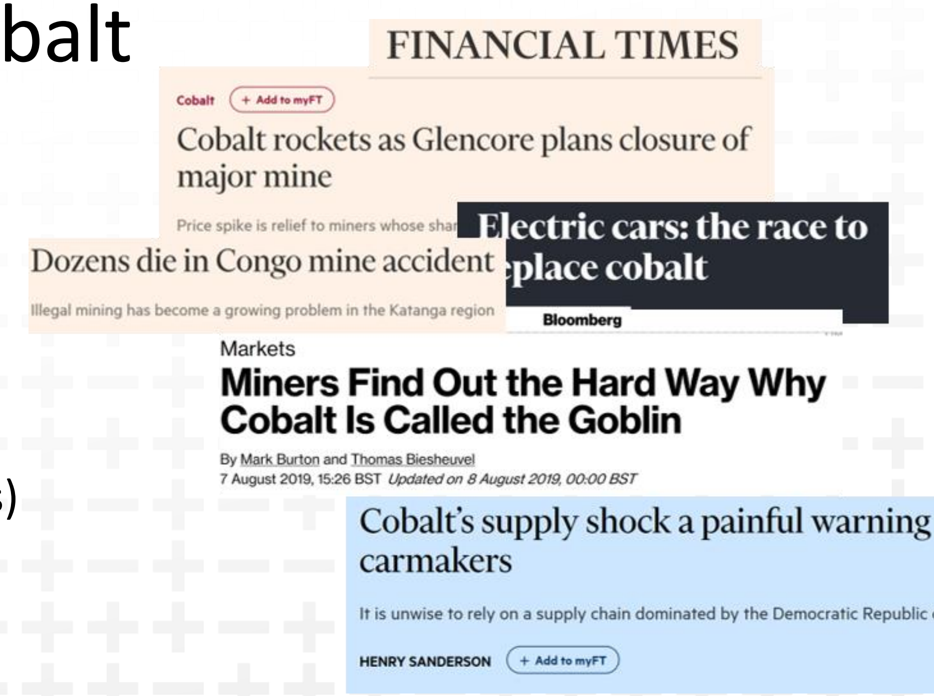
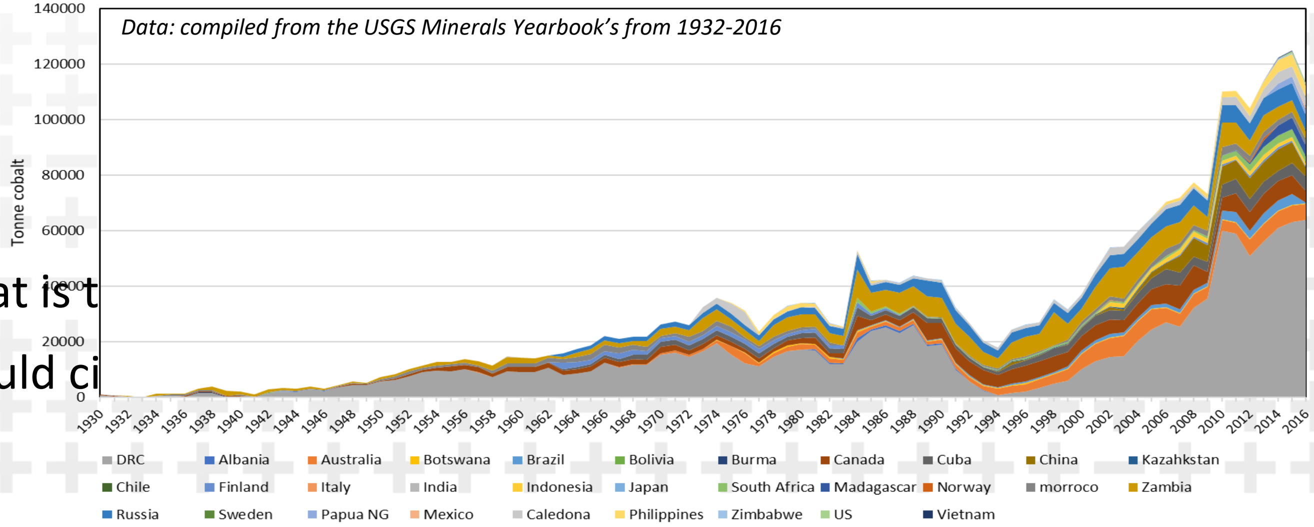
The trouble with cobalt
Three key issues



1. Byproduct nature
Supply of cobalt depended on the copper and nickel market

2. Substitution
Difficult of subsituting due to unique material features (batteries, alloys)

3. Centralised
Highly depended on low cost mines in the DR Congo



What is t … Europe?

Could ci … future?

