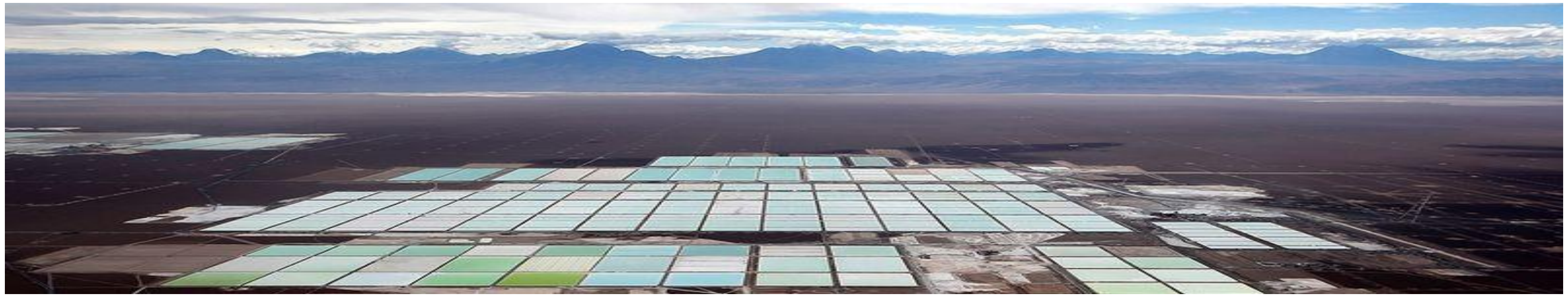


ETSAP SDG workshop, Thursday January 13th 2022

RAW MATERIAL CRITICALITY WITH A HIGH SHARE OF LOW-CARBON ENERGY TECHNOLOGIES FOR THE ENERGY TRANSITION

Dr. Gondia Sokhna SECK, Dr. Emmanuel HACHE

GENERATE PROJECT (2017-2020)
(Renewable Energy Geopolitics and Future Studies on Energy Transition)

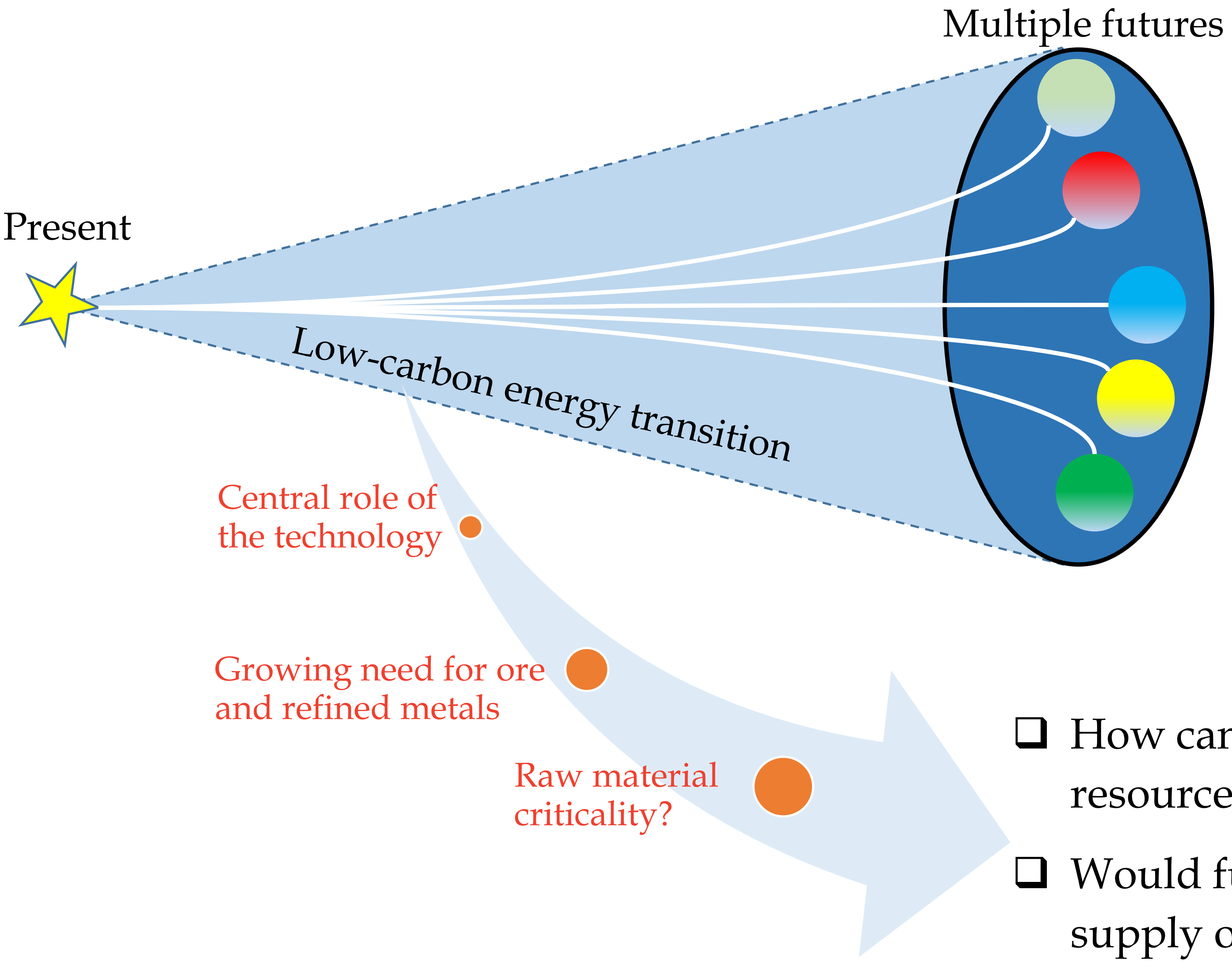
PRESENTATION

- Project goal: **Analyze the geopolitical consequences of a fast roll-out of renewable energy technologies (RETs) and other low-carbon technologies (LCTs) worldwide**
  - **The criticality of energy transition materials** for decarbonisation innovations (electric vehicle, solar panel, wind turbine etc.)
    - ✓ Raw materials considered: Lithium, Cobalt, Copper, Rare-Earths elements, Nickel, Aluminium, Zinc
    - ✓ Methodology: Long-term energy modelling (TIAM Model) supplemented by industrial (market power) and geopolitical analyses
  - **The new geography of patents for the RETs**
  - **The development model of oil producing countries and their place on the international energy scene**

- For more details: https://www.researchgate.net/project/Project-GENERATE

PLAN

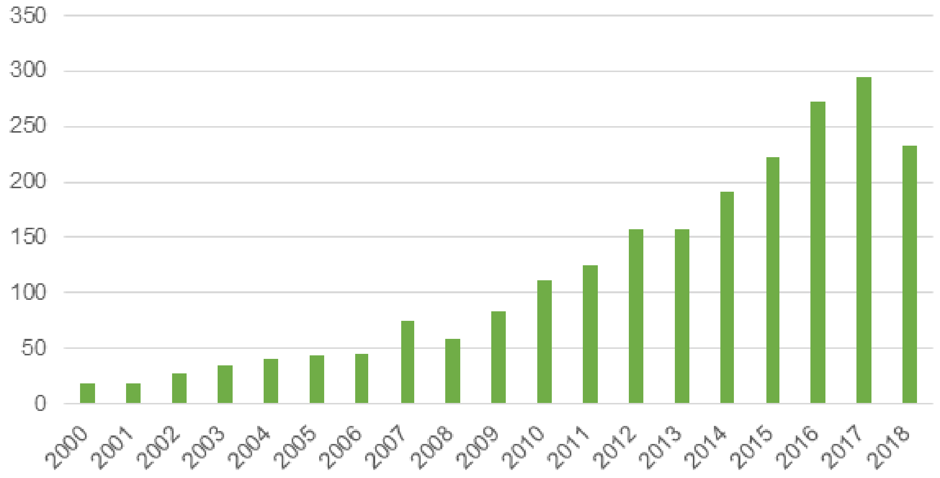
CONTEXT



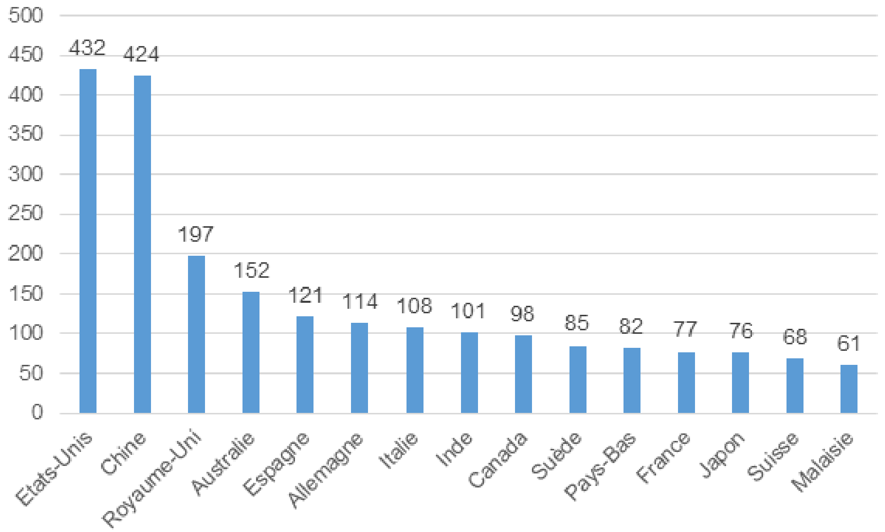
- ❑ How can these fast shifts impact material resource availabilities?
- ❑ Would future possible constraints on supply of materials impede this energy transition?

NUMEROUS PUBLICATIONS

Number of publications dedicated to raw material criticality



Number of publications per country



Source: Intellixir, Hache et al., 2019

PROJET GENERATE

RAW MATERIAL CRITICALITY ASSESSMENT: STATE-OF-THE-ART

Quantifying the implications of prospective energy scenarios on raw material resources

#APPROACH 1

Using the outputs of long-term energy model as inputs into LCA analyses.

