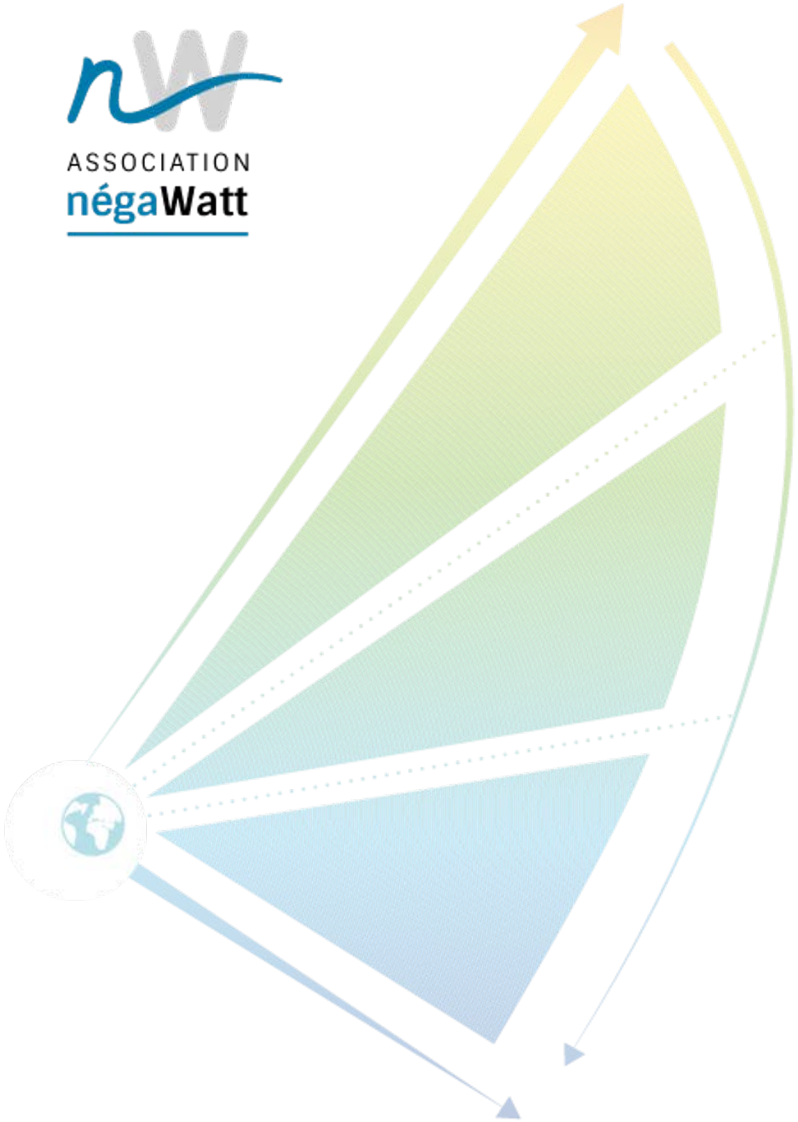


2022 June 07th

Emmanuel RAUZIER

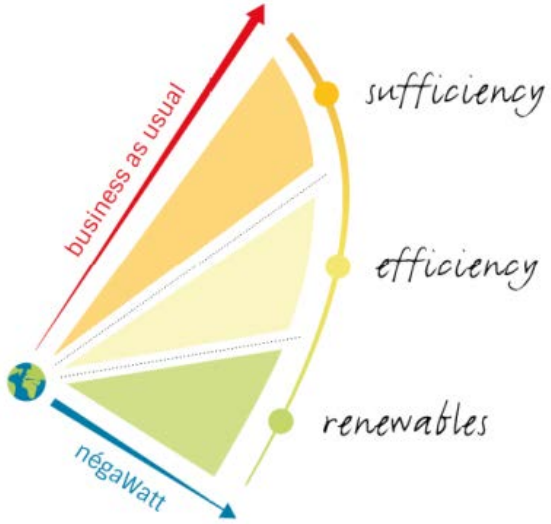
The material impacts of an energy transition based on sufficiency, efficiency, and renewables