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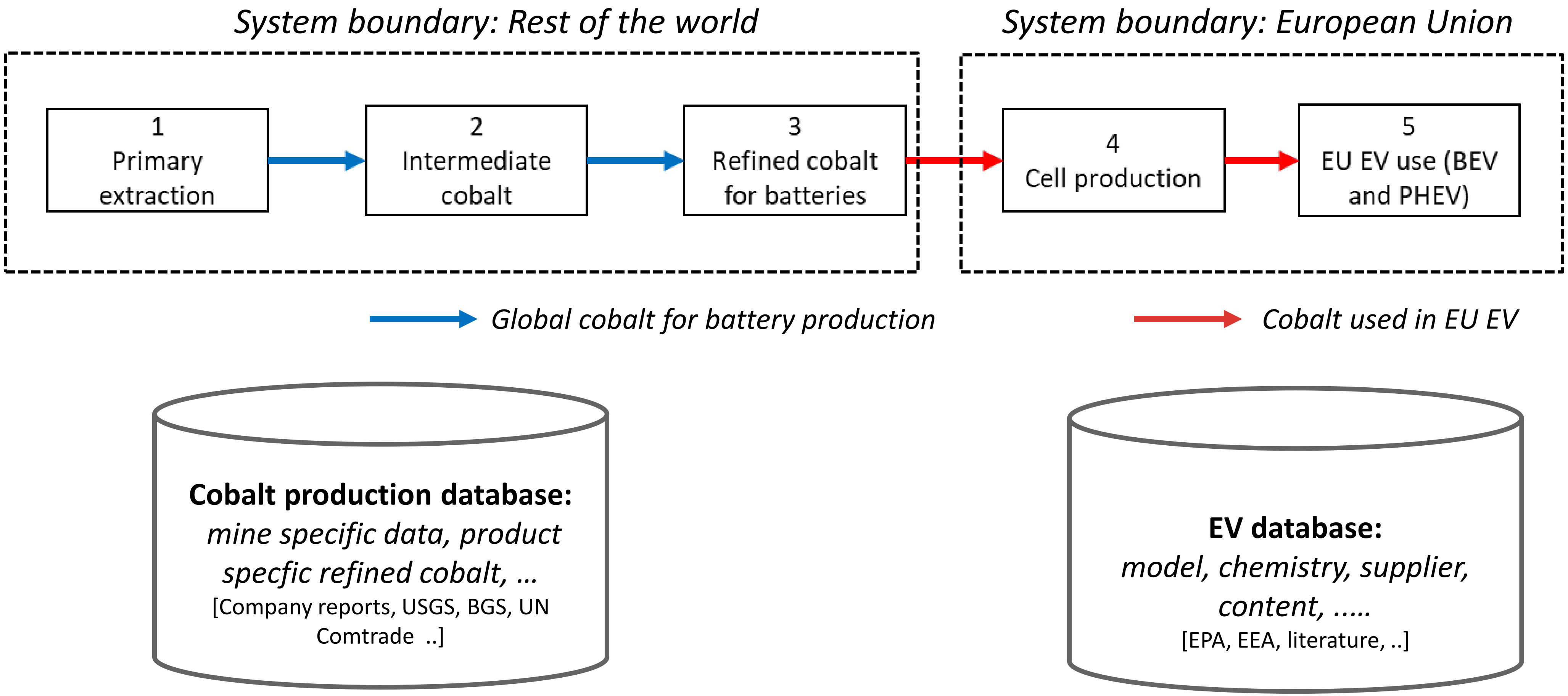
Static material flow analysis cobalt – 2017

European battery and plug in hybrid vehicles



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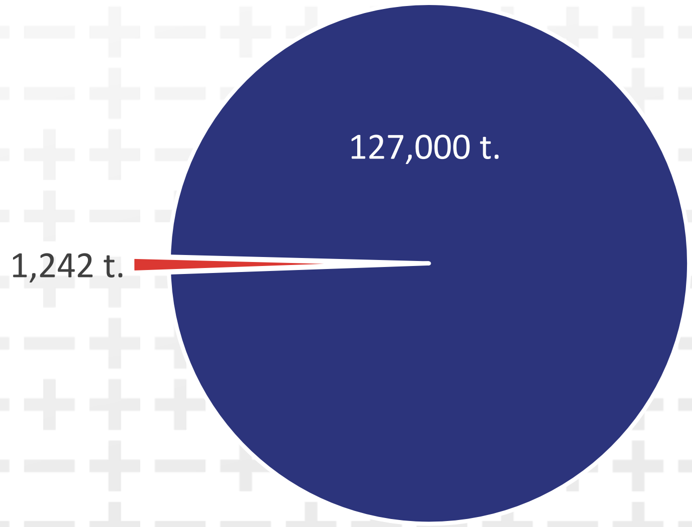
Results:
2017 cobalt supply chain for European EV (1)