WORLD LEVEL

- Devising Mineral Resource Supply Pathways to a Low-Carbon Electricity Generation by 2100 (TIAM-FR).

(Source: Boubault and Maizi, 2019)

REGION LEVEL

Analyses of the potential limiting role of metals in the specific deployment of the European Union's Strategic Energy Technology Plan (SET-Plan, 2013) based on scenarios for 2020 and 2030

(Source : Moss et al., 2013)

COUNTRY LEVEL

- Criticality of neodymium focused on the roll-out of wind turbines for the UK low-carbon electricity scenario generated by the IEA ETP model

(Source: Roelich et al., 2014)

- Some raw material needs to the French energy transition by 2050 on power sector based on prospective scenarios of ANCRE)

(Source: Beylot et al, 2019)

#APPROACH 2

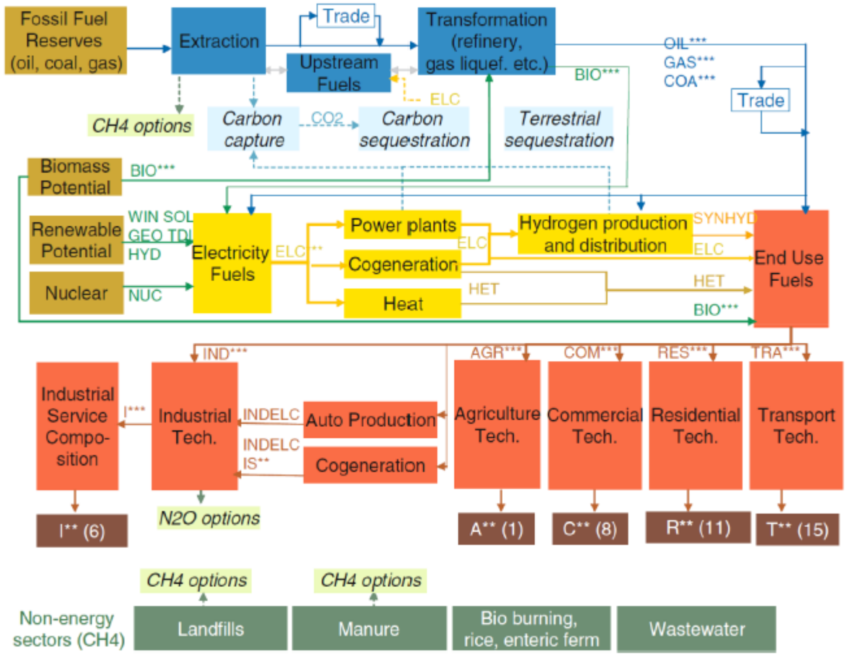
Using the outputs of LCI metrics as inputs into long-term energy models

GENERATE PROJECT

PROJET GENERATE

PLAN

ENERGY SYSTEM MODELLING: TIAM-IFPEN MODEL



Source: Loulou et Labriet, 2008

TIAM name	Region
AFR	Africa
AUS	Australia, New Zealand and Oceania
CAN	Canada
CHI	China
CSA	Central and South America
IND	India
JAP	Japan
MEA	Middle-east
MEX	Mexico
ODA	Other Developing Asia
SKO	South Korea
USA	United States of America
EUR	Europe 28+
RUS	Russia
CAC	Central Asia and Caucase (Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan)
OEE	Other East Europe (Albania, Belarus, Bosnia-Herzegovina, Macedonia, Montenegro, Serbia, Ukraine, Moldova)

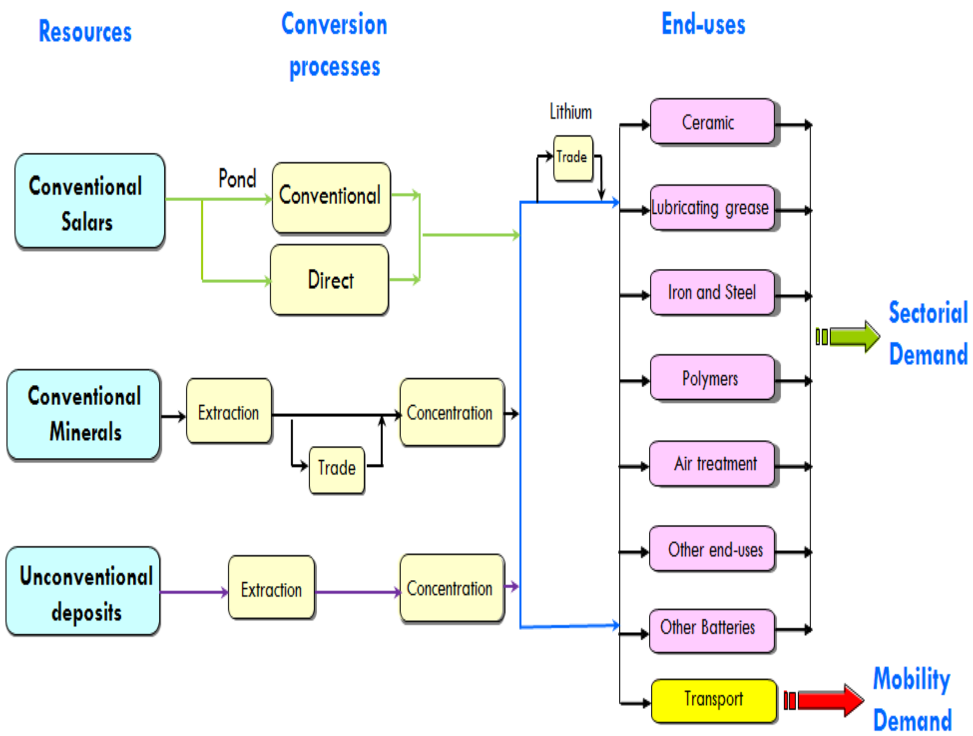
- **Main questions**
  - Long-term climate targets
  - Supply security (Energy and critical materials)
  - Extension beyond purely energy-oriented issues, to the representation of environmental emissions, and **materials, related to the energy system**.
  - Conditions of feasibility of the Energy transition

- **Model details**
  - Disaggregation of the world into 16 regions, each with its own energy system and main demand sectors.
  - The model fully describes within each region all existing and future technologies from supply (primary resources) through the different conversion steps to end-use demands.

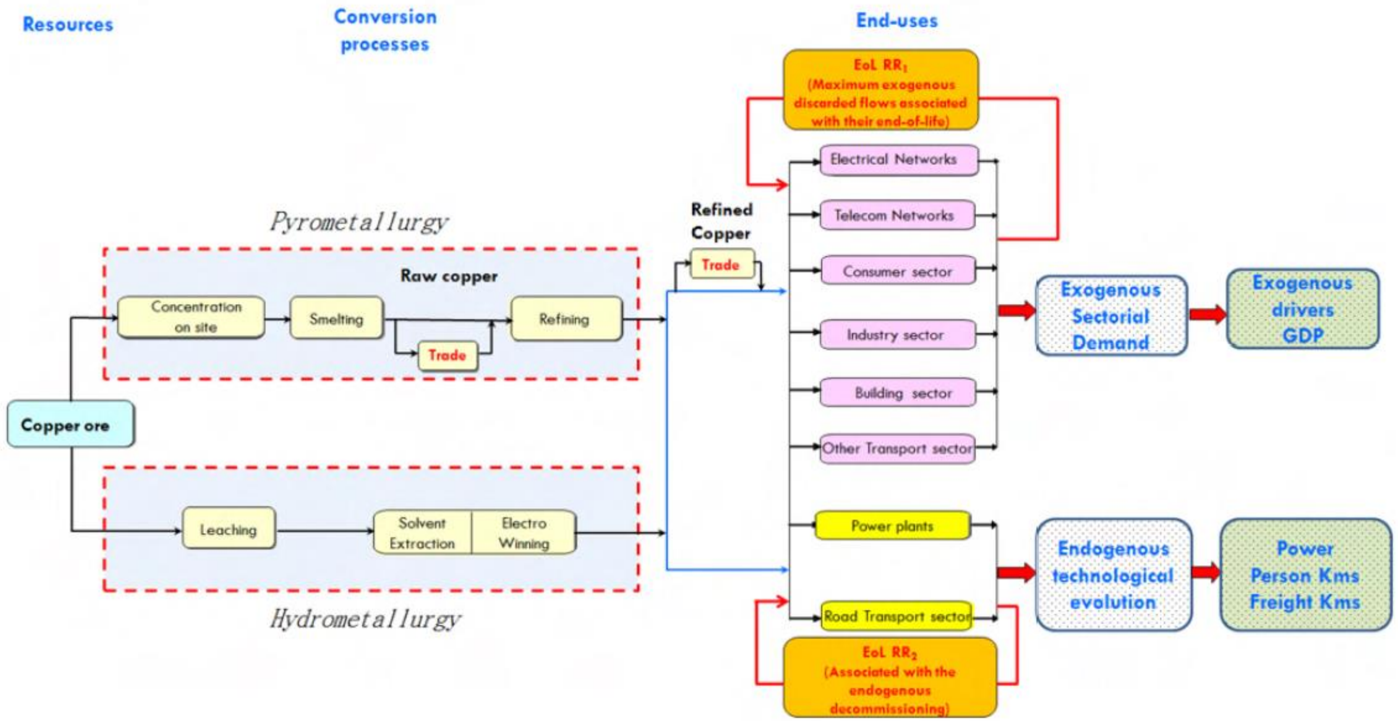
→ **Quantify to explain and not to predict**

EXAMPLES OF RAW MATERIAL SUPPLY CHAIN

Lithium



Copper



- ❑ **Implementation of the material intensities for each of the low-carbon technologies and their lifetime**
- ❑ **Distinction between exogenous sectorial demand and endogenous sectorial evolution**

- **Assessing the evolution of material consumption with regard to the deployment of low-carbon technologies**
- **Assessing trades of these materials between countries at different points of the value chain**
- **Analyses of the future geological, geopolitical and environmental risks**

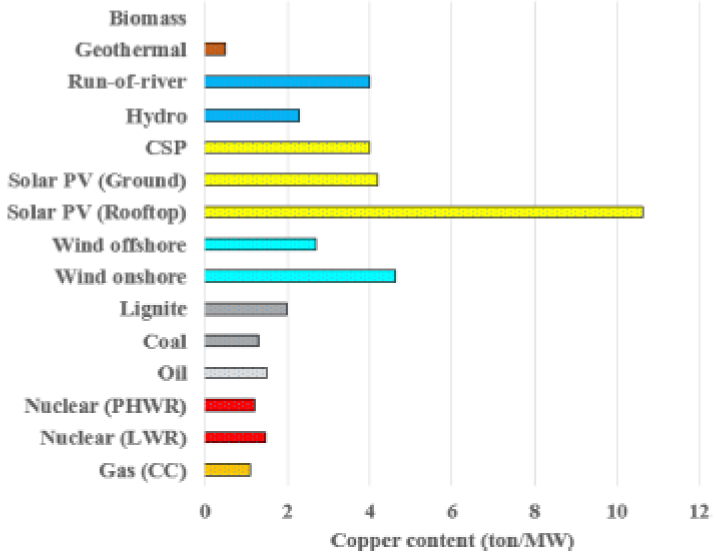
TIAM-IFPEN MODEL: EXAMPLES OF MATERIAL CONTENT

○ Copper

Variation of the copper content for power generation technologies in the literature.

