Electric Vehicles, Batteries and Climate Change: A perspective on sustainability

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The economics of biodiversity: The Dasgupta Review

- Our economies, livelihoods and well-being all depend on our most precious asset: Nature.
- We have collectively failed to engage with Nature sustainably, to the extent that our demands far exceed its capacity to supply us with the goods and services we all rely on.
- Our unsustainable engagement with Nature is endangering the prosperity of current and future generations.
- At the heart of the problem lies deep-rooted, widespread institutional failure.
- The solution starts with understanding and accepting a simple truth: our economies are embedded within Nature, not external to it.
- We need to change how we think, act and measure success.
  - Ensure that our demands on Nature do not exceed its supply, and that we increase Nature's supply relative to its current level.
  - Change our measures of economic success to guide us on a more sustainable path.
  - Transform our institutions and systems – in particular our finance and education systems – to enable these changes and sustain them for future generations.

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The Economics of Biodiversity: The Dasgupta Review (February 2021)
https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review

The context in which Engineering takes place

All the engineering we do happens here… (although we do sometimes send some of it elsewhere)

As engineering fundamentally involves change, we have to do it very carefully…

Image taken from Google Earth

The context in which Engineering takes place

- Anthropogenic climate change:
  - Global warming due to CO_2 and other 'greenhouse gases'
  - Build up of waste and deterioration of local environments
- World population growth:
  - Projected growth from 7.7 to 9.7 billion from 2019 to 2050 (+26%)[1]
  - Consumption of resources already exceeds rate at which planet replenishes them

- Increasing variety of resource use, due to **increasing complexity and demand on products**
- **Availability of resources** challenged by socio-economic-(geo)political factors
- **Cost of change** seen as a barrier despite **massive opportunity cost**

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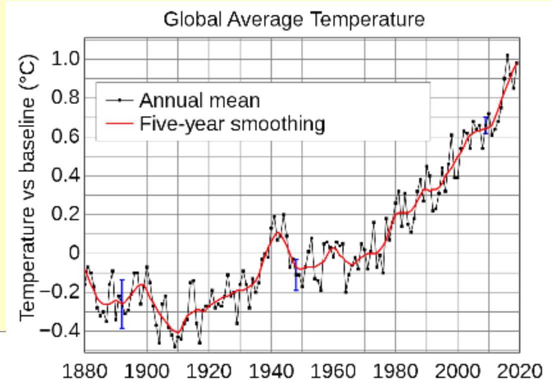
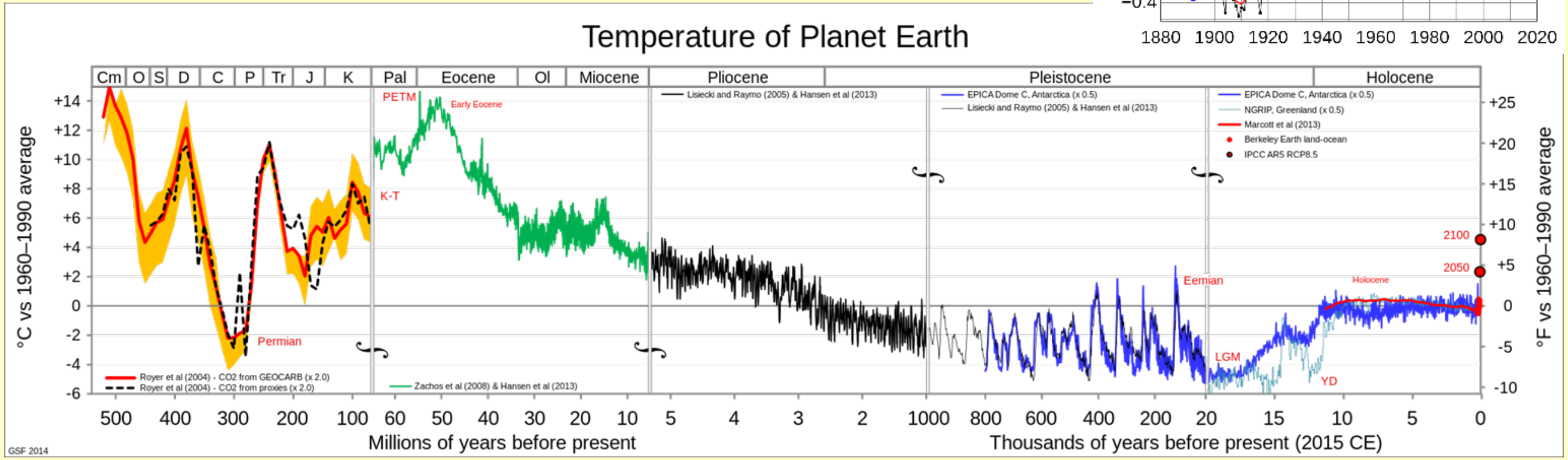
[1] Max Roser (2013) - "Future Population Growth". Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/future-population-growth [Online Resource]

Anthropogenic climate change – temperature

- Commonly simplified as ‘global warming’
- Since about 100 years ago, global temperatures have risen at an unprecedented rate
- Scientific consensus: it’s our fault!





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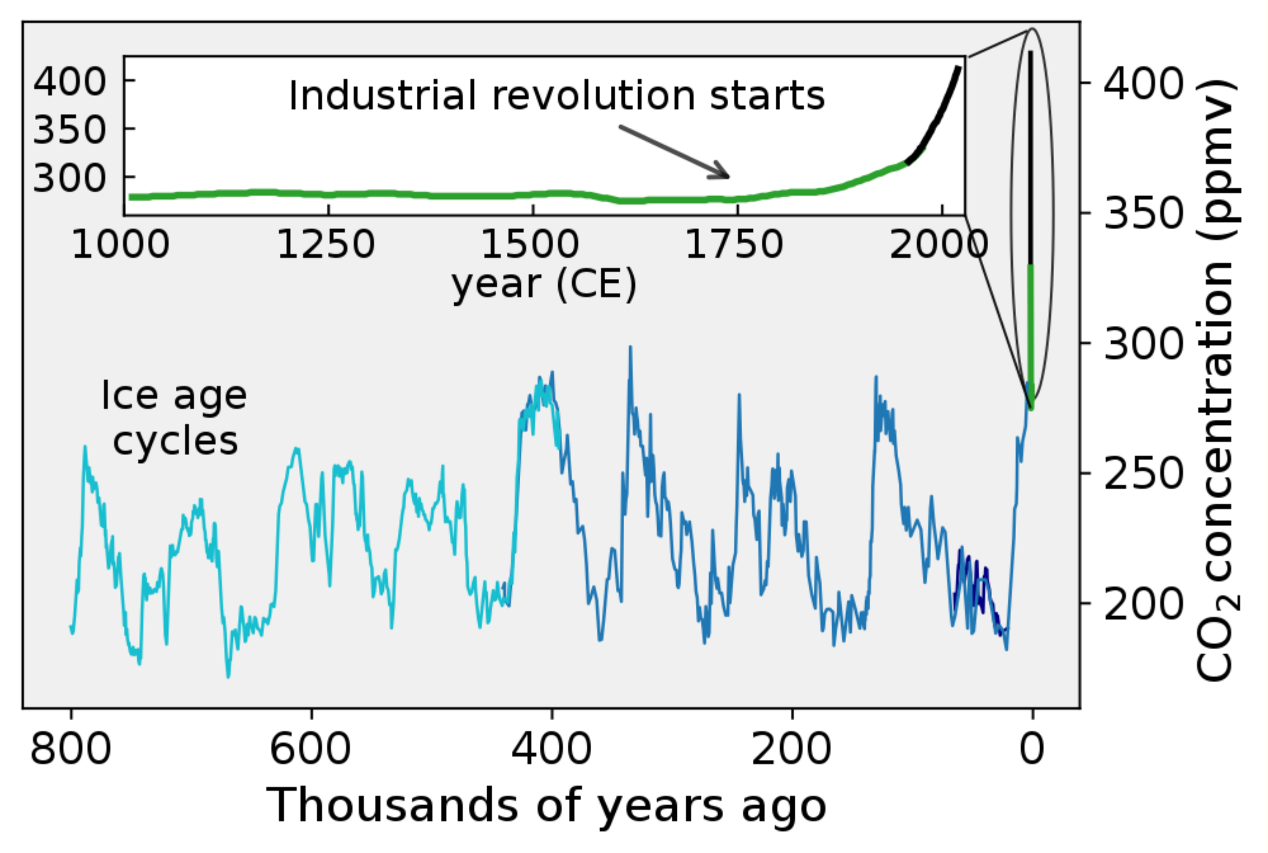
Anthropogenic climate change – Greenhouse gases

- ‘Greenhouse gases’ (GHGs) play a significant role
- Due to human activity, these are at unprecedented levels
- CO_2 most abundant but CH_4, NO_x and F-gases also important