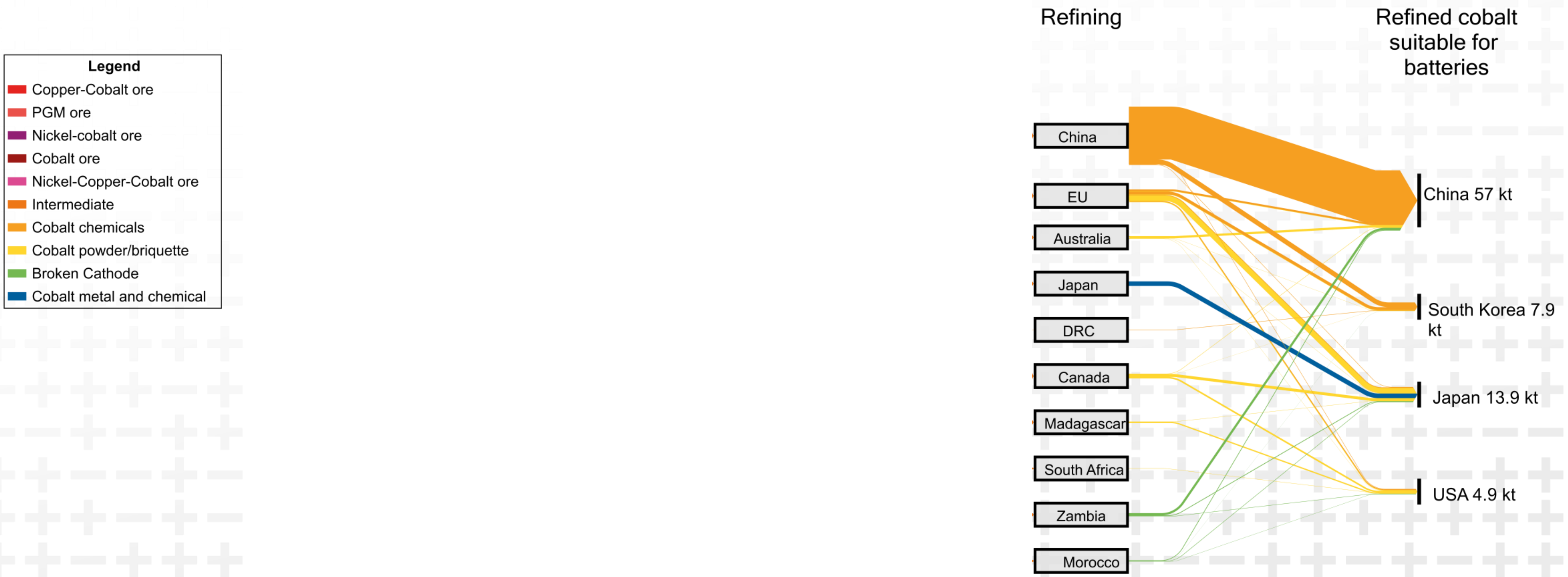
EV use in the EU

- BMW e.g. i3 (271t; 45,116 vehicles)
- Renault e.g. Zoe (210t; 28,353 vehicles)
- Tesla Model S & X (193 t; 17,778 vehicles)
- VW e.g. e-golf (157t; 25,130 vehicles)
- Daimler e.g. Fortwo (97t; 25,355 vehicles)
- Nissan e.g. Leaf (59.3t; 14,292 vehicles)
- Kia e.g. Soul EV (53t; 6,758 vehicles)
- Hyundai Ioniq (49t; 5,687 vehicles)
- Volvo e.g. S90 PHEV (40t; 10,614 vehicles)
- Audi e.g. Q7 E-tron (35t; 8,693 vehicles)
- Mitsubishi e.g. i-MiEV (25t; 14,173 vehicles)
- Porsche e.g. Cayenne (19t; 5,293 vehicles)
- Mini Countryman (11t; 3,901 vehicles)
- Ford e.g. Focus EV (9t; 2,747 vehicles)
- Opel Ampera-E (5t; 499 vehicles)
- Peugeot e.g. Ion (3t; 1,300 vehicles)
- Toyota Prius PHEV (2t; 1,975 vehicles)
- Citroen e.g. C-Zero (3t; 1,175 vehicles)

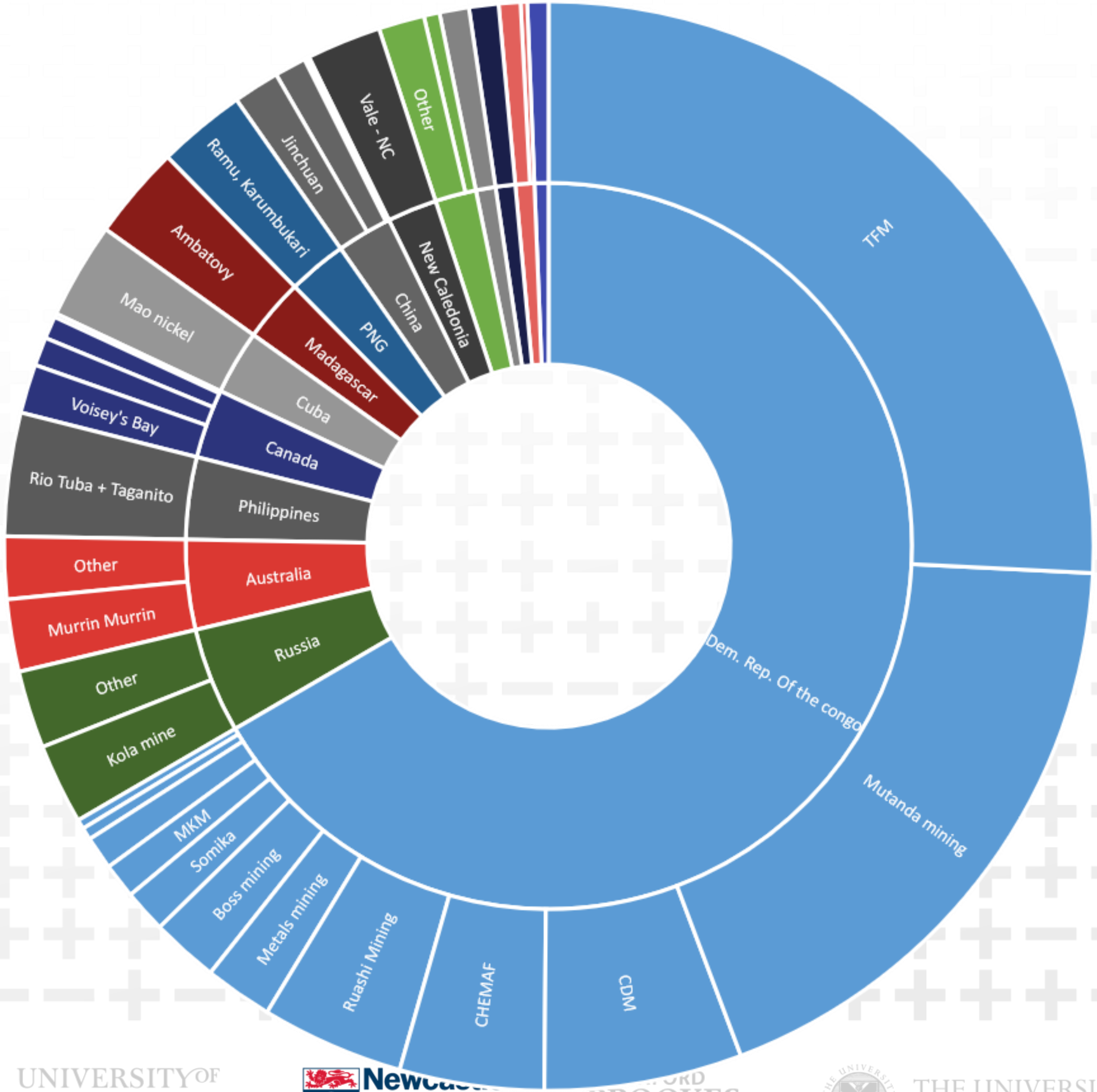
Total:



2017 cobalt supply chain for European EV (2)



2017 cobalt supply chain for European EV (3)



Cobalt mine production 2017:
Three mines accounting
for 50% of global production

Circular economy scenarios
Overview

Business as usual

Continuation of current trends but recycling capacity and collection rates based on current levels