Copper content (kt/GW)	Literature data Min.	Max.	
Gas	0.5	1.5	
Nuclear	0.06	1.5	
Oil	1.5		1.5
Coal	0.3	2	
Wind onshore	1.6	20.1	
Wind offshore	0.9	11.7	
Solar PV (Rooftop)	0.02	11.4	
Solar PV (Ground)	3	7.5	
CSP	0.4	12.4	
Hydro.	0.1	11.4	
Run-of-river	3.5	4	
Geothermal	0	0.5	
Biomass	0		0

Source: World Bank, 2017; O. Vidal, 2018



Source: Seck et al., 2020

Copper content in road transport according to the weight (kg/vehicle).

		ICE	HEV	PHEV	BEV	FCEV
Passenger light duty vehicles	Small	25.9	46.2	52.8	84.9	52.8
	Medium	26.4	60.6	71.3	121.3	67.6
	Large	33.5	83.0	98.5	172.0	97.9
Bus		90.5	224.0	265.8	369.0	210.1
Minibus		54.9	136.0	161.4	224.0	127.5
Commercial vehicles	Light	39.1	96.8	114.9	200.6	114.2
	Medium	57.2	141.5	167.9	233.1	132.7
	Heavy	190.5	471.6	559.7	776.8	442.2
2-wheelers		0.6			2.9	
3-wheelers		3.9			20.1	

Source: Burnham, 2012; ECI/CA; Seck et al., 2020

○ Cobalt

Battery size assumed for EVs in TIAM-IFPEN model.

		Battery size (kwh/veh)			
		PHEV		EV	
		2015	2030	2015	2030
Passenger light duty vehicles	Vehicle small size	8	12	40	60
	Vehicle medium size	12	15	40	80
	Vehicle large size	15	20	60	90
Bus				340	340
Commercial vehicles	Light	12	15	60	90
	Medium	35	35	170	200
	Heavy	50	50	350	350
2-wheelers				3	4
3-wheelers				4	6

Cobalt content by cathode chemistry type considered in TIAM-IFPEN model.

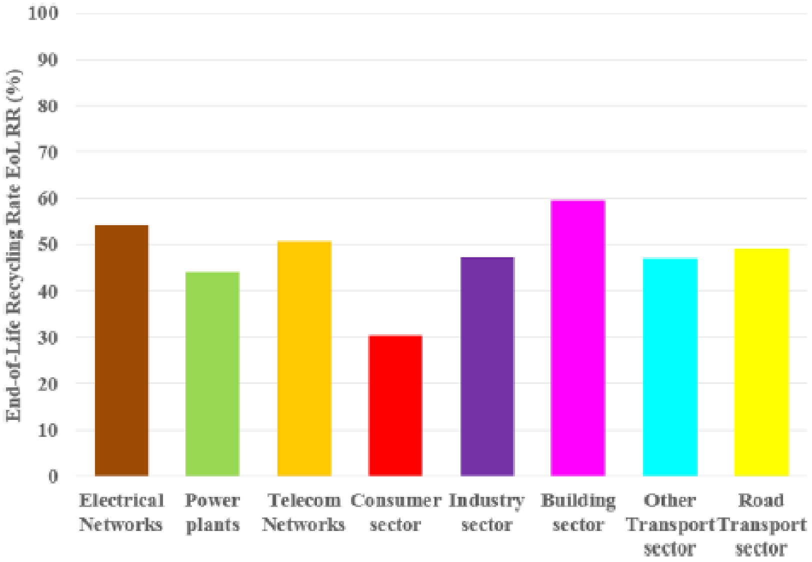
	Cobalt content (kg/kWh)
NCA	0.13
NMC 111	0.40
NMC 622	0.19
NMC 811	0.09
LFP	

Source: IEA GEVO, 2018

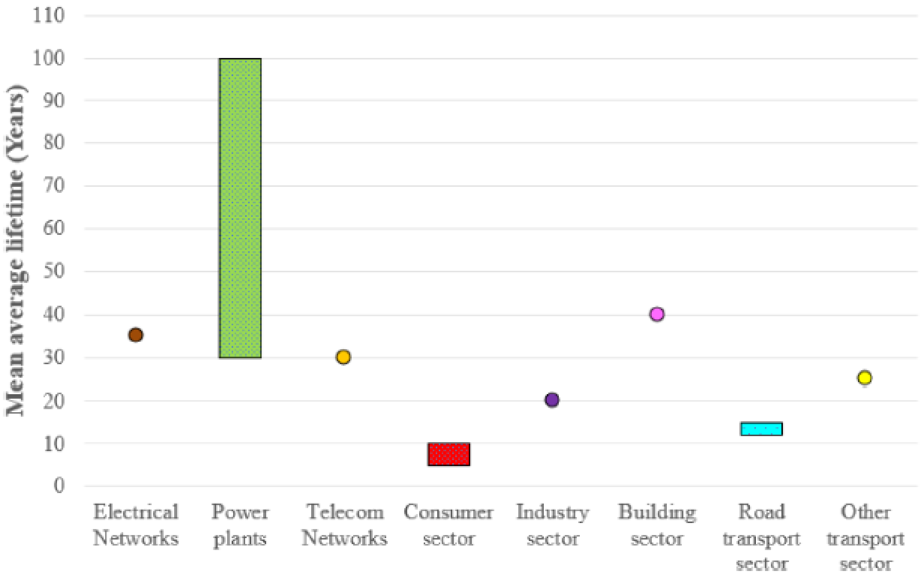
PROJET GENERATE

TIAM-IFPEN MODEL: CONSIDERING RECYCLING…

○ Copper



End-of-life recycling rate (EoL-RR) by end-use sector in the model.



Mean average lifetimes by end-use sector in the model

Source: Glöser et al., 2013; Seck et al., 2020

○ Cobalt

		EoL-RR	
		2020	2030
EV batteries		66.5%	80.8%
Other end-uses	OCDE	35%	
	Non-OCDE	30%	

Source: Alves Dias et al., 2018; Drabik and Rizos, 2018; Seck et al., 2020

	Average lifetime (in years)
EV batteries	8
Other batteries	5
Super-alloys	5
Hard metals	1
Ceramics/Pigments	5
Others	5

Source: Alves Dias et al., 2018; Seck et al., 2020

PROJET GENERATE

SCENARIO SPECIFICATION

- ✓ For the purpose of the present study, **we run 4 scenarios where we have considered two climate scenarios with two different shapes of mobility each** in order to assess the impact on the lithium market along with the transportation electrification:

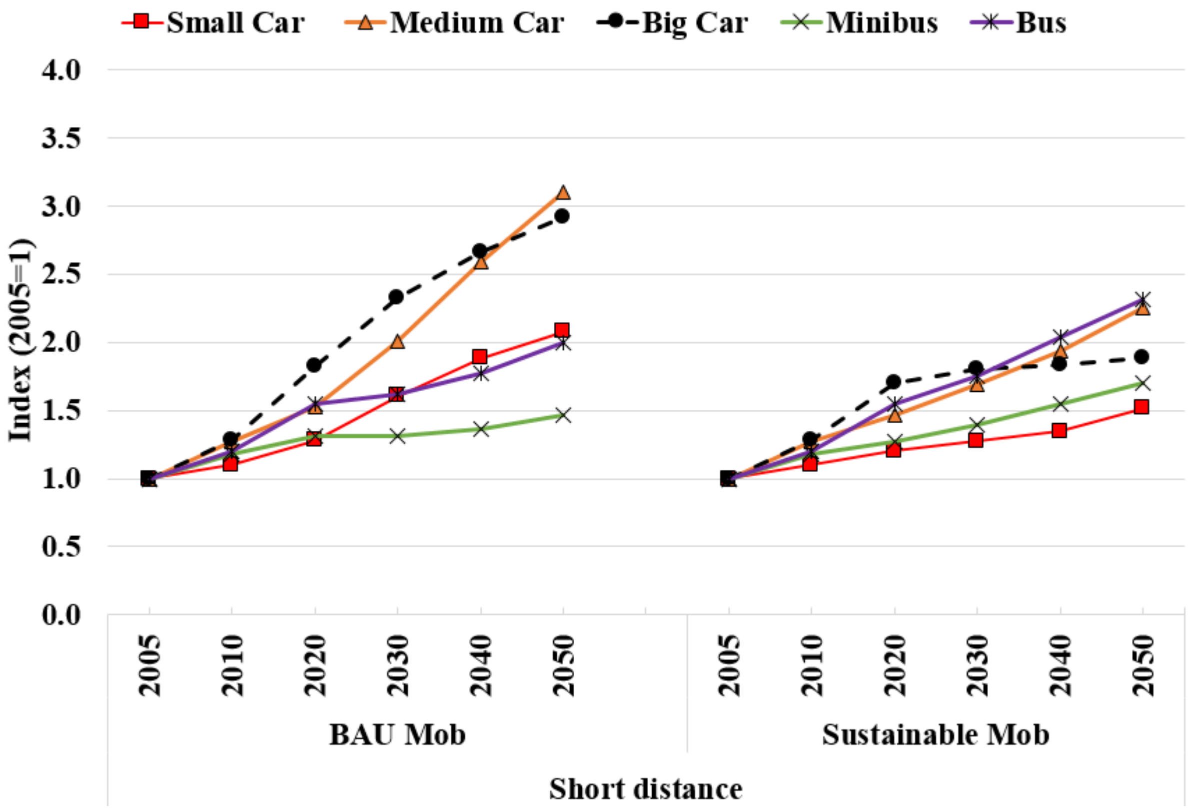
  - ❑ Scen 4D which is consistent with limiting the expected global average temperature increase to 4°C above pre-industrial levels by 2100.
  - ❑ Scen 2D which is a more ambitious scenario, which translates the climate objectives of limiting global warming to 2°C by 2100.