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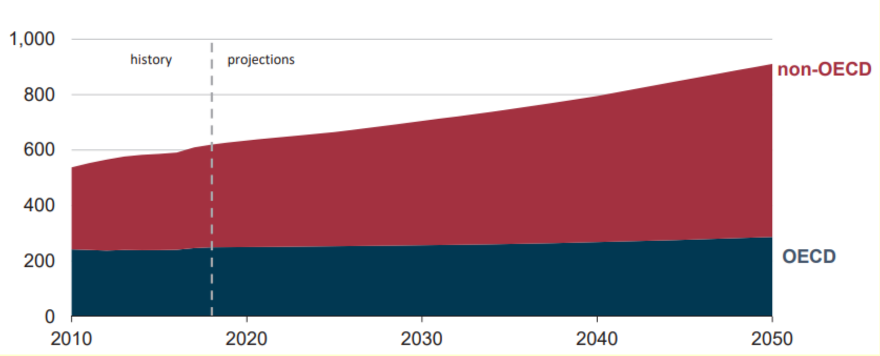
World energy consumption

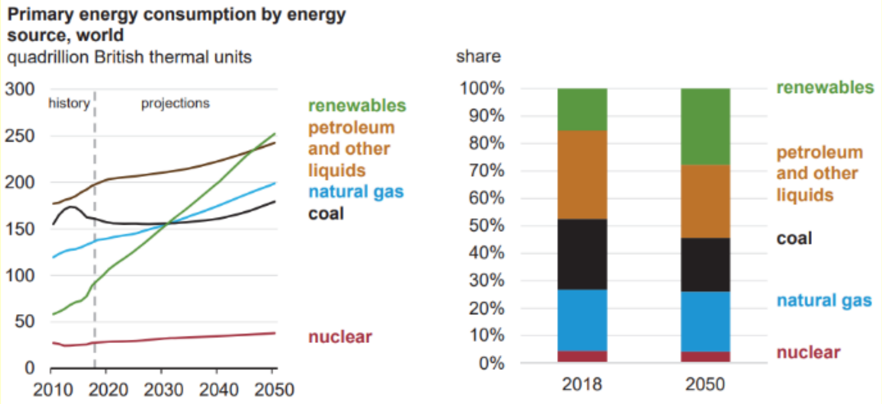
- World energy consumption projected to rise by 50% by 2050 to approx. 264,000 TWh

- Share generated by renewables and other low carbon sources (e.g. nuclear) projected to rise from 20% to 32%

- Use of natural gas also projected to increase, while coal and petroleum will remain in significant use

Note: 1 quadrillion (10^{15}) Btu ≈ 293 TWh





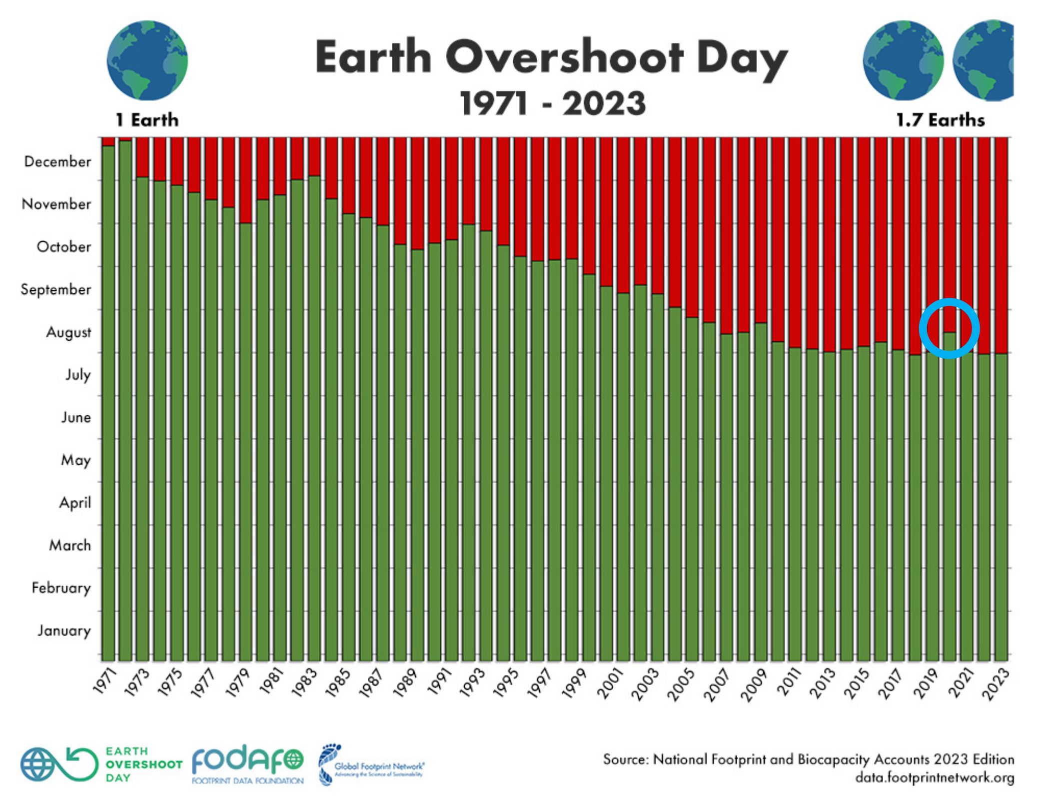
U.S. Energy Information Administration, Principal Contributor: Ari Kahan (2019), International Energy Outlook 2019, Retrieved from: https://www.eia.gov/todayinenergy/detail.php?id=41433, All rights reserved.

Global resource usage

- Models have been produced to indicate how much we are overusing the Earth's resources

- Since 1970 we have used more resources than are replenished each year

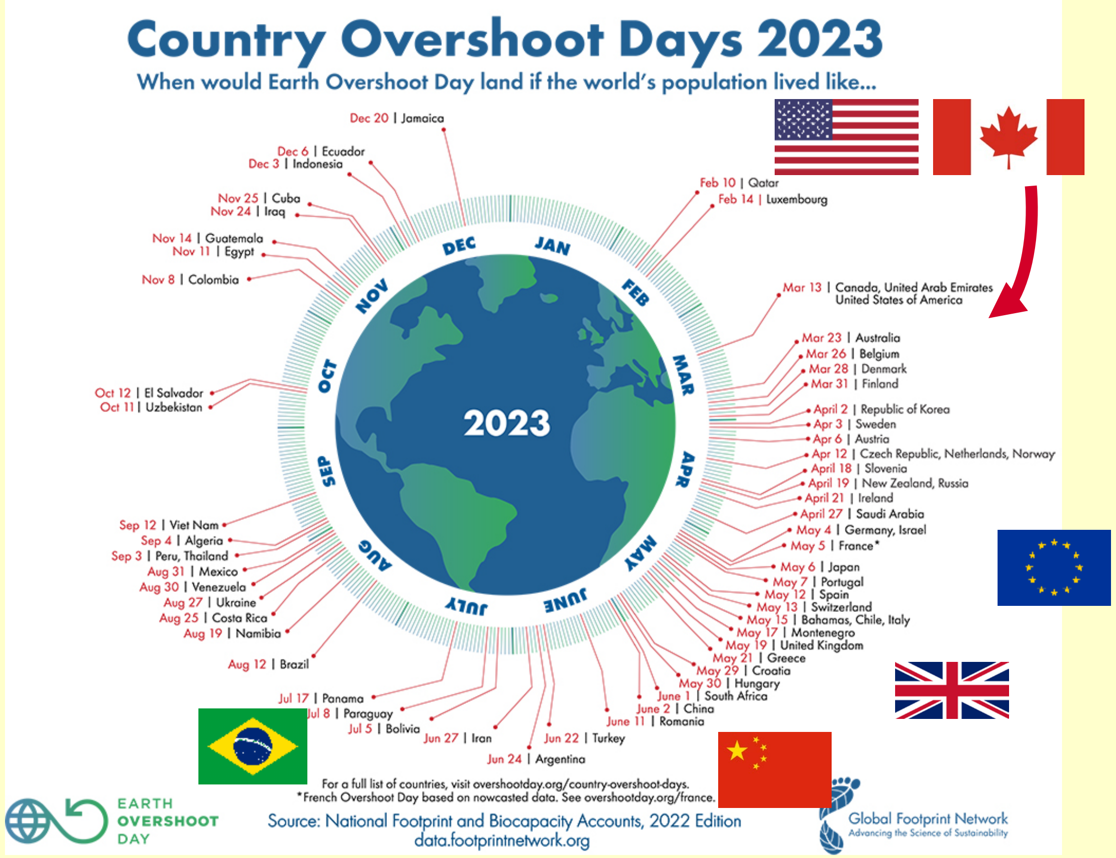
- 2020 is the only year when Earth Overshoot Day has been significantly pushed back #silverLinings…!



David Lin et al. (2021) - "Calculating Earth Overshoot Day 2021". Published online at OvershootDay.org. Retrieved from: https://www.overshootday.org/2021-calculation/
[Online Resource]

Global resource usage

- Countries consume resources at widely varying rates
- Advanced economies tend to reach the overshoot day early
- However, virtually all large countries must reduce their resource requirements – notable exception?



Unknown (2021) - “Calculating Earth Overshoot Day 2021". Published online at OvershootDay.org. Retrieved from: https://www.overshootday.org/newsroom/country-overshoot-days/ [Online Resource]

Number crunching…

- We consume **170%** of Earth's annual resources each year
- Global population is projected to **increase by 26%** between now and 2050
- **Question:** By how much must we reduce our rate of consumption to become sustainable (i.e. only use 100% of Earth's annual resources each year) by 2050?