ECEE Paper 9-089-22

The négaWatt association

- Association founded in 2001 by energy experts
- Missions :
  - **Energetical expertise and prospective**
  - **Advocacy**
- 12 employees – 30 active members – 1500 adherents

www.negawatt.org

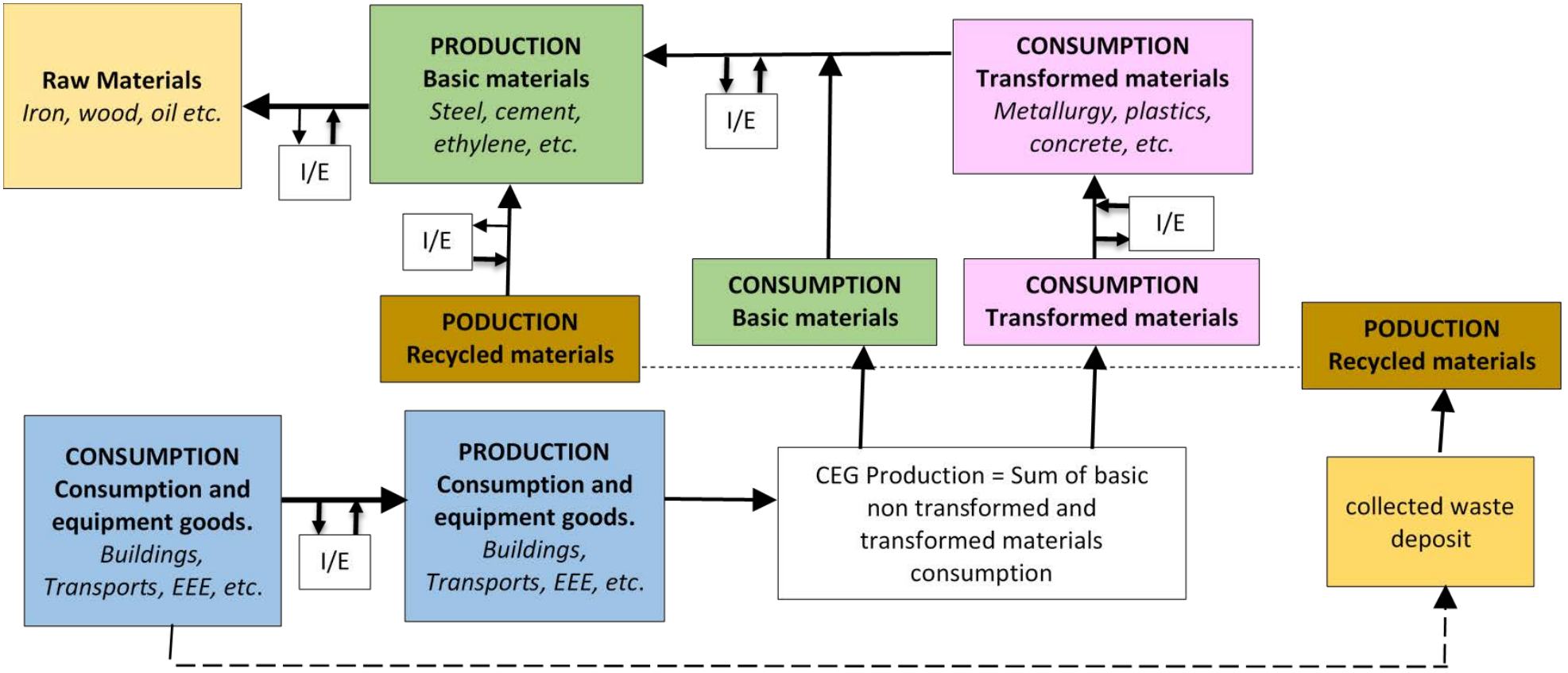


THE NEGAWATT APPROACH

1. Which energetical services and how much useful energy do we need ?
2. With which devices ?
3. With which energy sources ?