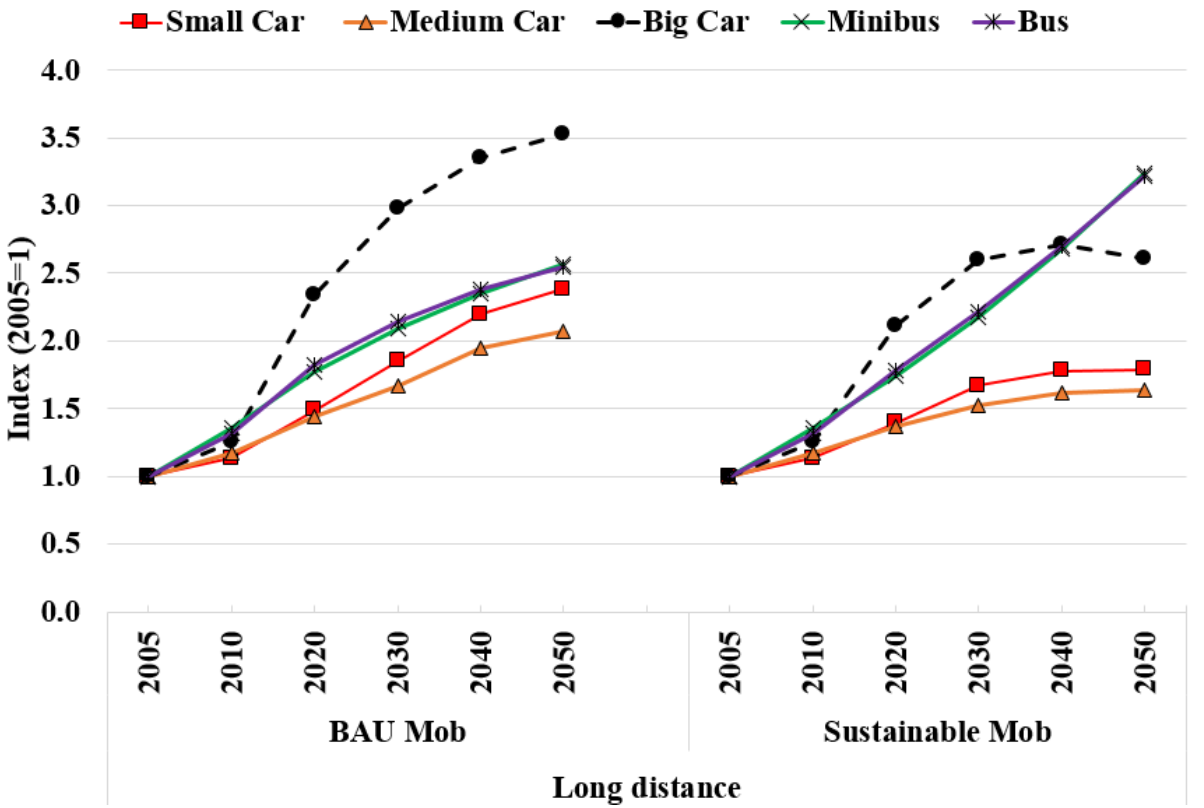
- ✓ In each climate scenario, two future shapes of mobility have been assumed and derived from the IEA Mobility Model (MoMo)

  - ❑ BAU Mobility (BAU Mob)
  - ❑ Sustainable Mobility (Sustainable Mob)

TWO DIFFERENT SHAPE OF MOBILITY (BAU AND SUSTAINABLE)

Source : IEA Mobility Model 2018



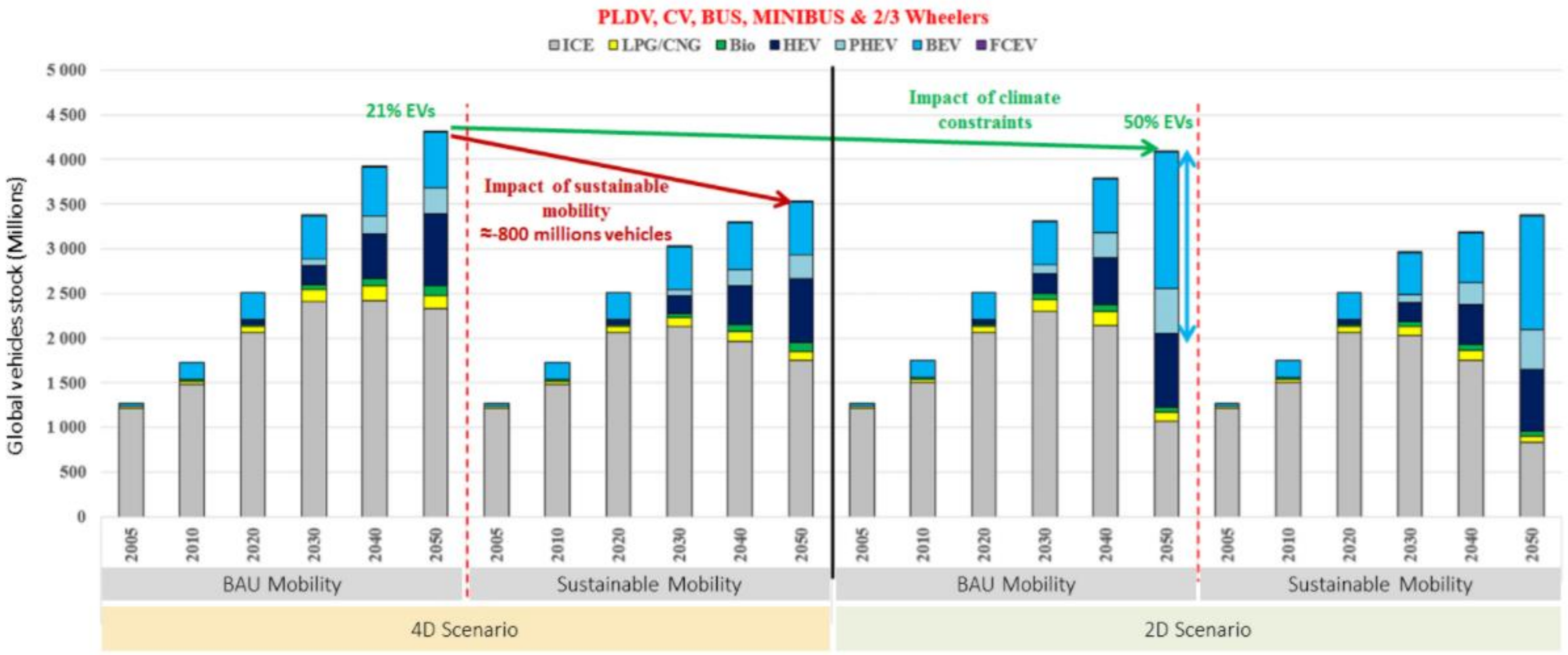


- **«BAU» mobility** where it is assumed a continuous increase of the ownership rate and a higher car-dependency.
- **Sustainable mobility** where the idea of a sustainable mobility is assumed due to stronger fiscal and regulatory policies, and priority is given to sustainable modes of mobility such as public and non-motorized transport