Year	Relative population	Consumption	Consumption per person, *C*
2023	1.00	1.70	= 1.70/1.00
2050	1.26 (proj.)	1.00 (target)	= 1.00/1.26

Consumption per person in 2023 vs 2050,

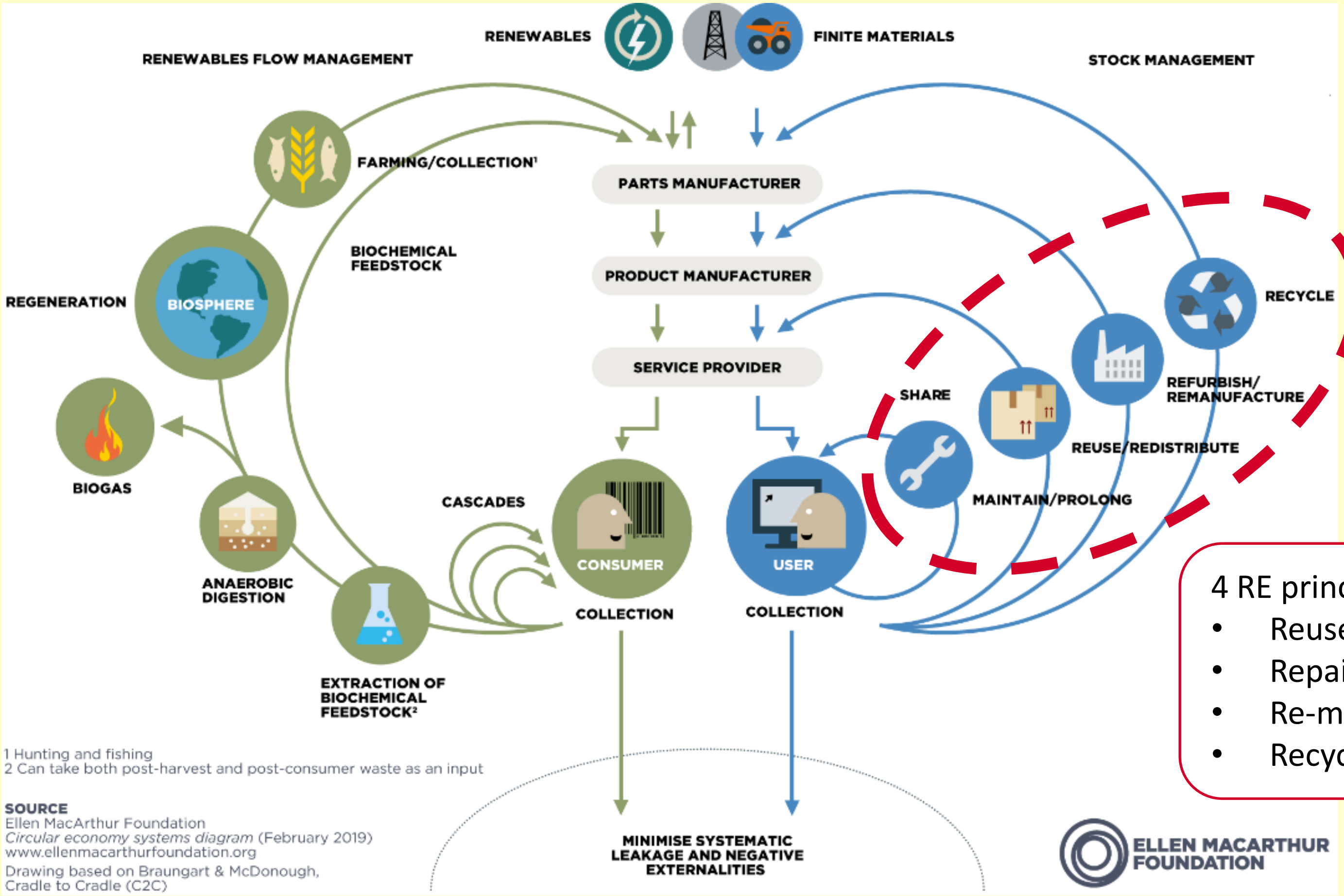
$$C_{23} = \frac{1.70}{1.00} = 1.70 \qquad C_{50} = \frac{1.00}{1.26} = 0.79$$

Rate of consumption must change by,

$$\frac{\Delta C}{C} = \frac{C_{50} - C_{23}}{C_{23}} = \frac{0.79 - 1.70}{1.70} = -0.535 = \underline{-54\%}$$

Note: These figures are not likely to be accurate. They are intended to give a general sense of scale.

Circular Economy model – Inter/national context



4 RE principles:

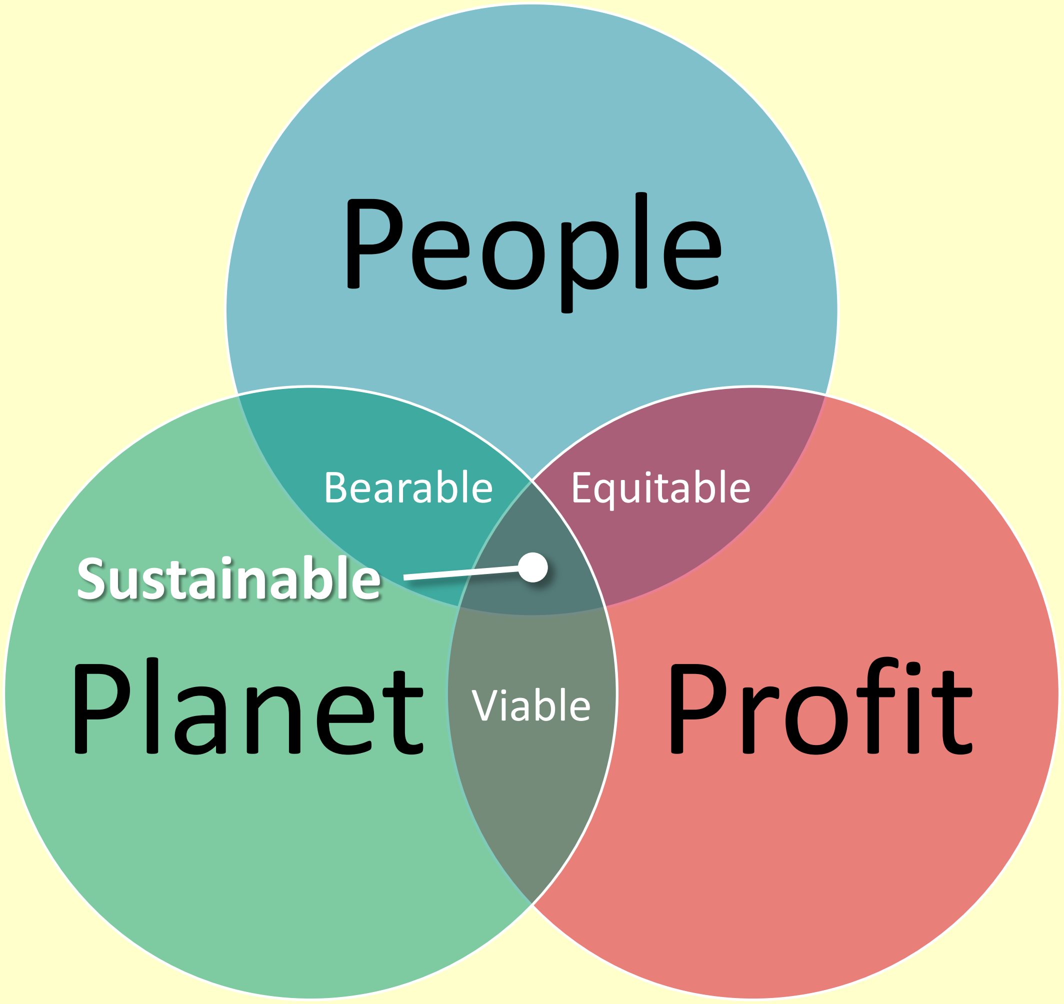
- Reuse
- Repair
- Re-manufacture
- Recycle

The Triple Bottom Line – Organisational context

The ‘bottom line’ refers to the profit made by a company – the ‘triple bottom line’ refers to the **total cost of doing business**

Economic theory that advocates balancing social, environmental and economic concerns

Social and environmental aspects may be difficult to measure but can be promoted by taking a ‘sustainability first’ approach



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There’s a great series of illustrated videos about sustainability on YouTube, including this one about the Triple Bottom Line: https://www.youtube.com/watch?v=2f5m-jBf81Q

Comparison of energy storage rate (power)

Determination of efficiency and power level during refilling fuel tank using fossil fuel

Flowrate of the pump: 38 l/min   with 42 MJ/kg,   0,83 kg/dm^3, P_{eq} = 22 MW !

Power consumption of the pump: 0,5 kW   Efficiency η = (22MW-0,5kW)/22MW = 0.99997

Design of electrical charging system at the same power level and efficiency as fuel pump

22 MW

$\eta = 0{,}99997$

Assumed length of copper cable used for charging l_{Cu} = 10 m

Voltage U	100 kV	10 kV	1 kV	Voltage at which the charging system operates
Current I	220 A	2,2 kA	22 kA	
Resistance of cable	10 mΩ	100$\mu\Omega$	1$\mu\Omega$	
M_{Cu}	1,4 kg	142 kg	14’200 kg	Mass of the copper cable needed!