Technology driven reduce scenario

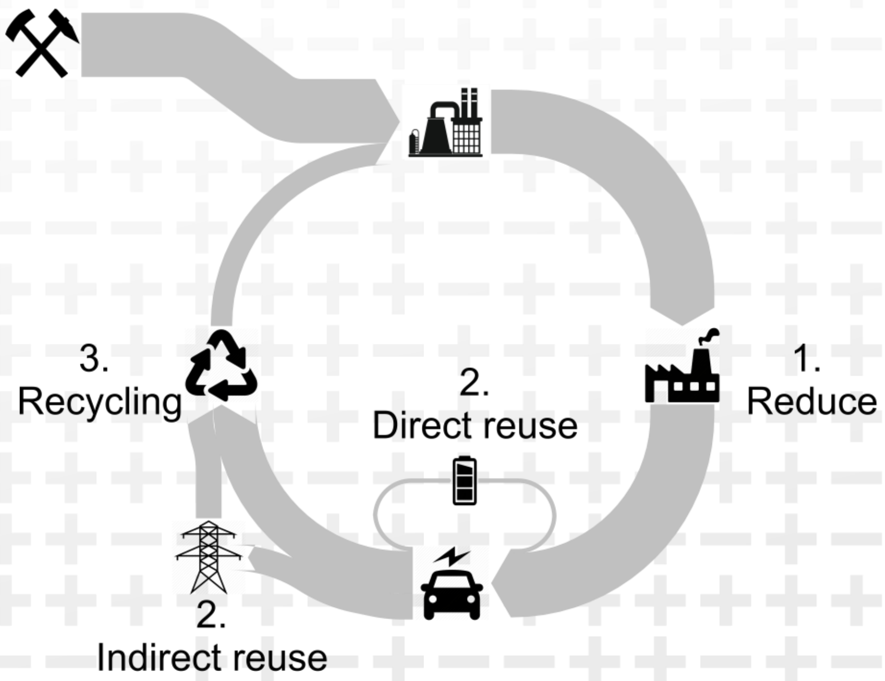
Rapid adoption of new battery technologies with a small to zero cobalt content

Reuse business model scenario

Battery leased to vehicle owner and replaced after 8 years to foster second life

Policy-driven recycling scenario

Updated policy to increase collection rates, including an increase in recyling capacity



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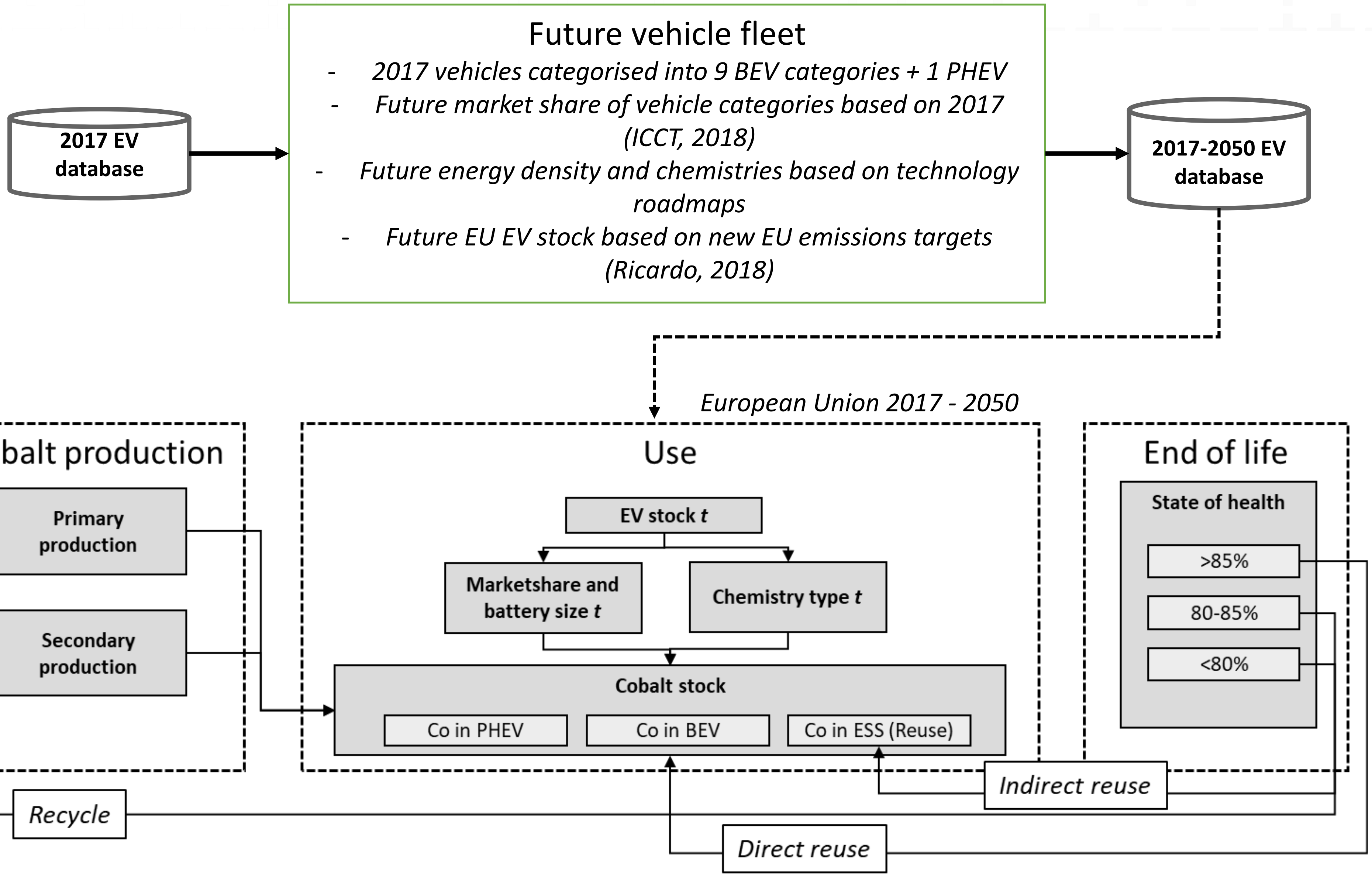
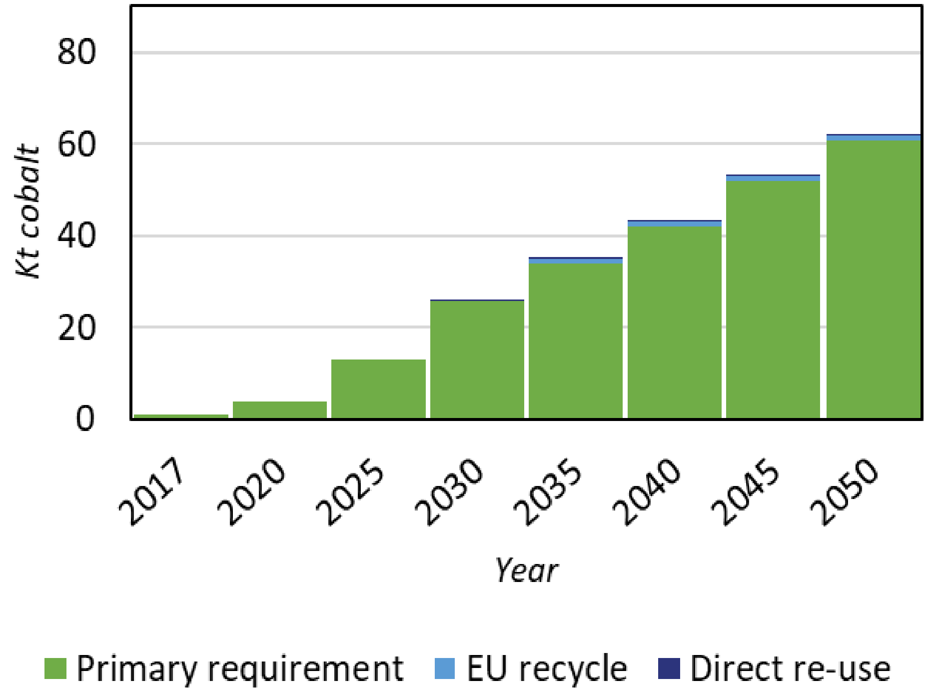
Methodology