PLAN

PROJET GENERATE

EVOLUTION OF THE GLOBAL VEHICLE STOCK 2005-2050

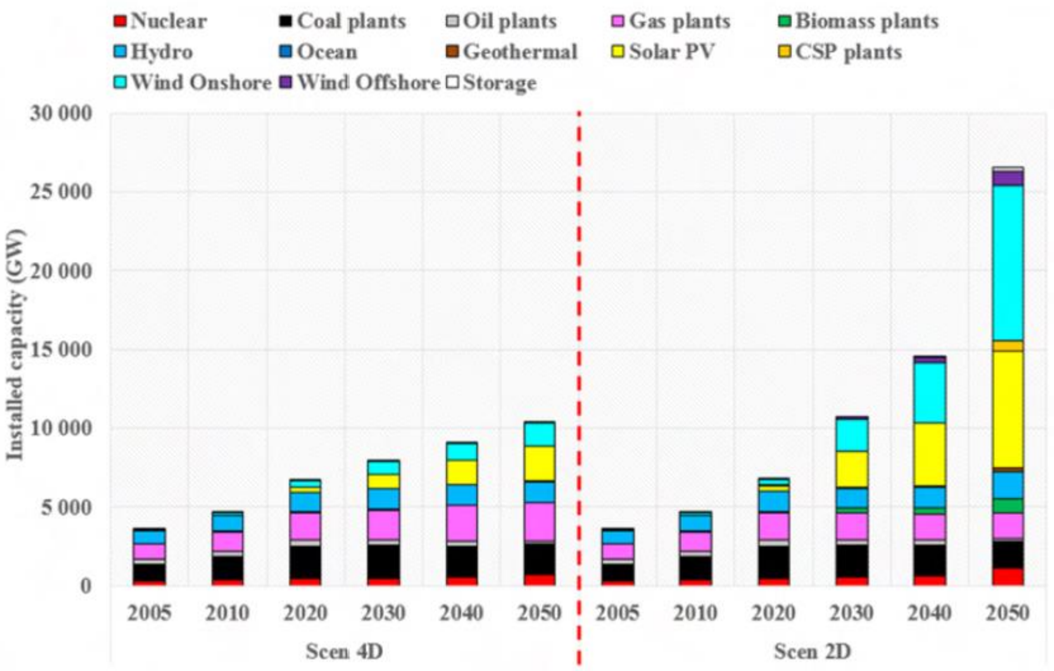


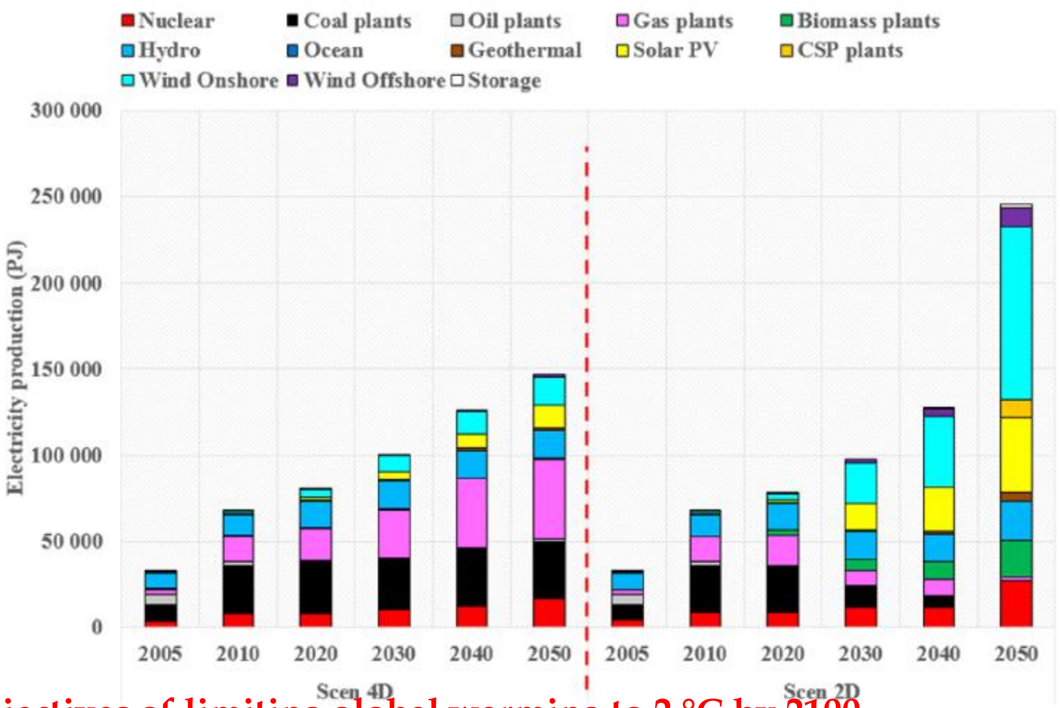
- **World fleet dominated by ICE between 2005-2050 (except in Scen 2D from 2040 onward)**
- **More than 800 million vehicles less with more sustainable mobility**
- **Around 1/3 of the world fleet are 2/3-wheelers (mostly in China and India)**
- **Electric vehicles**
  - More than 50% of the electric fleet are 2/3-wheelers
  - EV fleet is mostly located in Asian countries (China, India and Other developing countries in Asia) due to the large presence of 2/3-wheelers

Comparison of our modelling results in future global EV stock in 2030 with recent literature.

	Our results		IEA GEVO 2019	
	4 °C Scenario	2 °C Scenario	Stated Policies scenario	EV30@30 scenario
2030	110 million	180 million	130 million	250 million

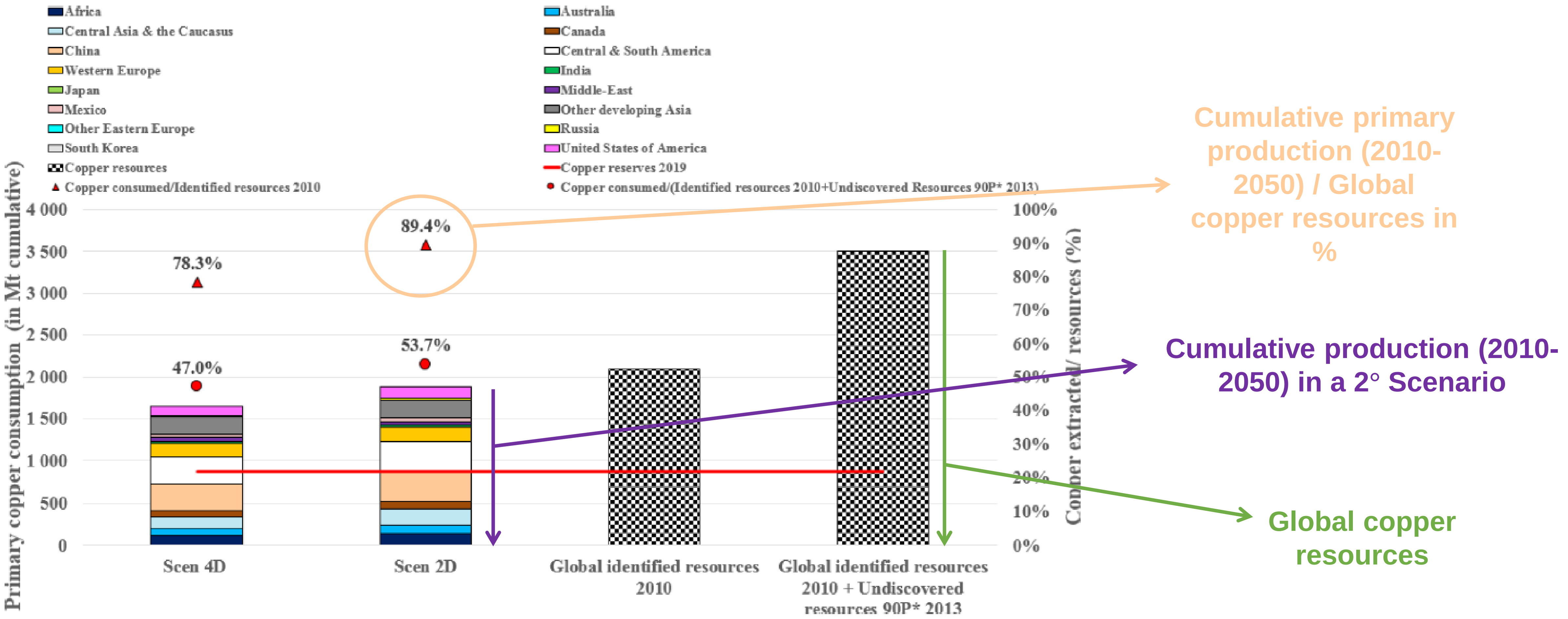
EVOLUTION OF THE GLOBAL POWER INSTALLED CAPACITY 2005-2050





- **Fast shift to the low carbon technologies to achieve the climate objectives of limiting global warming to 2 °C by 2100**
  - The total installed capacity by 2050 in the 4 °C scenario, which is 10.5 TW, will be multiplied by around 2.5 in the 2 °C scenario.
  - Wind and solar represent around 35% by 2050 in 4 °C while it is reaching more than 69% in the 2 °C scenario in terms of installed capacity
- **Fossil-based plants (coal, gas and oil) remains the main source of power production in the world in the 4 °C scenario with around 55% of overall production while it drop to 0.8% in the more stringent scenario (2 °C scenario).**
- **Wind and solar reach around 21% by 2050 in the 4 °C while it is more than 67% of the total production in the 2 °C scenario**