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EV sales overview

Over 26 million electric cars were on the road in 2022, up 60% relative to 2021 and more than 5 times the stock in 2018

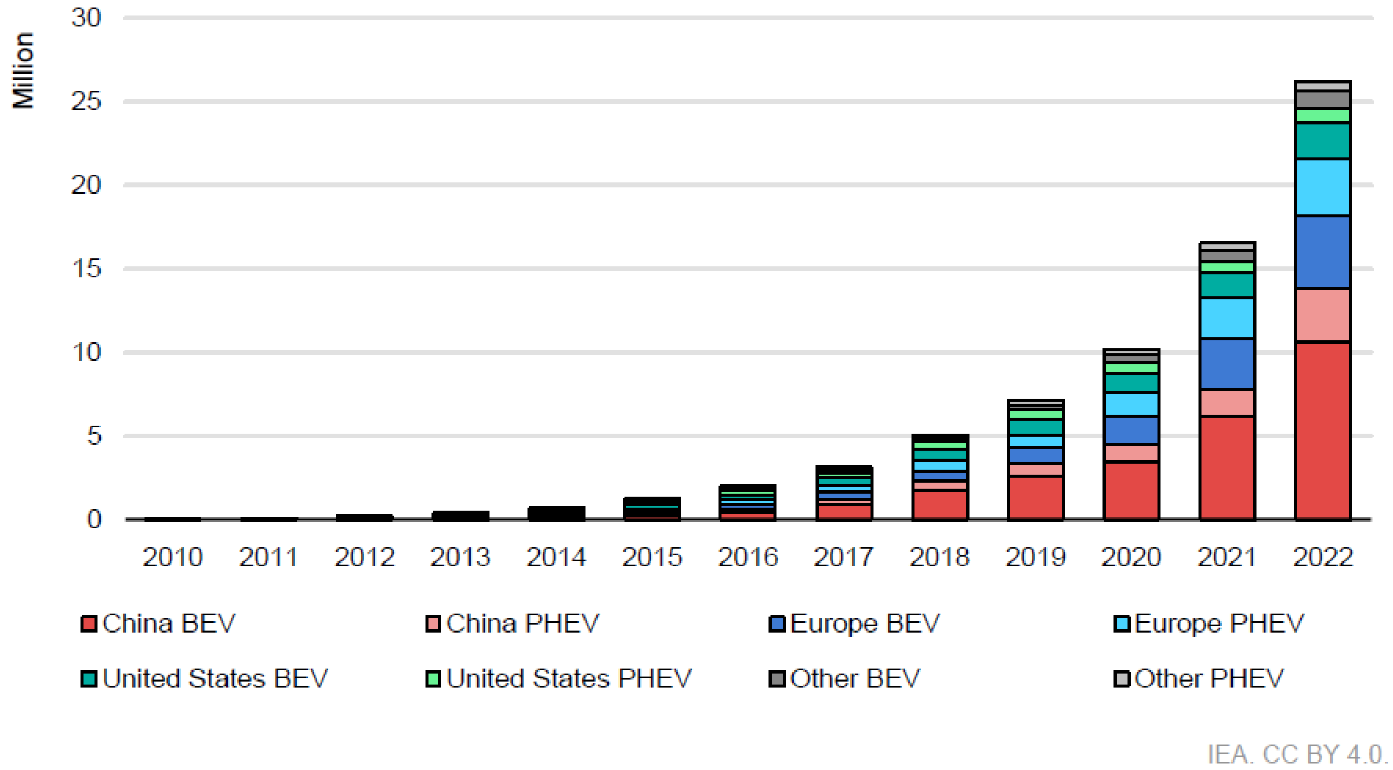
Electric car markets are seeing exponential growth as sales exceeded 10 million in 2022.

A total of 14% of all new cars sold were electric in 2022, up from around 9% in 2021 and less than 5% in 2020.

Electric car sales are expected to continue strongly through 2023.

Over 2.3 million electric cars were sold in the first quarter, about 25% more than in the same period last year.

Figure 1.1 Global electric car stock in selected regions, 2010-2022



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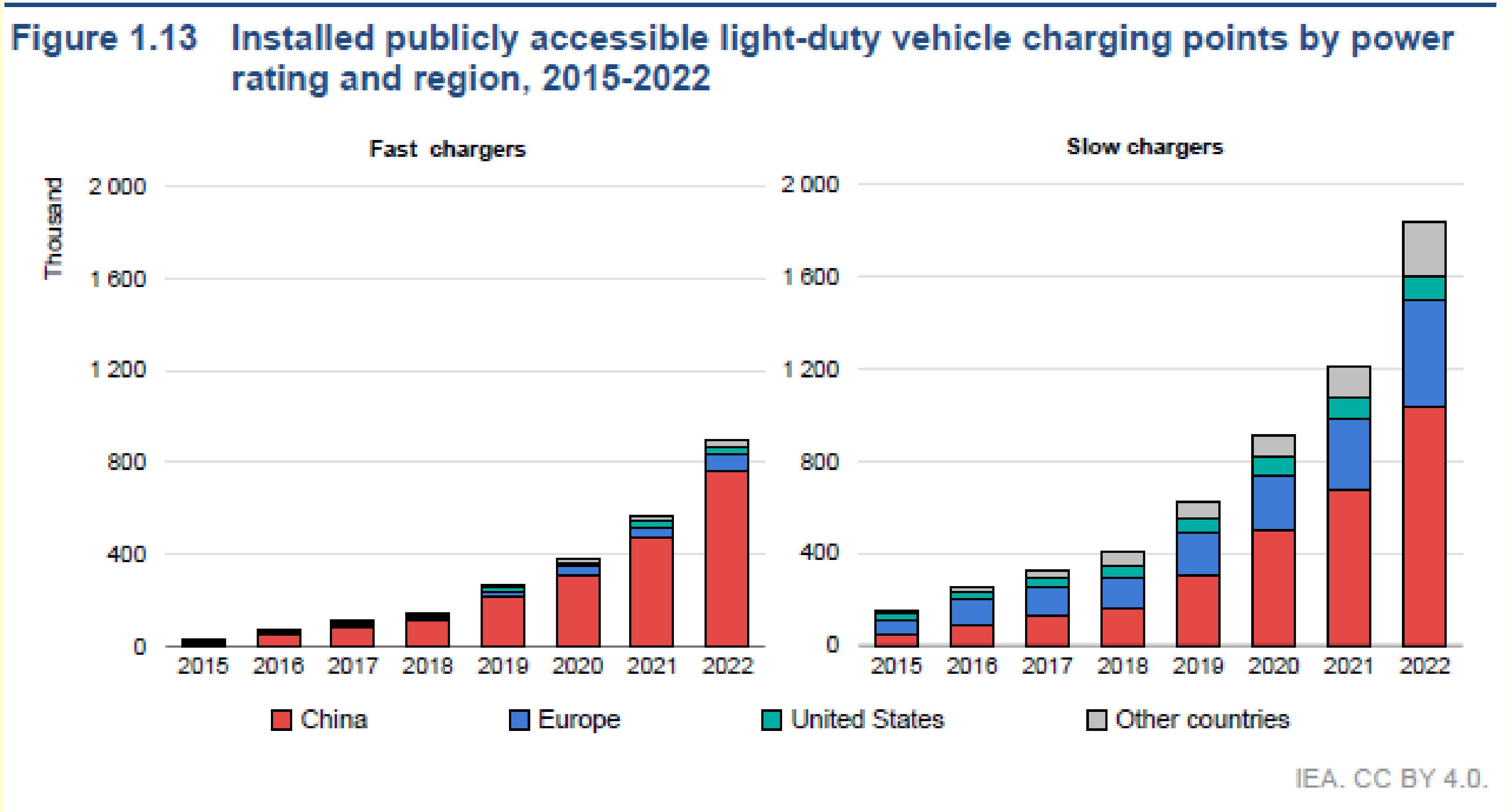
Public charging points