1. The négaMat approach
2. Some results

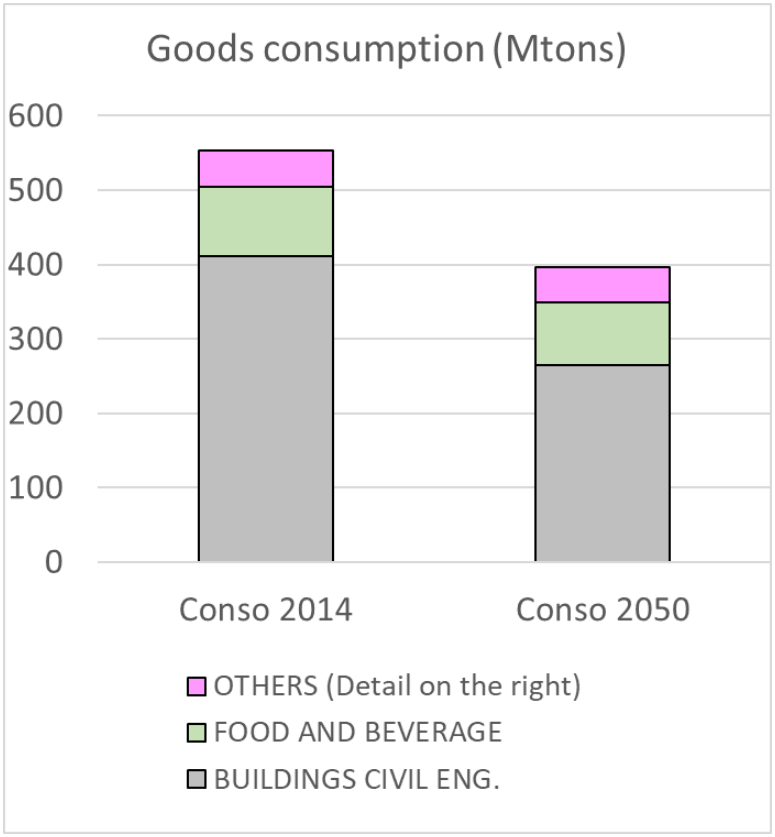
NegaMat : The general frame

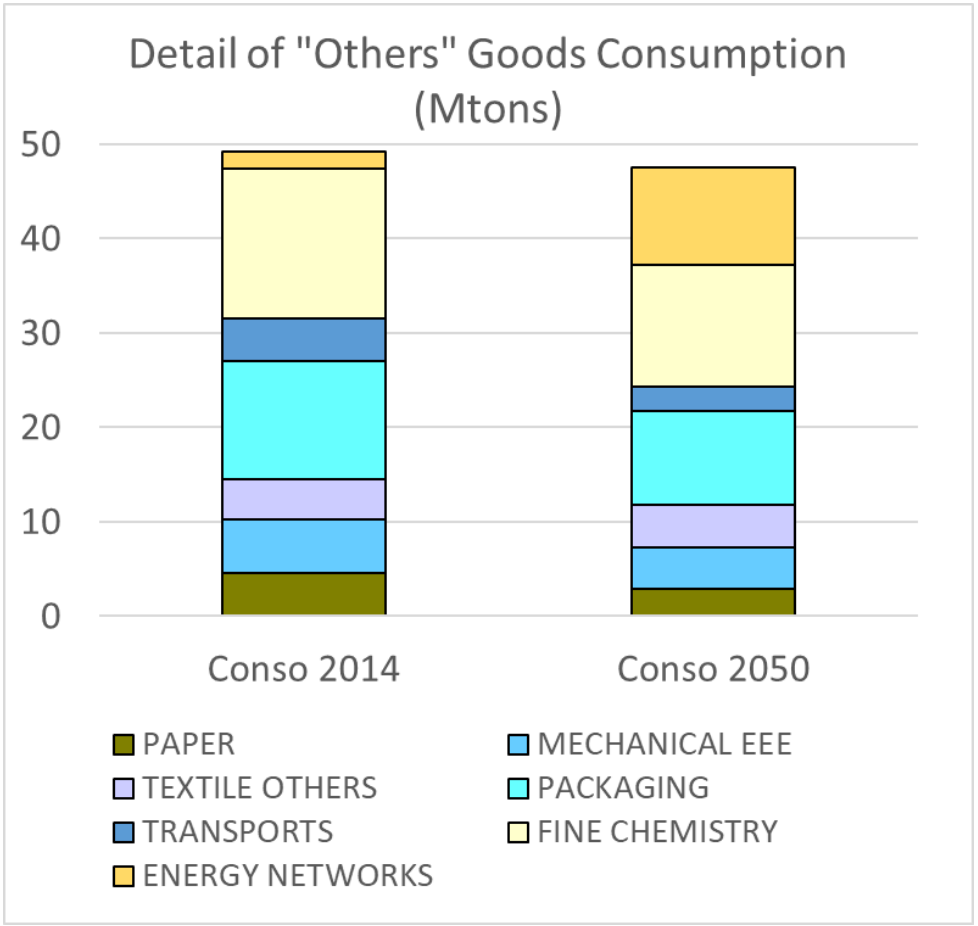


Step1: what demand will we have to face in the future?