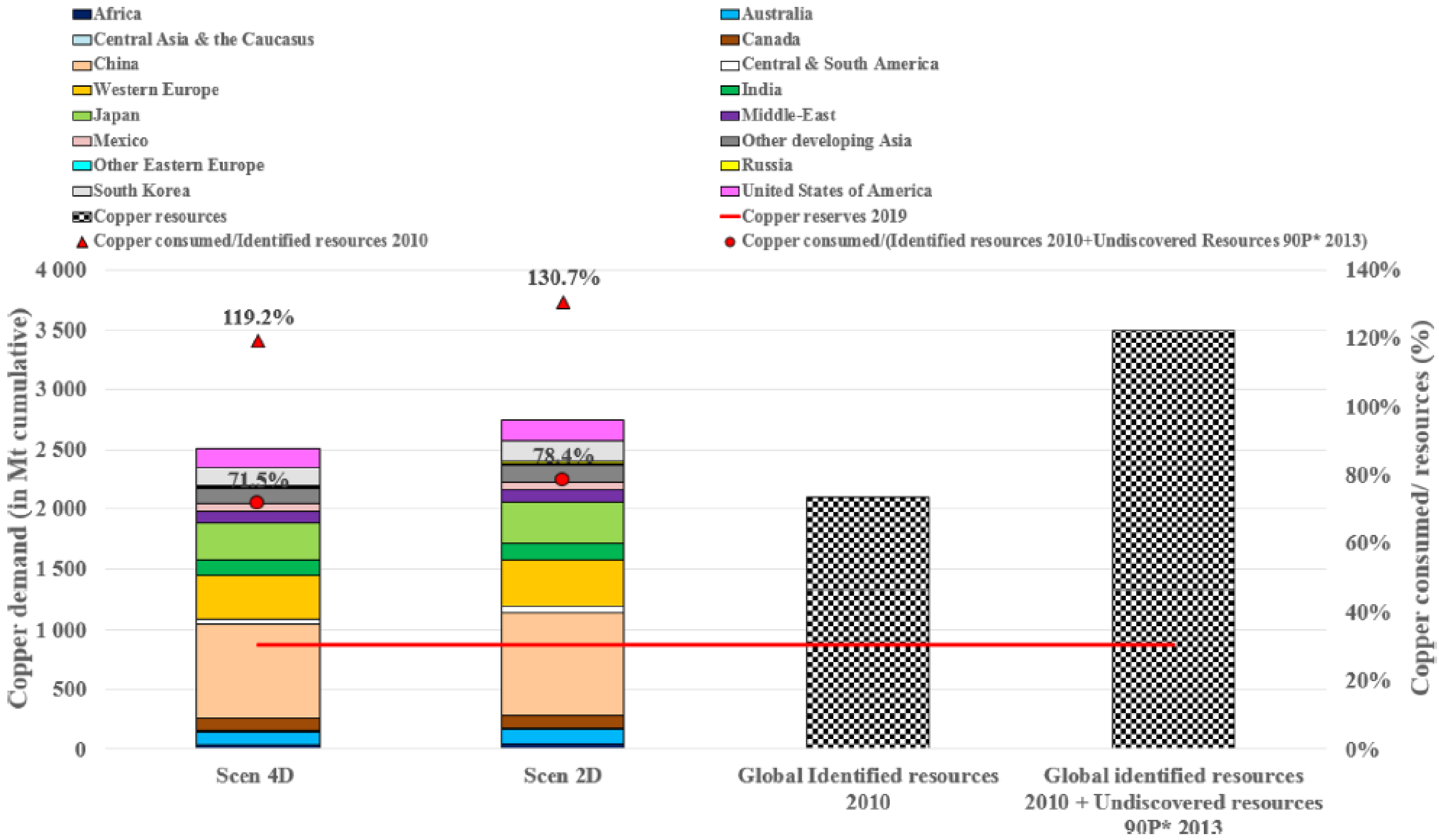
IMPACT OF THE ENERGY TRANSITION ON COPPER PRODUCTION: 4°C VS. 2°C



	Our results		Schipper et al. (2018)	Elshkaki et al. (2016)
	4 °C scenario	2 °C scenario	SSP1, SSP2 and SSP5 scenarios	EF, SF, PF and MF scenarios
Cumulative primary copper demand	1600 Mt	1900 Mt	800 – 1000 Mt	1500 – 1900 Mt
Average recycling rate considered	45%		70% and 90% for each scenario	45%

IMPACT OF THE ENERGY TRANSITION ON COPPER CONSUMPTION: 4°C VS. 2°C

RESULTS

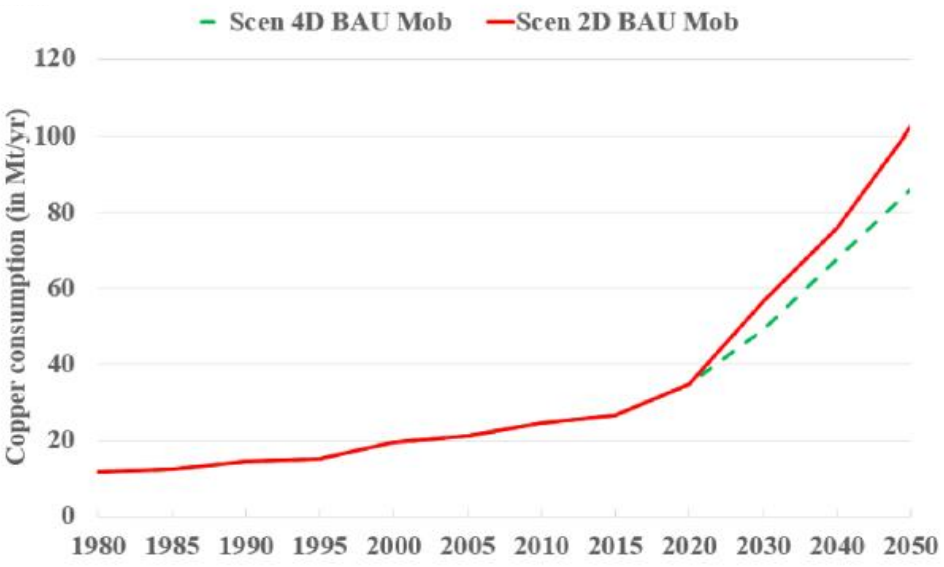


- **China, Western Europe, Japan and United States of America represent almost 65% of the total cumulative copper consumption (averaging 31%, 14%, 13% and 6%, respectively) between 2010 and 2050 in both scenarios.**
- **More than 50% of the total cumulative copper mined between 2010 and 2050 was done in only three regions: Central and South America, China, Other developing Asian countries (averaging 20%, 18% and 13%, respectively) in the 4 °C and 2 °C scenario**

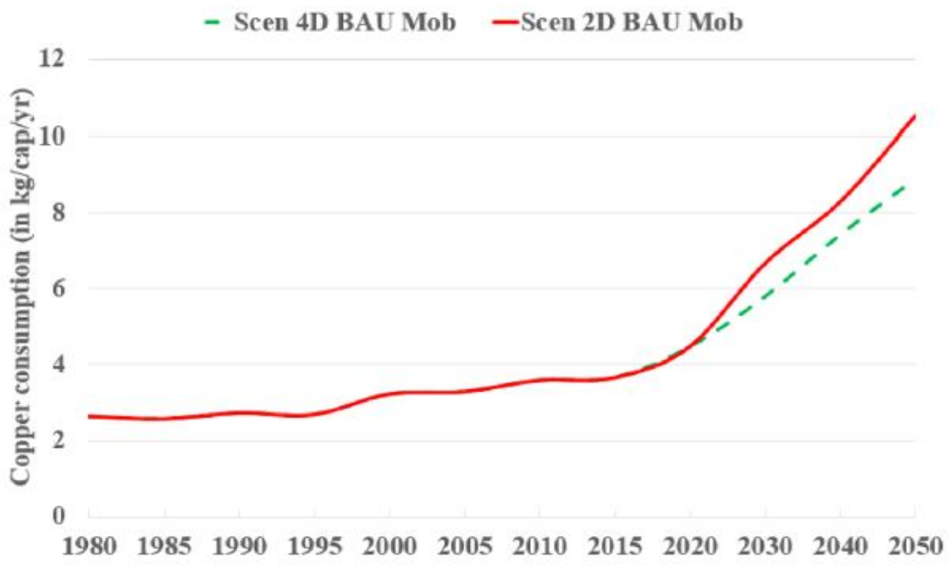
PROJET GENERATE

IMPACT OF THE ENERGY TRANSITION ON COPPER CONSUMPTION: 4°C VS. 2°C

Evolution of the yearly copper consumption



Evolution of yearly copper consumption per capita

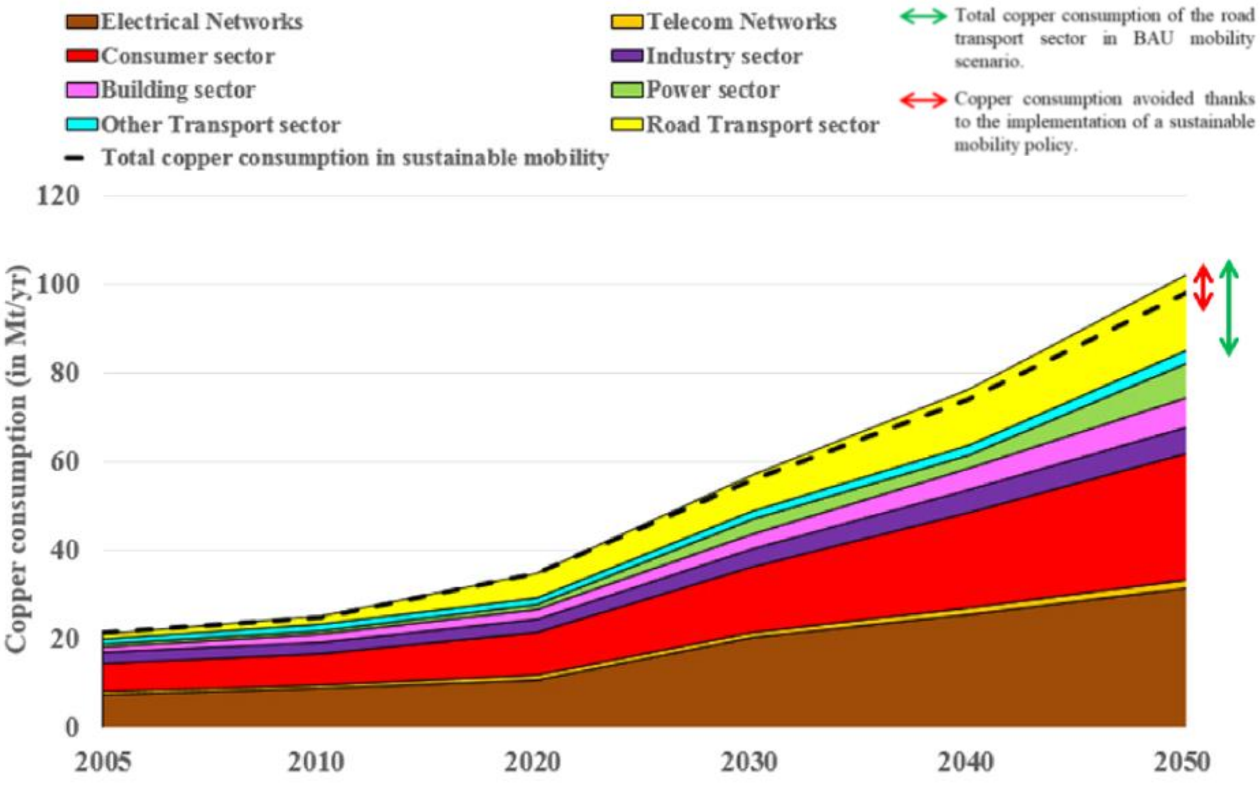


Comparison of our modelling results in global copper demand in 2050 with recent literature