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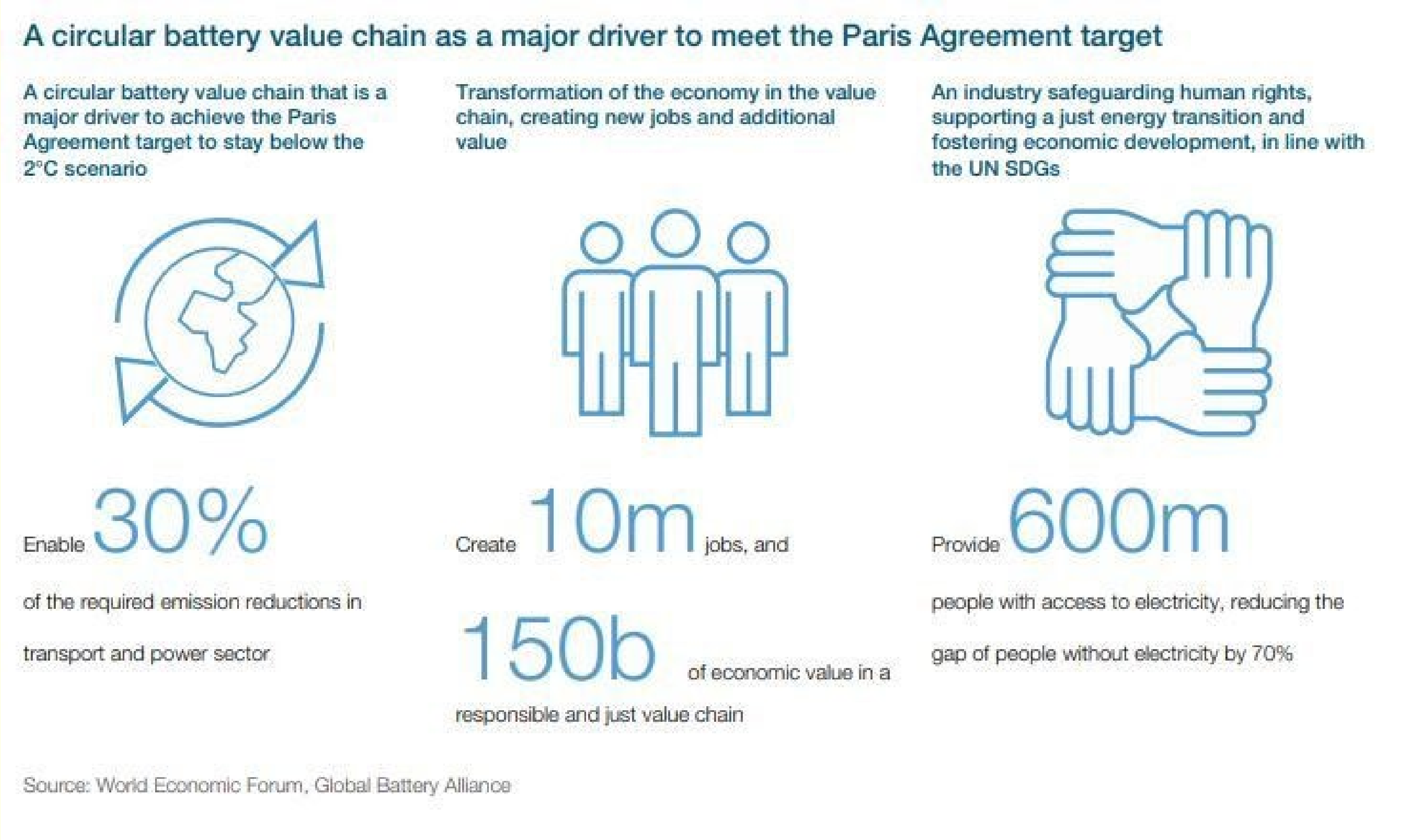
Battery value chain - vision



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Battery value chain - Challenges

3 challenges to scale up the battery value chain

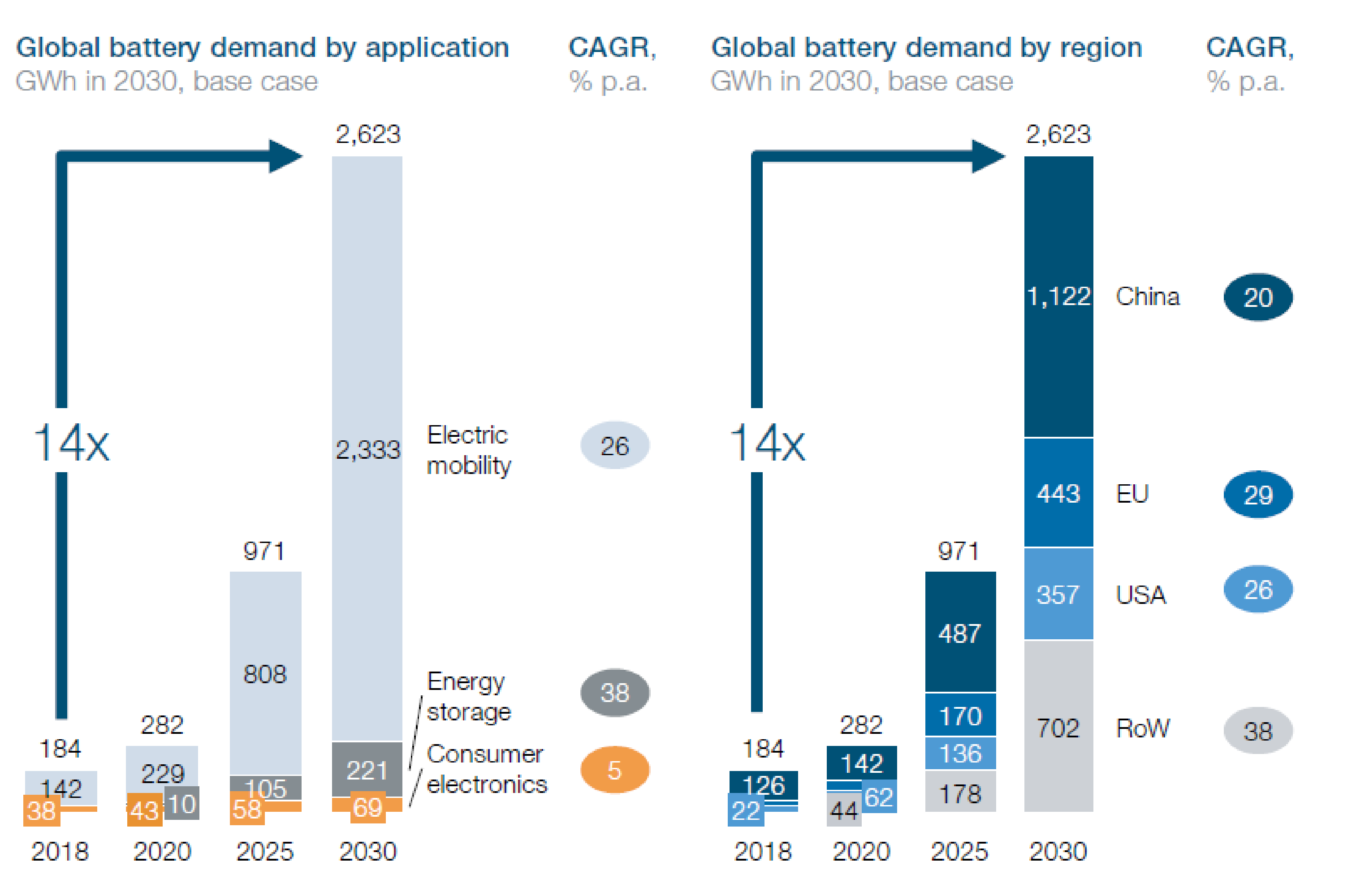
Battery production has a significant GHG footprint

Raw material supply has significant social and environmental risks

The viability of battery-enabled applications is uncertain

Global Battery Alliance, World Economic Forum - A Vision for a Sustainable Battery Value Chain in 2030 (Insight report – September 2019) License CC BY-NC-ND 4.0

Battery demand – region and application



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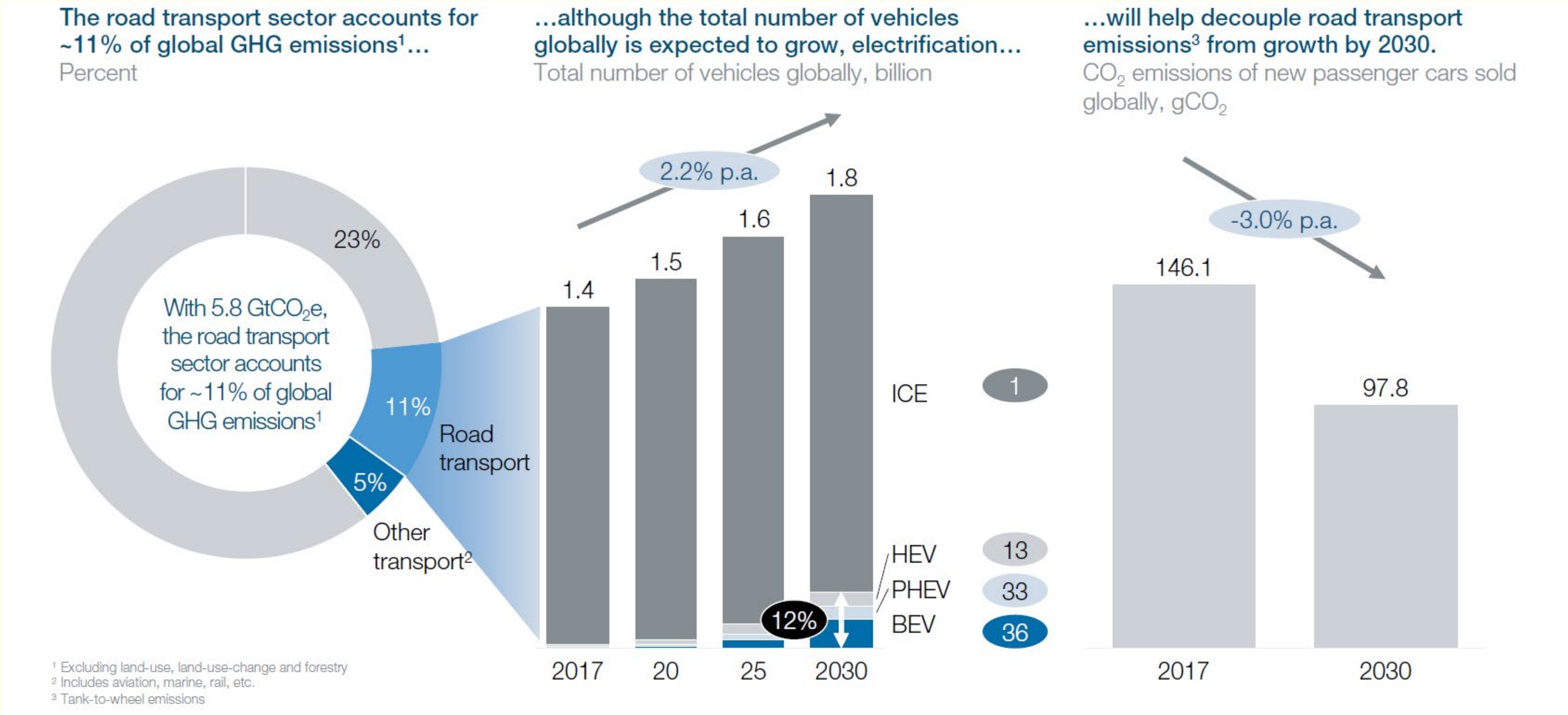
Road transportation