Business as usual scenario – *Cobalt supply and demand*



Key issues

- Lack of recycling due to low capacity in the EU
- High amount of missing vehicles (illegal export, dismantling and theft)

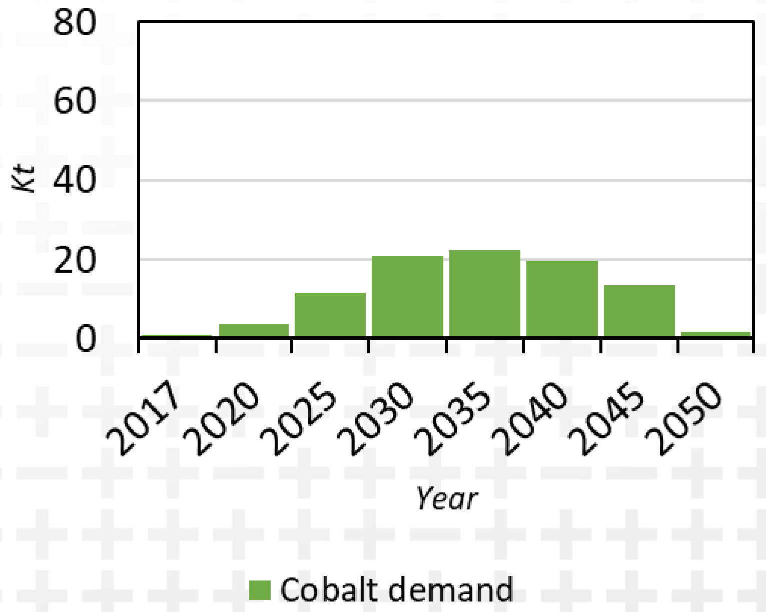
End of life	15 year
EU recycling capacity	41,500 tonne of battries (as of ‘17, no additional capacity added)
Chemistry	Shift to NMC811 and NCA

Technology driven reduce

Rapid technological development

Case one:

Alternative chemistry without cobalt by 2030



Search Bloomberg

Hyperdrive

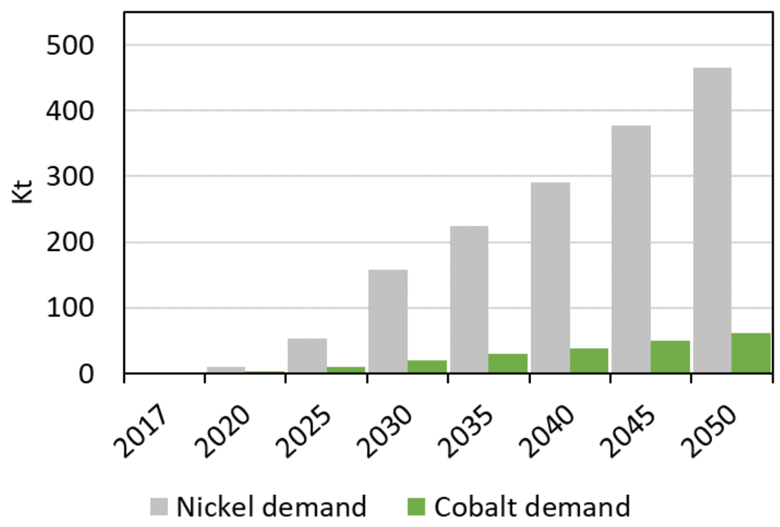
The Top Miners Are Split on How to Chase the EV Battery Boom

By David Stringer

5 August 2019, 01:53 BST

Case two:

Rapid shift to low Co and high Ni chemistry



2017 Nickel production in: 2,160 kt (USGS, 2017)

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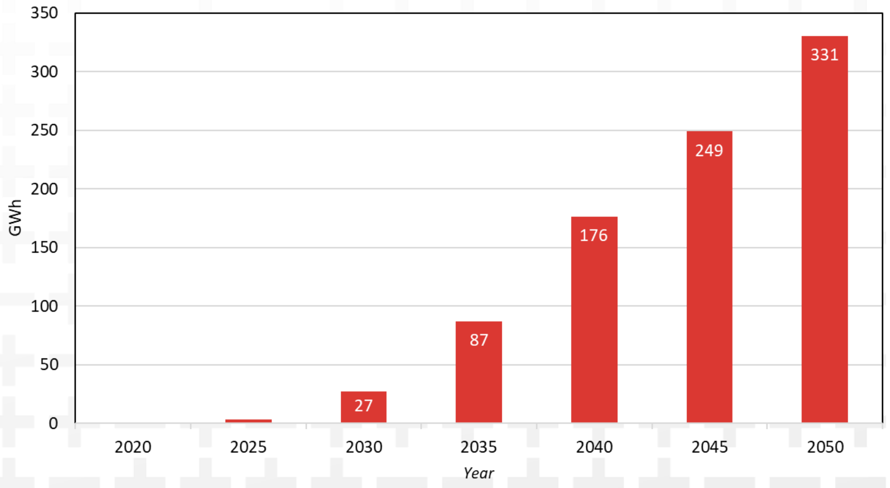
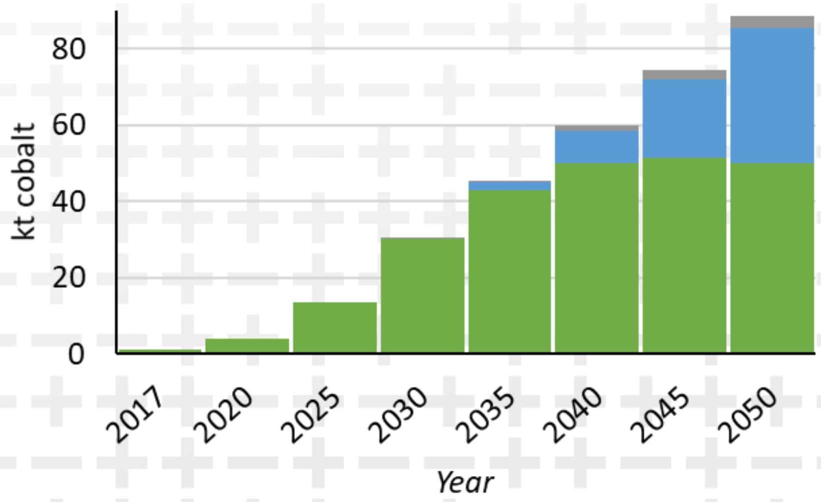
Reuse business model scenario
Early battery replacement (8 yr.)

Annual available second life energy storage in GWh



Total installed energy storage 2018 (excl. Pumped hydro) :
17 GWh (Bloomberg, 2019)

Cobalt requirement



Assuming all batteries are recycled in the EU

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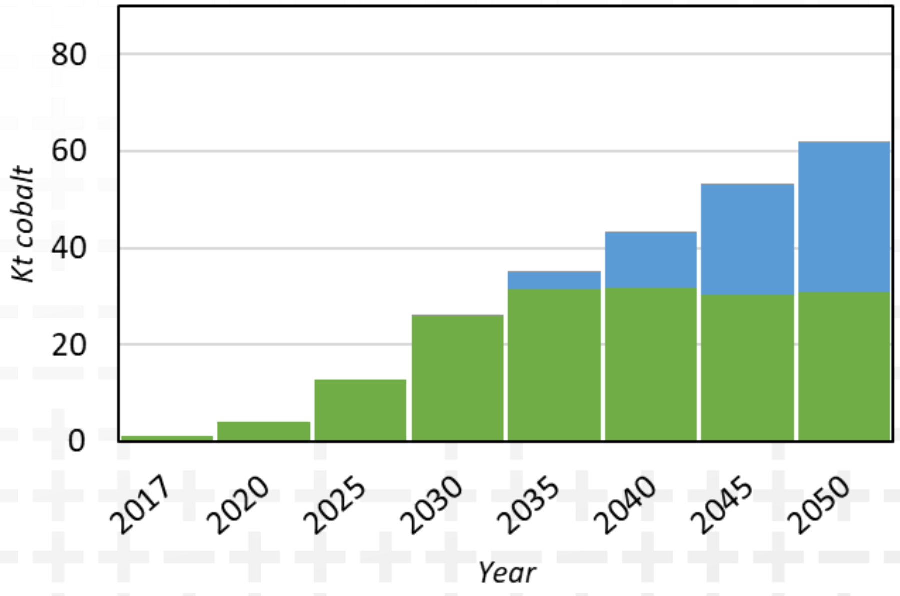
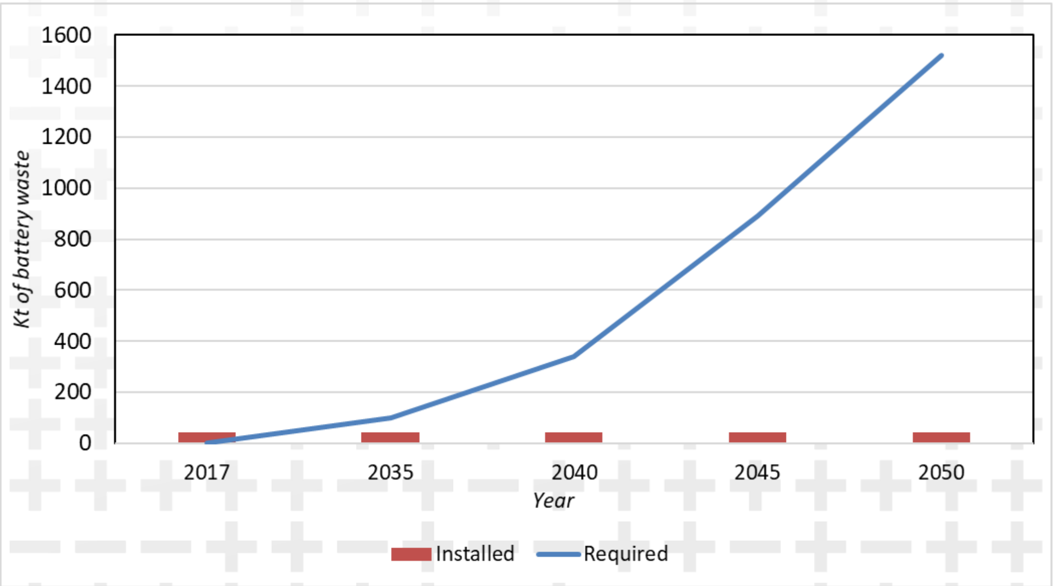
Recycle

Improving collection rates and EU recycling capacity



- Saturation by 2035 at 31 Kt annually

End of life batteries and required recycling capacity



- Currently installed EU liB recycling capacity: 41.5 kt

Conclusion and outlook

- New chemistries will be key in reducing cobalt demand but resources issues need to be considered to avoid burden shifting
- New business models and innovation should be explored to enhance re-use of EV batteries
- Recycling of key importance for cobalt supply issues on a medium term, need to build up a recycling industry and improve collection

-> Whole of the supply chain needs to be taken into account when planning for a EV revolution

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Thank your for your attention!