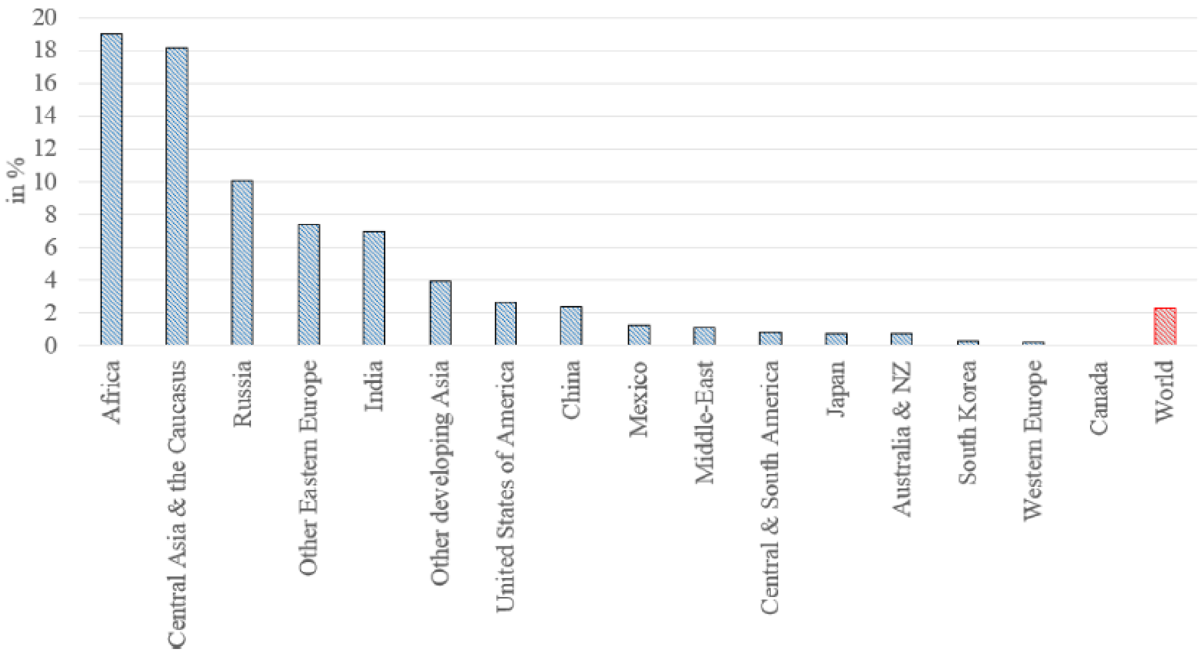
	Our results		Vidal et al. (2019)	Schipper et al. (2018)	Elshkaki et al. (2016)	Halada et al. (2008)
	4 °C scenario	2 °C scenario	Main scenario	SSP1, SSP2 and SSP5 scenarios	EF, SF, PF and MF scenarios	Scenario for only 10 countries (BRICS and G6)
Global copper demand in 2050	86 Mt	102 Mt	45 Mt	70 – 125 Mt	40 – 70 Mt	45 Mt

SUSTAINABLE MOBILITY IS A KEY ISSUE IN COPPER DEMAND

Evolution of copper consumption in a 2°C scenario: Impact of the road transport mobility shift



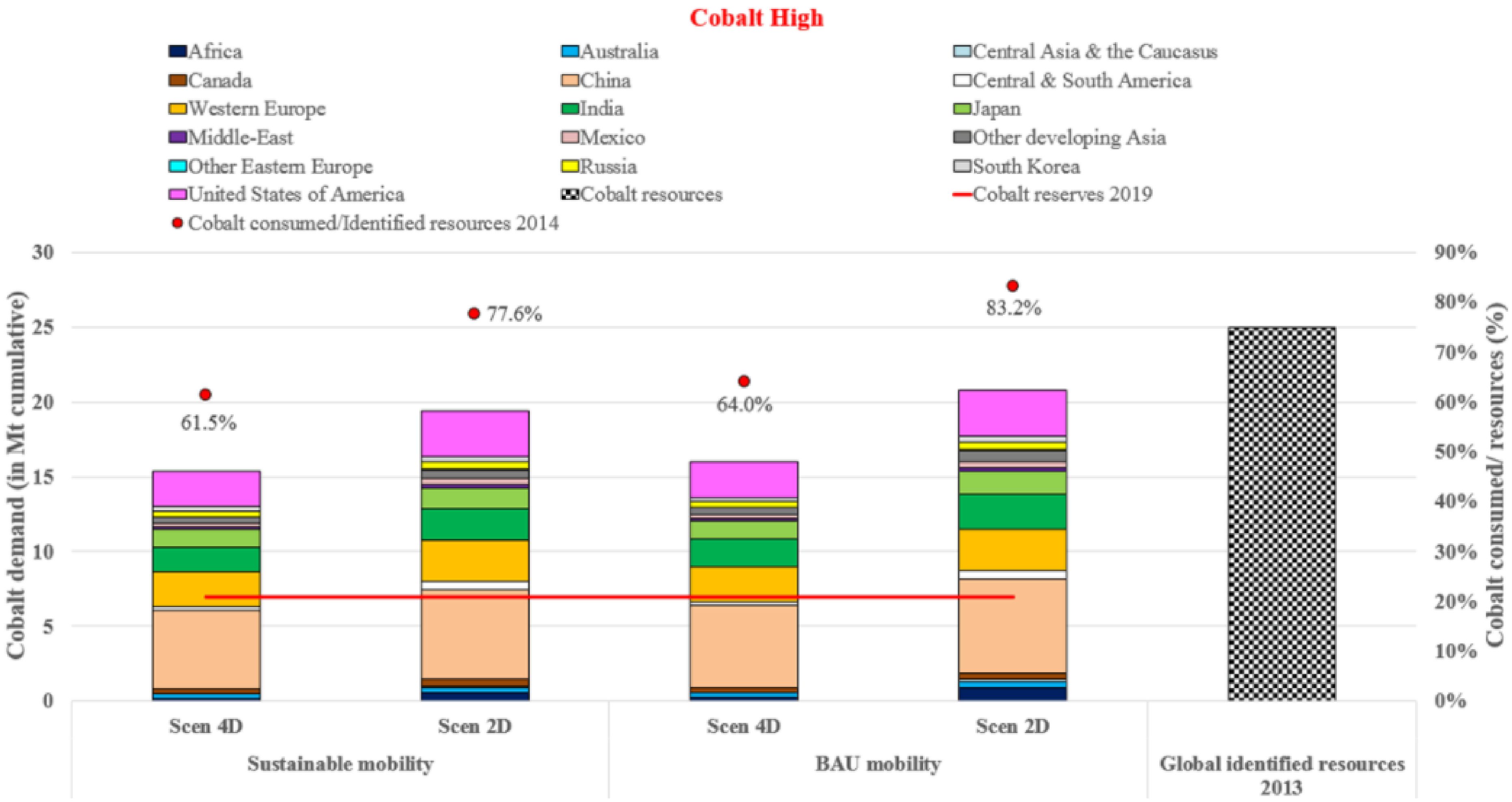
Share of copper consumption avoided through a sustainable mobility scenario (in%), 2010–2050



- The reduction in cumulative copper consumption is between 2% to 20% over the period 2010–2050