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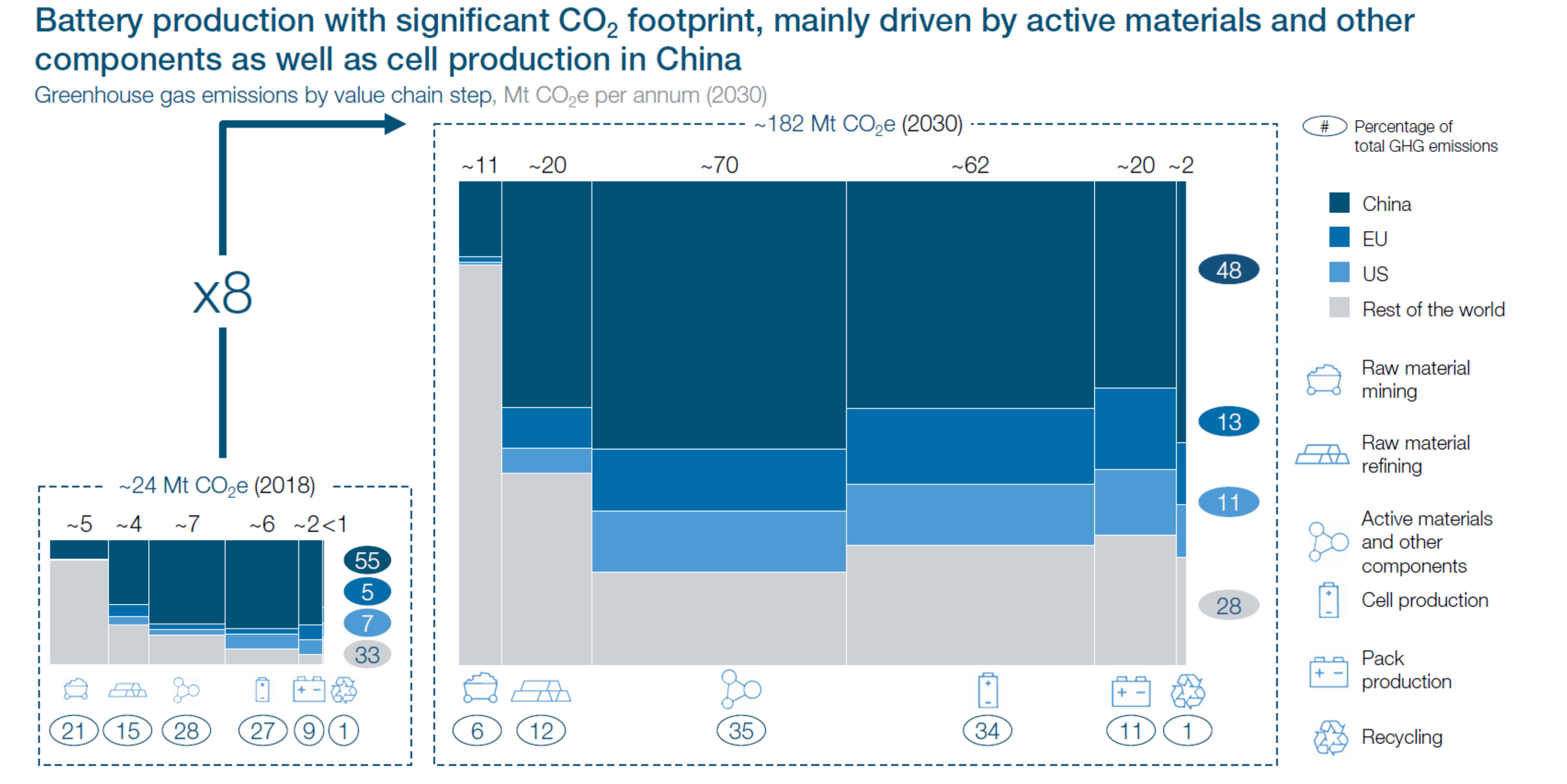
Battery production – Footprint



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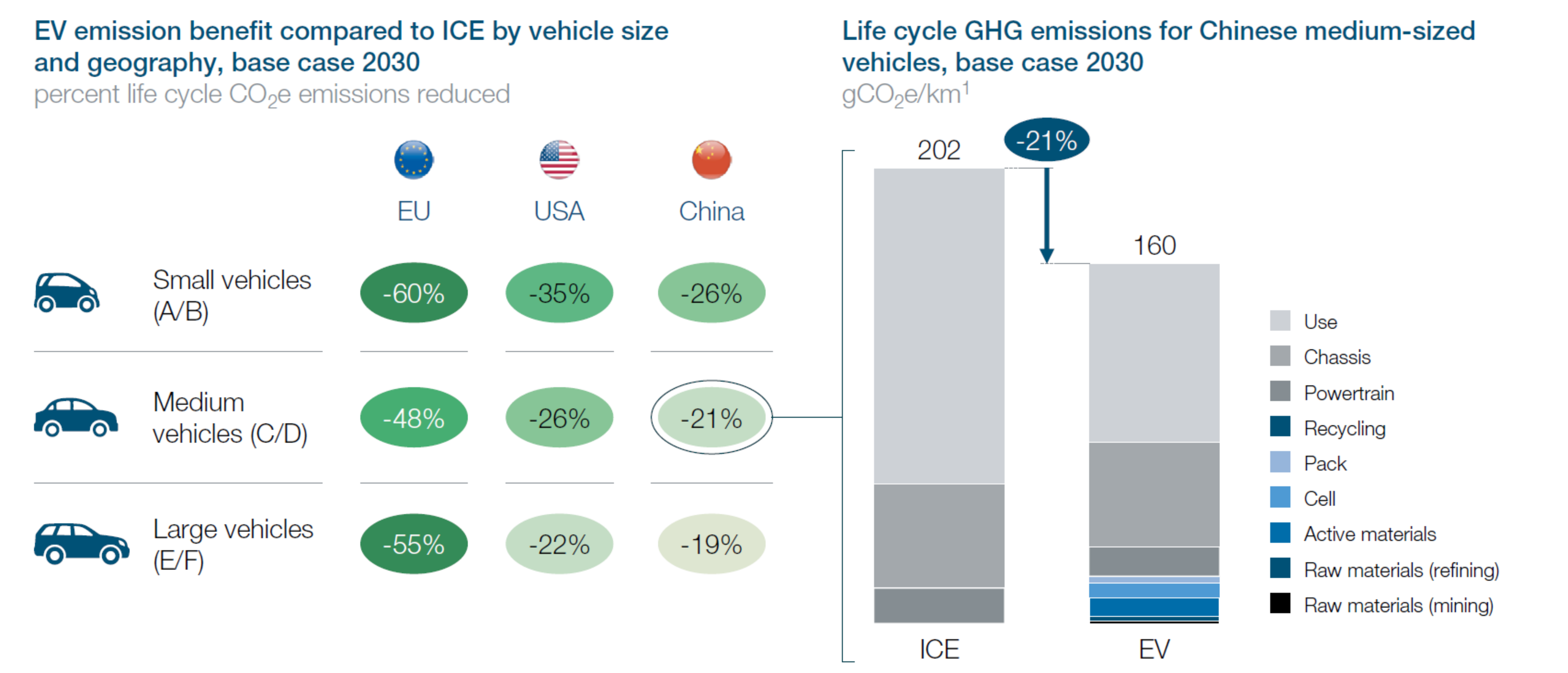
EV Emission benefits compared to ICE



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Opportunity

Scaling battery production by a factor of 19 is a major opportunity for every step of the value chain

Raw material mining	Raw material refining	Active materials	Cell production	Recycling
5-40x	14x	15x	19x	15x
The mining industry needs to extract a volume equivalent to >300 Great Pyramids of Giza per year in 2030	A weight equivalent to >110K Boeing 787s (Dreamliners) is refined per year in 2030	Active materials produced in 2030 are enough to produce >800B battery cells (AA type)	~120 additional Giga Factories (today's largest) must be operational in 2030	An equivalent of >10B mobile phone batteries are expected to reach end-of-life in 2030