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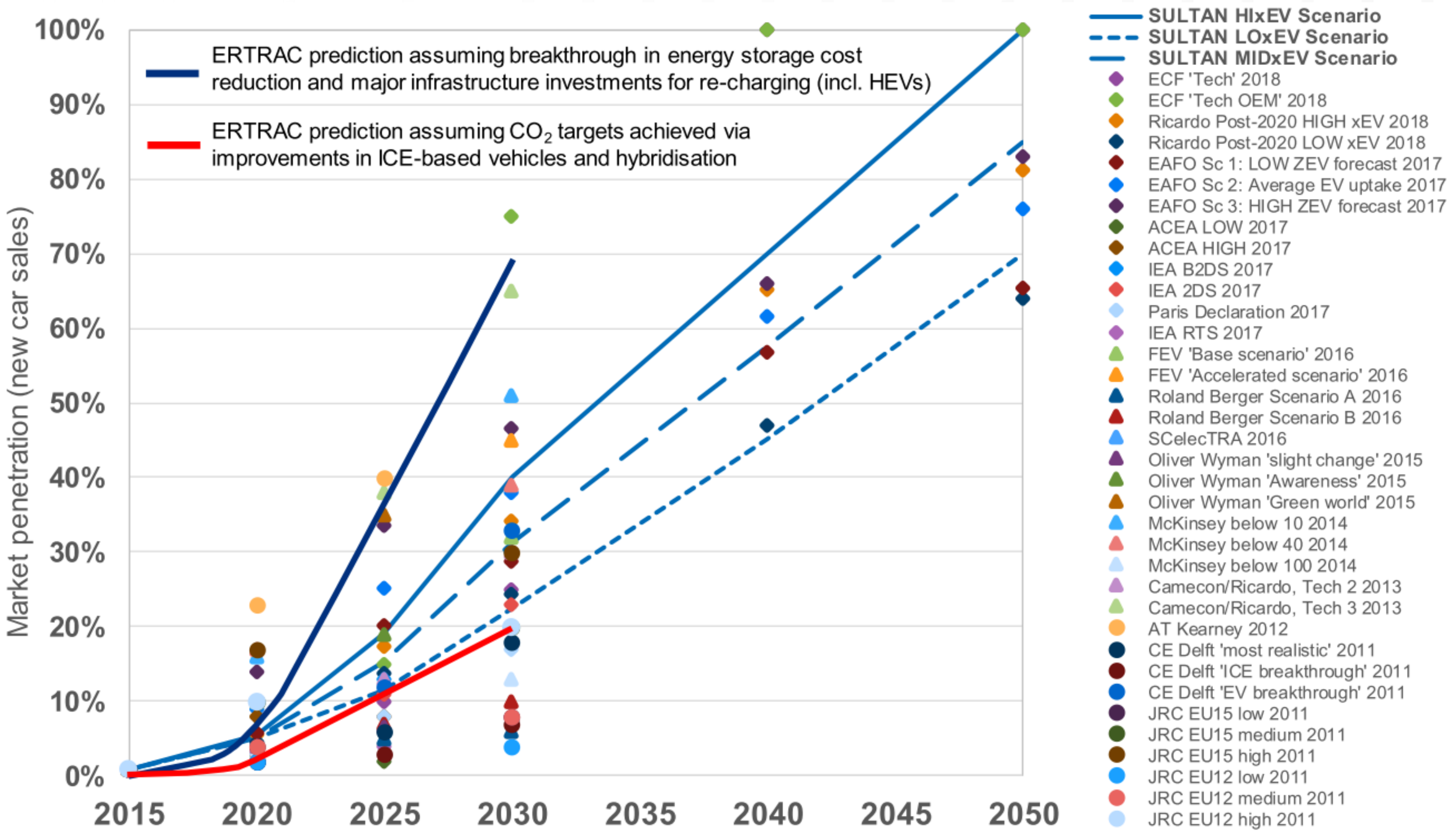
Comparison future EV scenarios (Ricardo,2017)



Notes: xEVs = BEVs, PHEVs, REEVs and FCEVs.