THE COBALT CASE

RESULTS

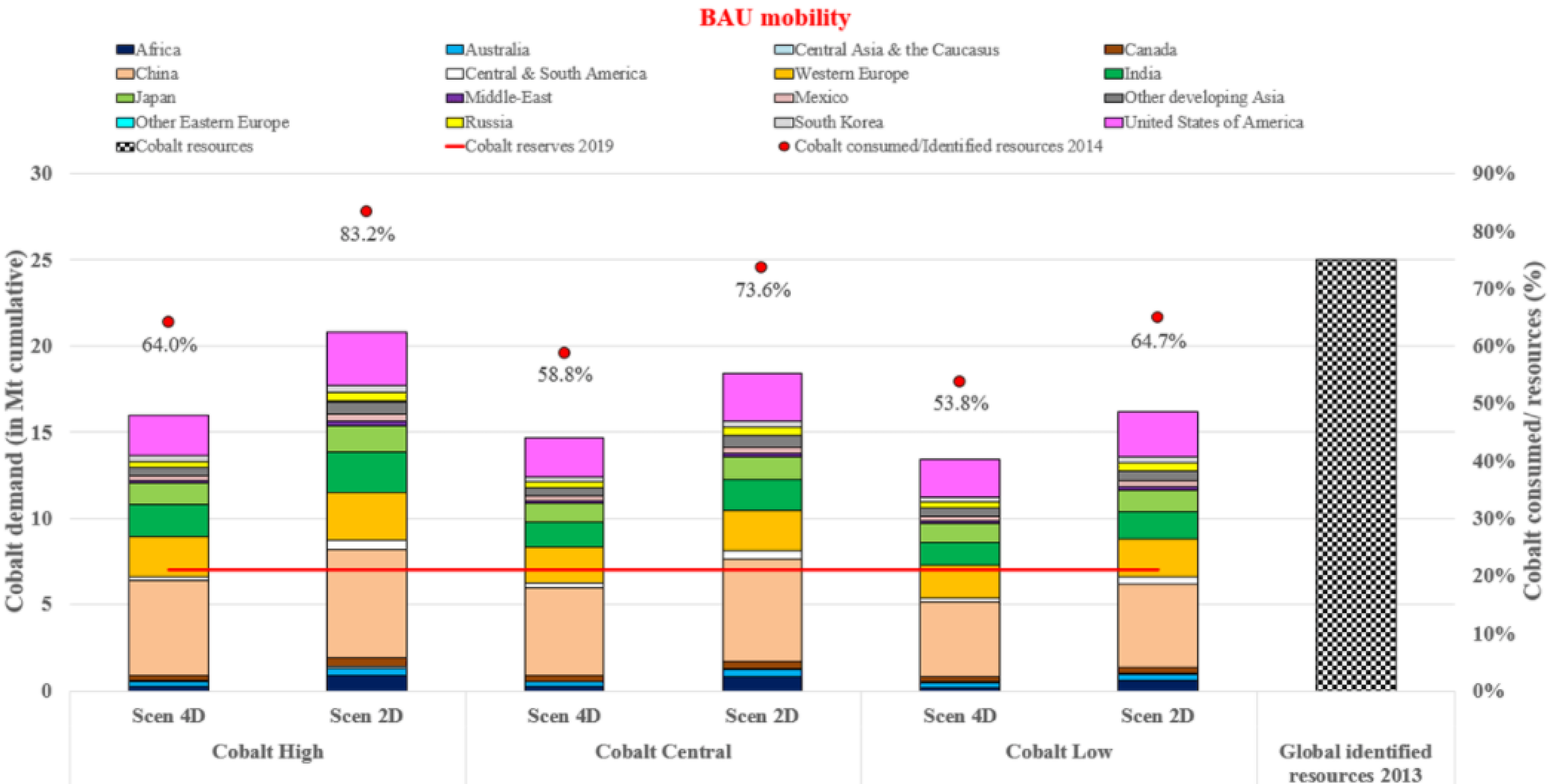


THE COBALT CASE: BATTERY TECHNOLOGIES MATTER

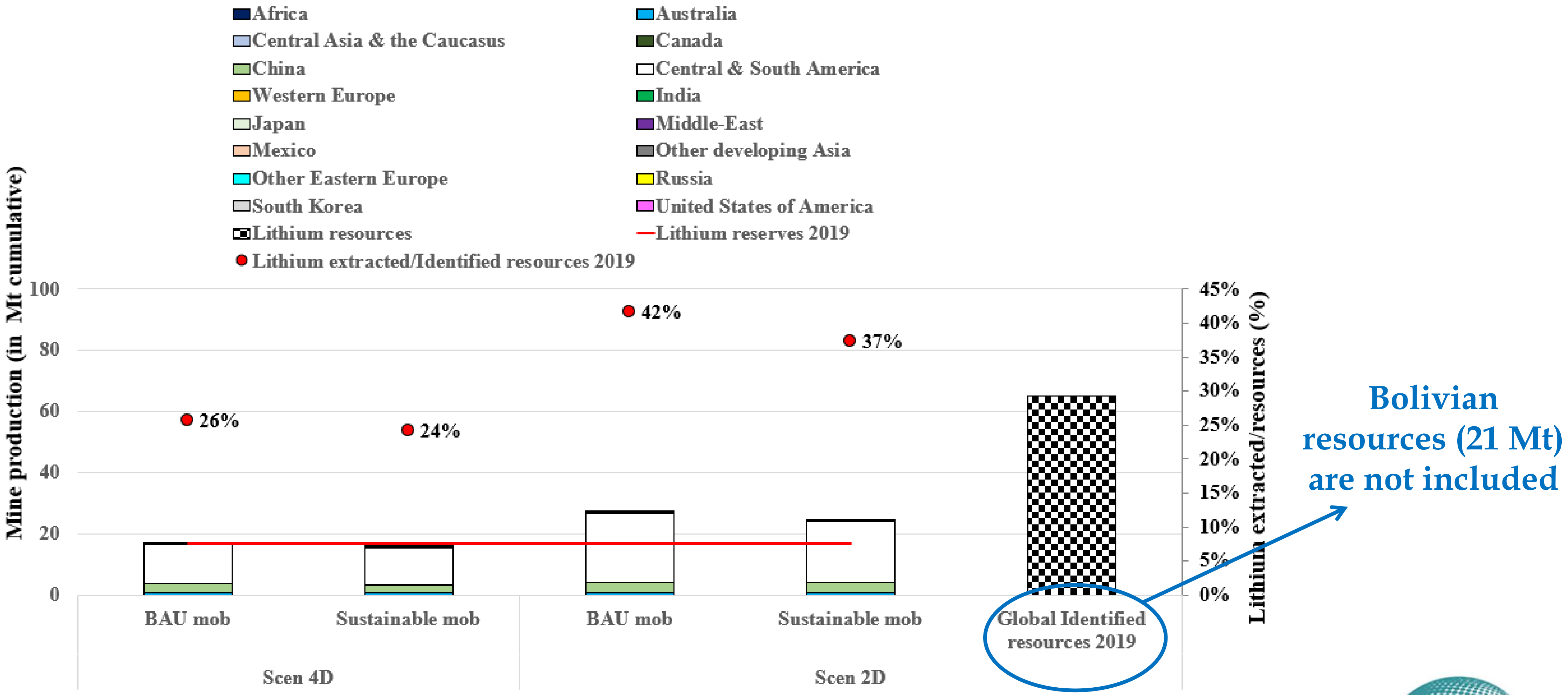
RESULTS

Scenario of cathode Chemistry in EVs assumed in our model.

Cobalt content scenarios	Mix of chemistries from 2030
High Cobalt	10% NCA, 90% NMC622
Central Cobalt	10% NCA, 40% NMC622, 50% NMC811
Low Cobalt	10% NCA, 90% NMC 811

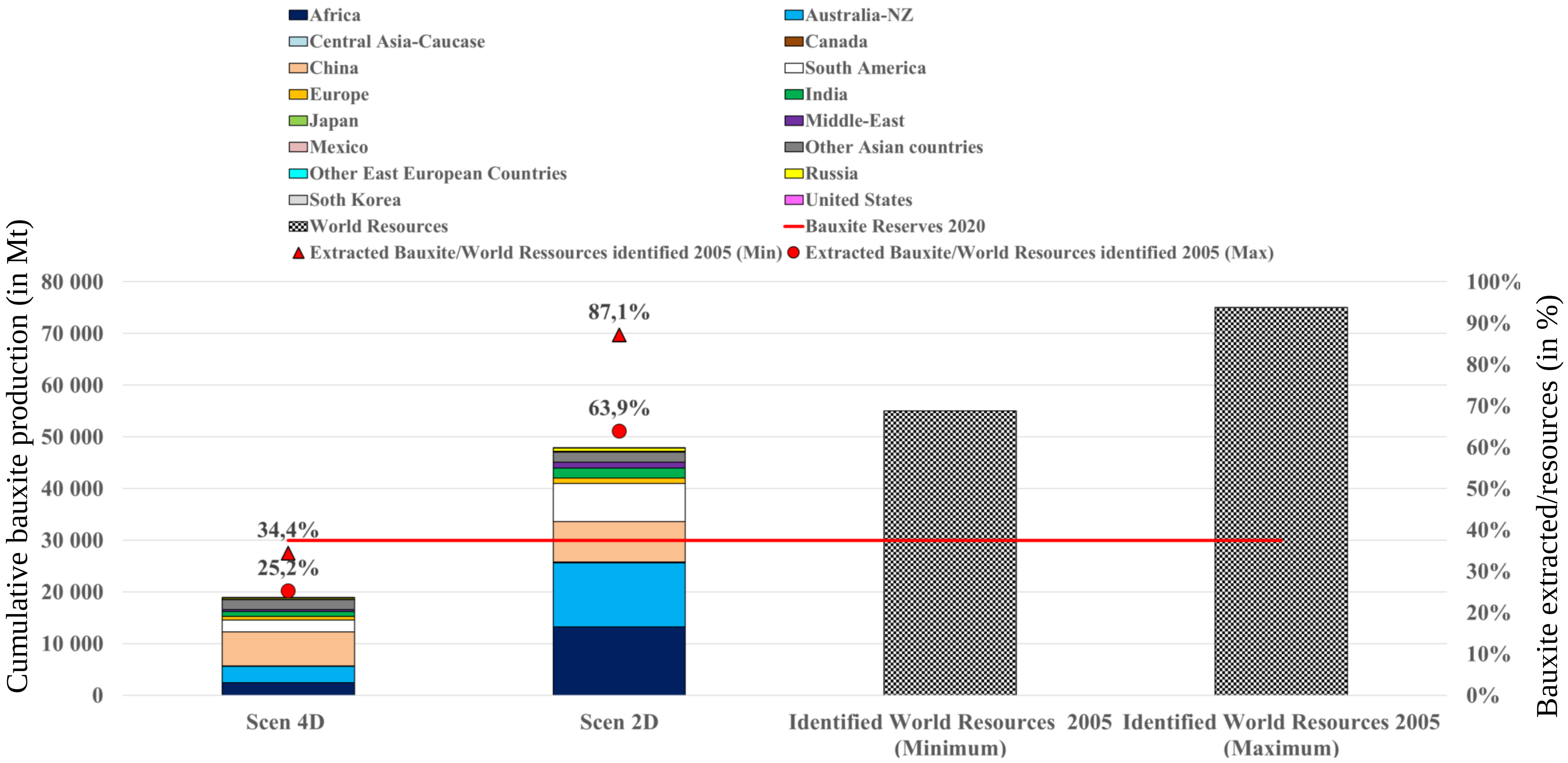


IMPACT OF THE ENERGY TRANSITION ON LITHIUM PRODUCTION: 4°C VS. 2°C



- **High global dependence on Central/South America (Lithium triangle)**
- **Margin of 74% on current global resources (not incl. Bolivia) in the Scen 4°C to 58% in the Scen 2°C**

BAUXITE PRODUCTION



PLAN

PROJET GENERATE

CONCLUSIONS

- ✓ The scenarios developed tend to show that energy transition dynamic could lead to an increase of material criticality in the 2°C, the most stringent climate scenario, with a business-as-usual mobility.

- ✓ Raw material criticality within the BAU mobility constraint

	2° Scenario	4° Scenario
Copper	89,4%	78,3%
Bauxite	87,1%	34,4%
Cobalt	83,2%	64%
Nickel	61,3%	52,8%
Lithium	42%	26%
Rare Earths	3,8%	1,6%

- ✓ Other different forms of vulnerability, whether economic, industrial, geopolitical or environmental.
  - ❑ Uncertainties about the market's ability to meet the new and growing demand on time.
  - ❑ Uncertainties about the commercial strategy of large consumers (especially China).
  - ❑ Uncertainties about the consequences of national strategies.
    - **Possible high dependence on supplies from a specific region**
    - **The current contrasting national strategies** could have a decisive influence on the medium- and long-term capacity to supply to industrial players
  - ❑ Uncertainties related to the environmental impacts of the material production.
    - **Future volume production could have serious social and environmental consequences**.
    - **Destruction of fauna and flora or the degradation of landscapes**
- ✓ Public Policy is a key issue : Recycling and sustainable Mobility

Innovating for energy

Find us on:

www.ifpenergiesnouvelles.com

@IFPENinnovation