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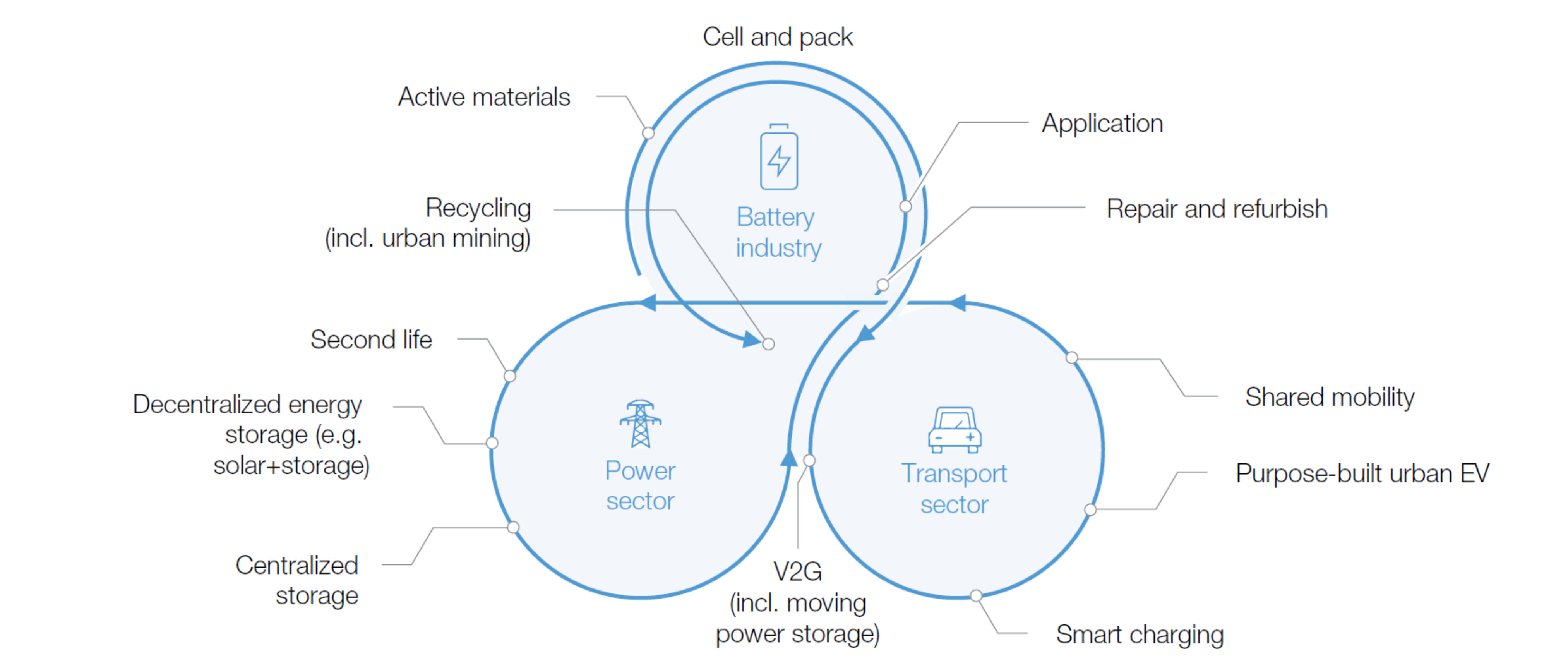
Coupling transport and energy sectors



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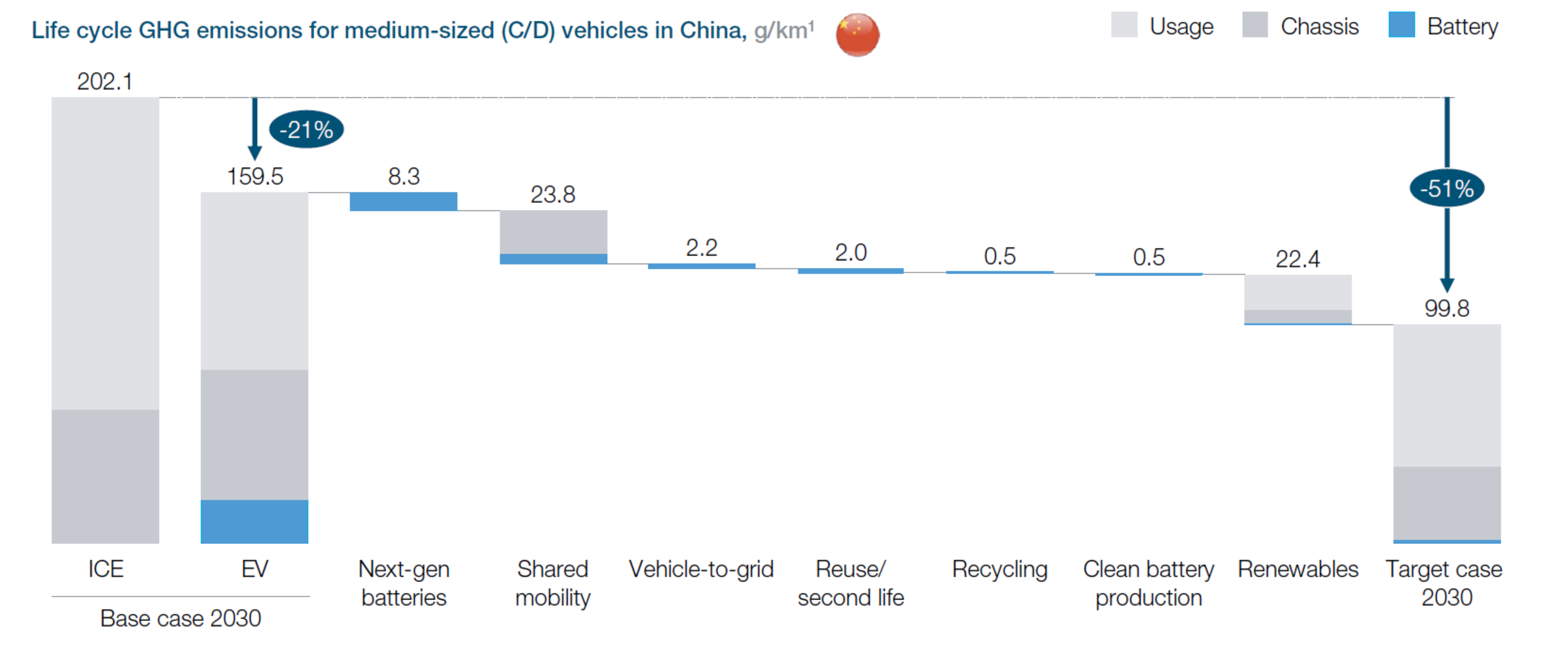
EV emissions – circular economy levers



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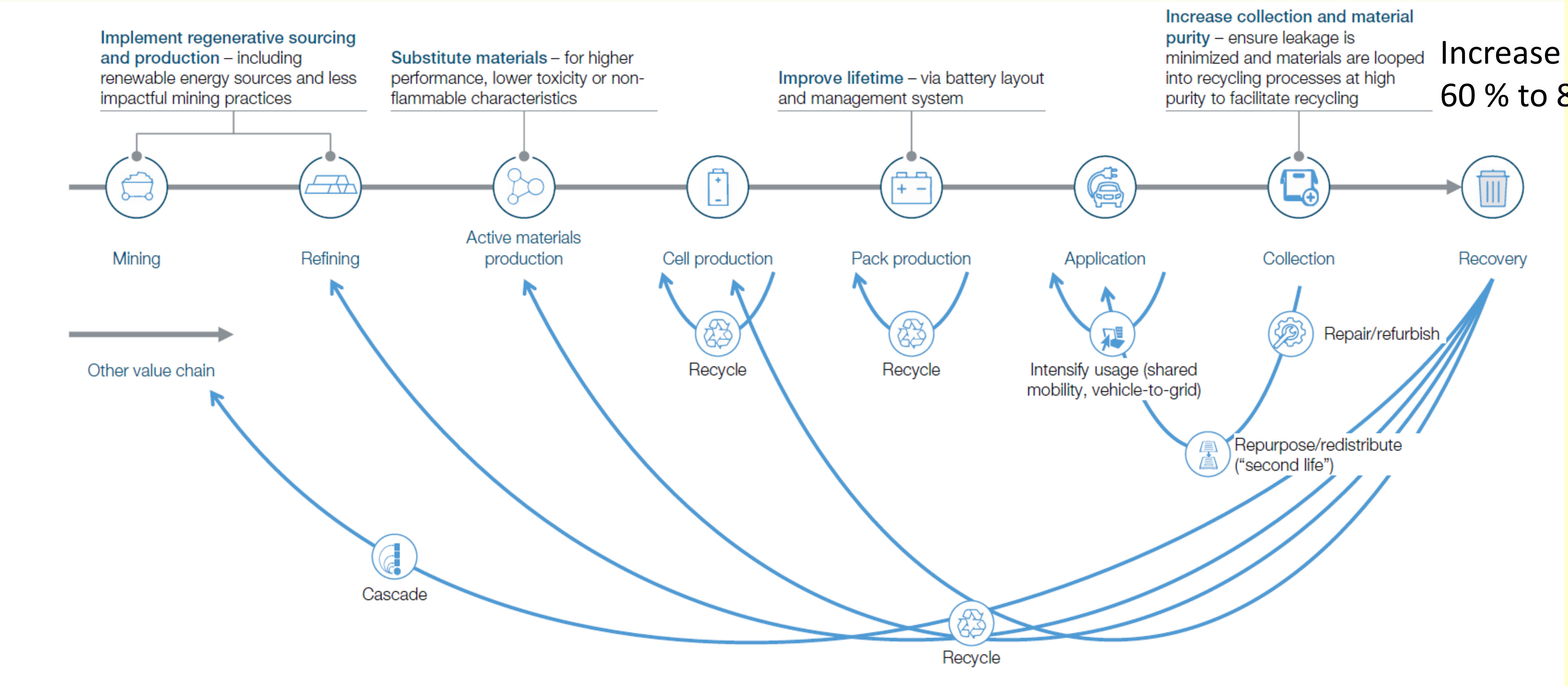
Circular Economy Levers – Batteries