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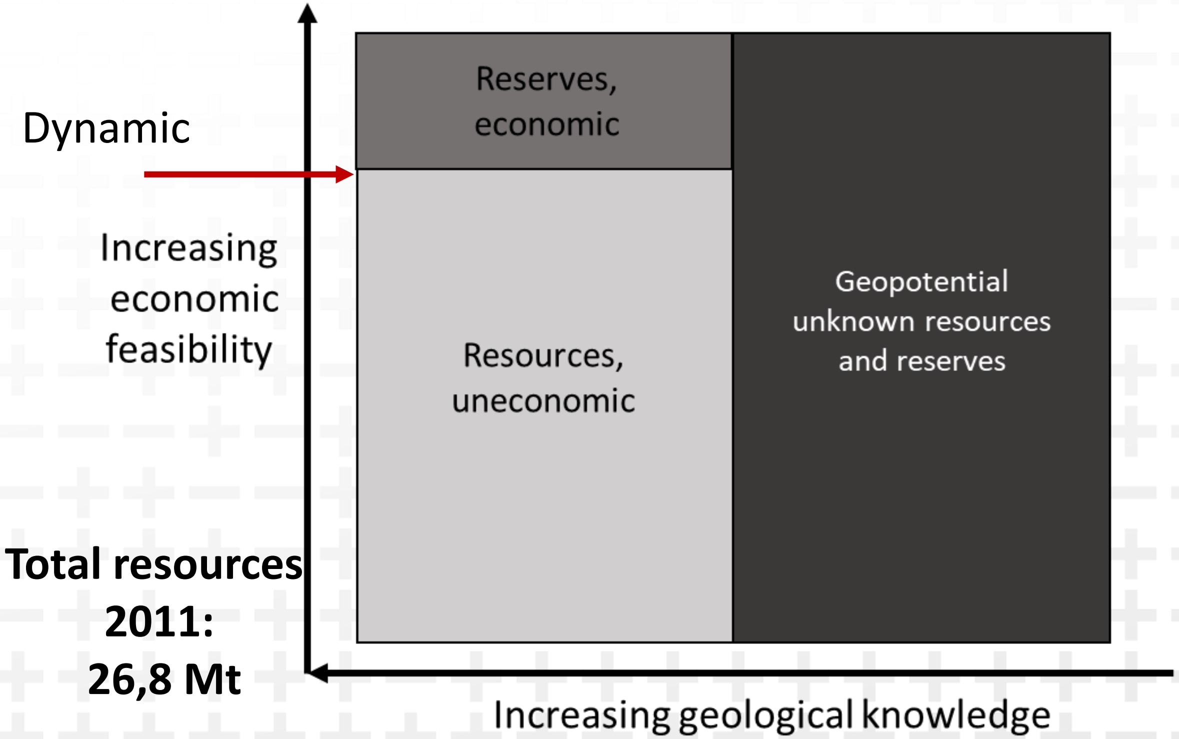
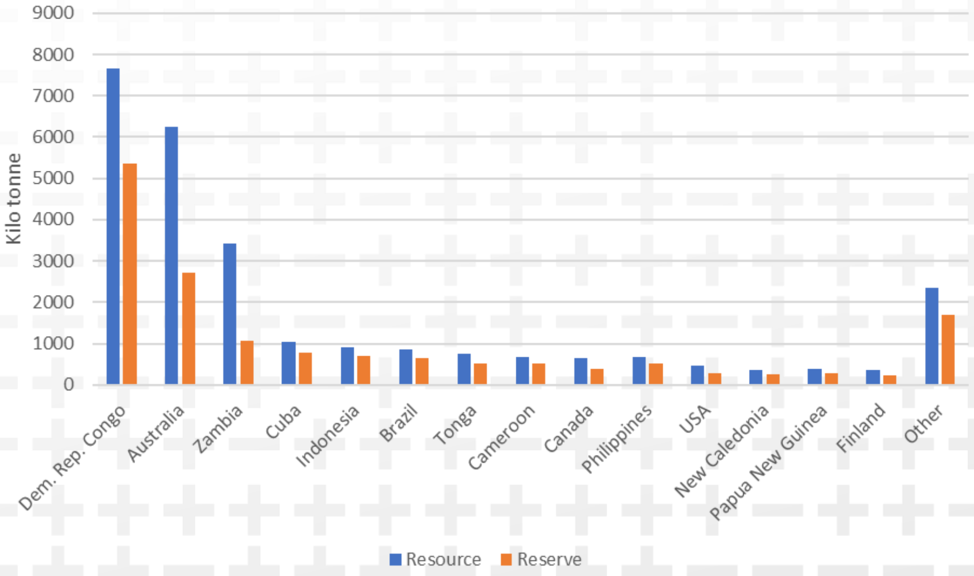
Reserves and resources

Total reserves 2011: ~15.9 Mt



Total resources 2011: 26,8 Mt

Cobalt production 2017: 0,11 Mt (USGS, 2018)



	Resource	Reserve
Dem. Rep. Congo	29%	34%
Australia	23%	17%
Zambia	13%	7%
Cuba	4%	5%
Indonesia	3%	4%
Total	**72%**	**67%**

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Based on data from Mudd et al., 2013

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2017 material intensity

Process	Product	Measure	Cobalt content	Source
EV Use	NCA	Kg/kWh	0.13	(ANL, 2018)
	NMC-333	Kg/kWh	0.37	(ANL, 2018)
	NMC-622	Kg/kWh	0.19	(ANL, 2018)
	NMC-811	Kg/kWh	0.09	(IEA, 2018)
	LMO-NMC (52%/48%)	Kg/kWh	0.14	(ANL, 2018; Cusenza, Bobba, Ardente, Cellura, & Di Persio, 2019)
	LFP	Kg/kWh	X	(ANL, 2018)
Refined cobalt trade	Cobalt chemicals (HS code 282200)	%	72%	(EC, 2017)
	Cobalt powders/briquettes and broken cathode (HS 810520)	%	27-100%	(EC, 2017; Gulley, McCullough, & Shedd, 2019)
Intermediate trade	Cobalt mattes and other intermediate products of cobalt metallurgy (HS 810520) with a value of <$10/kg	%	27%	(EC, 2017)
	Nickel sulfide (HS750120)	%	4.2%	(CBNC, n.d.; Schmidt, Buchert, & Schebek, 2016)
	Nickel matte (HS750110) from Australia	%	0.9%	(Schmidt et al., 2016)
	Nickel matte (HS750110) from Russia	%	1.5% (average of Ni matte)	(Schmidt et al., 2016)
	Cobalt hydrometallurgy intermediate (HS 81052010) for Chinese import	%	27%	(Gulley et al., 2019)
	Cobalt mattes and other intermediate products of cobalt metallurgy (HS 81052090) for Chinese import	%	22%	(Gulley et al., 2019)
Ore trade	Co ores and concentrates (HS code 260500)	%	7%	(Gulley et al., 2019)

Battery production

Cell producer	production capacity (GWh)	Note
AESC/Envision	Japan (2.6), UK (1.9), US (3.0)	Assumed that all cells in EU EV where produced in the UK
LG Chem	China (0.6), US (1.0), Korea (3.2)	Assumed all cells for GM, Ford and Chrysler produced in the US (ETNEWS, 2018). All other cells where derived from the Nanjing plant in China and the Ochang plant in South Korea.
Panasonic	Japan (5.0), US (xx), China (xx)	Gigafactory in US not producing for Model S in 2017 (Tesla, 2017). Dalia plant in China not yet producing in 2017 (Panasonic, 2018)
Samsung SDI	Korea (1.4), China (2.0)	
SK Innovation	Korea (0.8)	
GS Yuasa	Japan (2.5)	New plant in Hungary only producing batteries for starting purposes