Increase from 60 % to 80%

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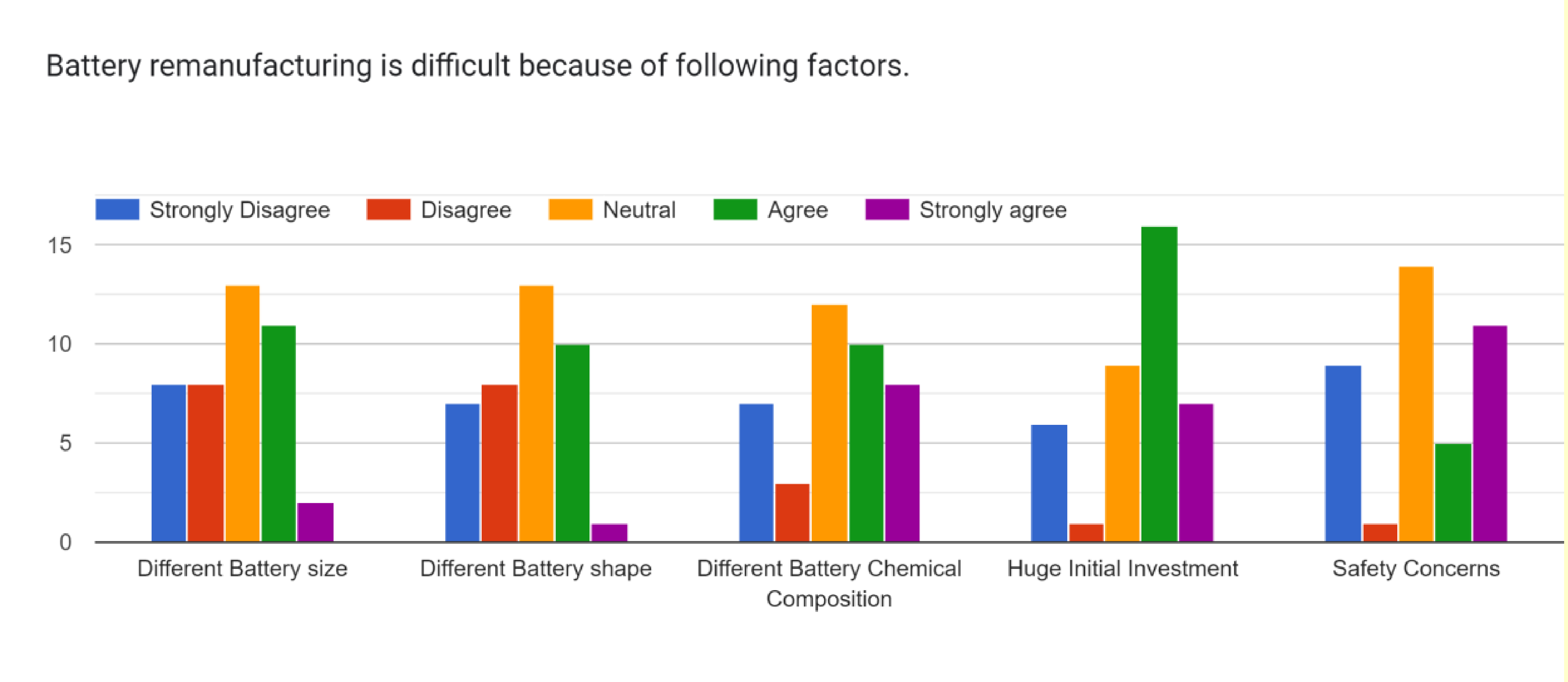
What professionals say?



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Ranking of barriers for EV remanufacturing

Criteria Nomenclature	Description	Grouping Criteria	Weightage	Ranking
C11	Market Size of Remanufacturing	**Economic**	0.711	1
C3	Different Battery Size	**Technical**	0.676	2
C1	Huge industrial Setup	**Operational**	0.28	3
C4	Different Battery Shape	**Technical**	0.246	4
C14	Sourcing Vehicles for Remanufacturing	**Operational**	0.2	5
C2	Skilled labour	**Economic**	0.2	6
C10	Performance of Products	**Operational**	0.18	7
C8	Recovery Rate of Remanufacture Products	**Operational**	0.18	8
C6	Huge Initial Investment	**Capital**	0.159	9
C15	Legislation Restrictions	**Legislation**	0.127	10
C9	Number of Parts in vehicle	**Operational**	0.12	11
C13	Manpower Cost	**Economic**	0.088	12
C5	Different Battery Chemical Composition	**Technical**	0.076	13
C7	Safety Concern	**Safety**	0.041	14
C12	Testing Equipment’s For remanufacturing	**Operational**	0.04	15

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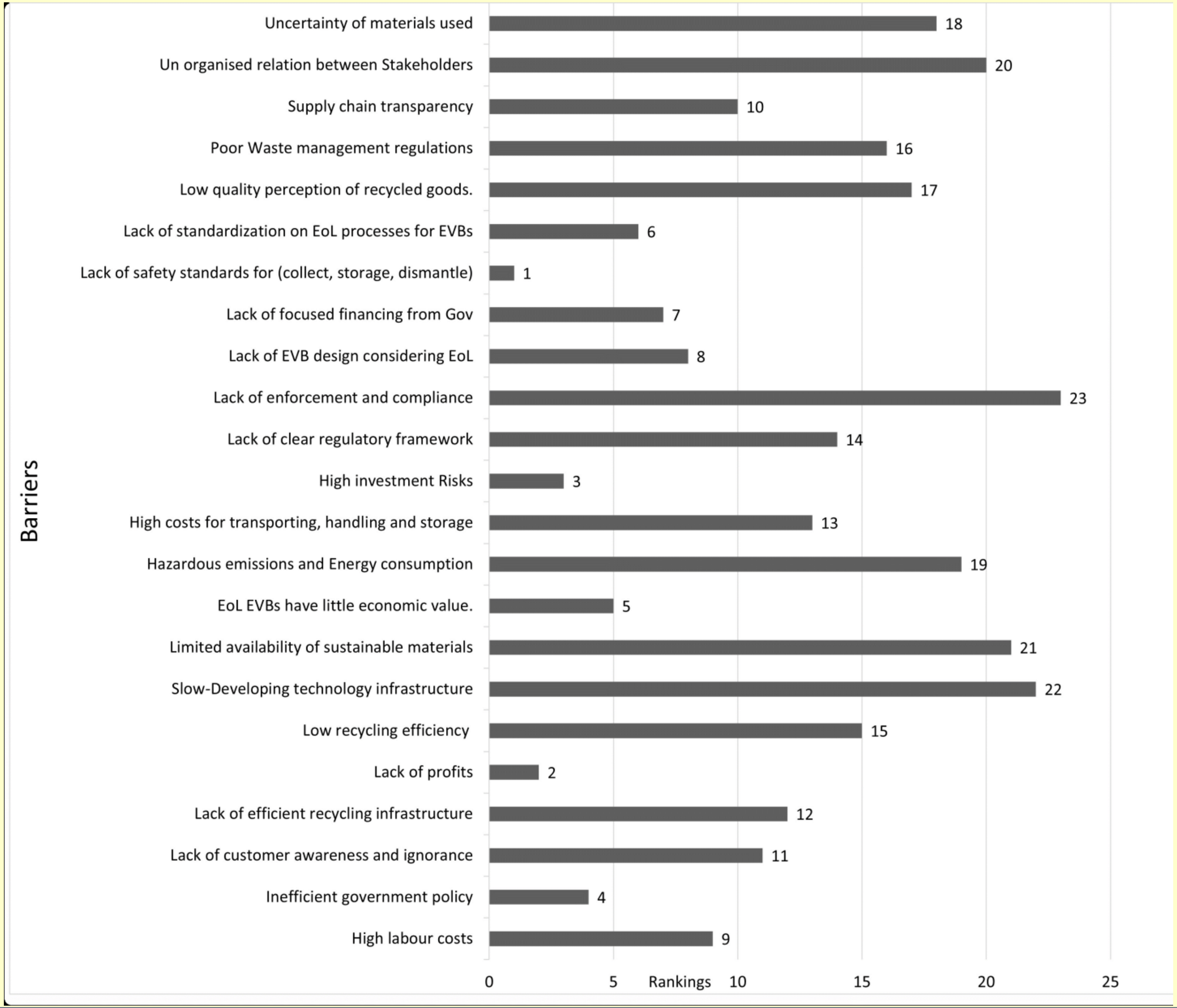

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Key takeaways

- Stakeholder engagement
- New metrics
- Circular economy
- Regulatory support

Transformative change is possible – we and our descendants deserve nothing less!