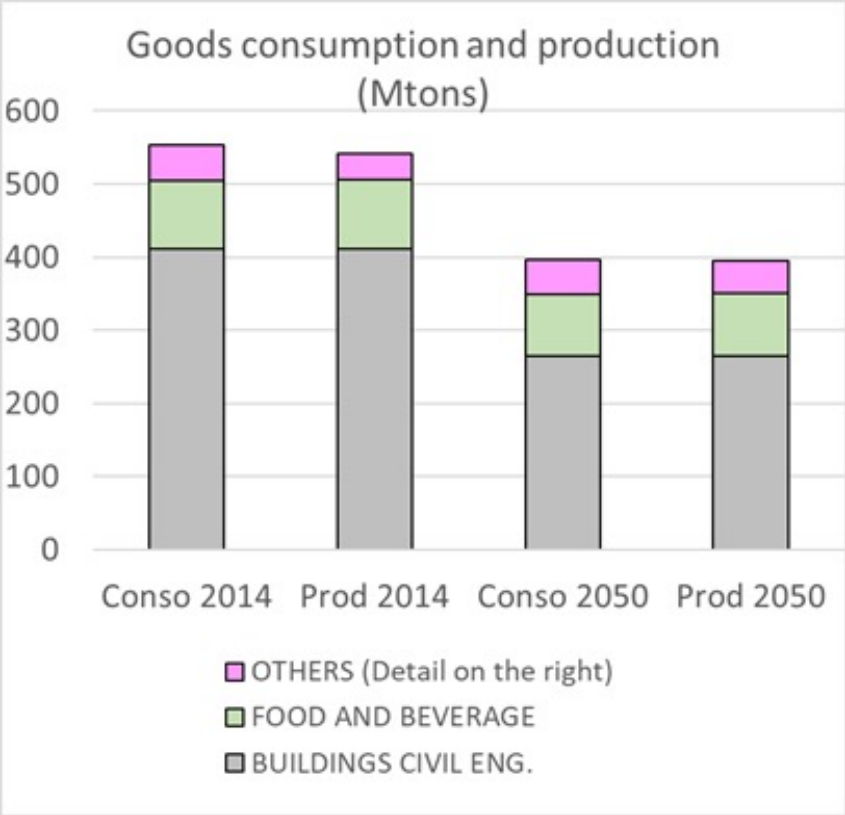
	Size suffic.	Use suffic.	Share suffic.	Reuse	Repair	Recycle	nb Sub Sectors
FOOD AND BEVERAGE	YES	YES	NO	NO	NO	NO	8
PAPER	YES	YES	NO	NO	NO	YES	3
MECHANICAL EEE	YES	YES	YES	YES	YES	YES	15
TEXTILE OTHERS	YES	NO	Seldom	YES	YES	YES	14
PACKAGING	YES	YES	NO	YES	Seldom	YES	11
TRANSPORTS	YES	YES	YES	YES	YES	YES	15
FINE CHEMISTRY	YES	YES	NO	NO	NO	NO	11
BUILDINGS CIVIL ENG.	YES	YES	YES	YES	YES	YES	19
ENERGY NETWORKS	NO	NO	NO	NO	YES	YES	32
GLOBAL							128

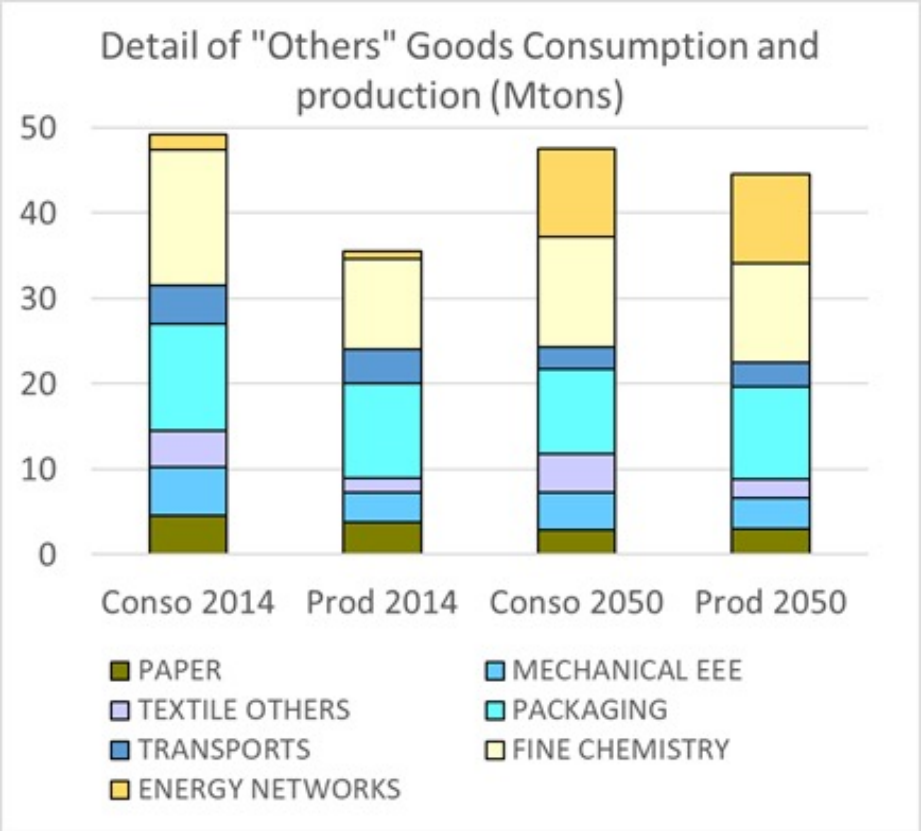
Step1: what demand will we have to face in the future?



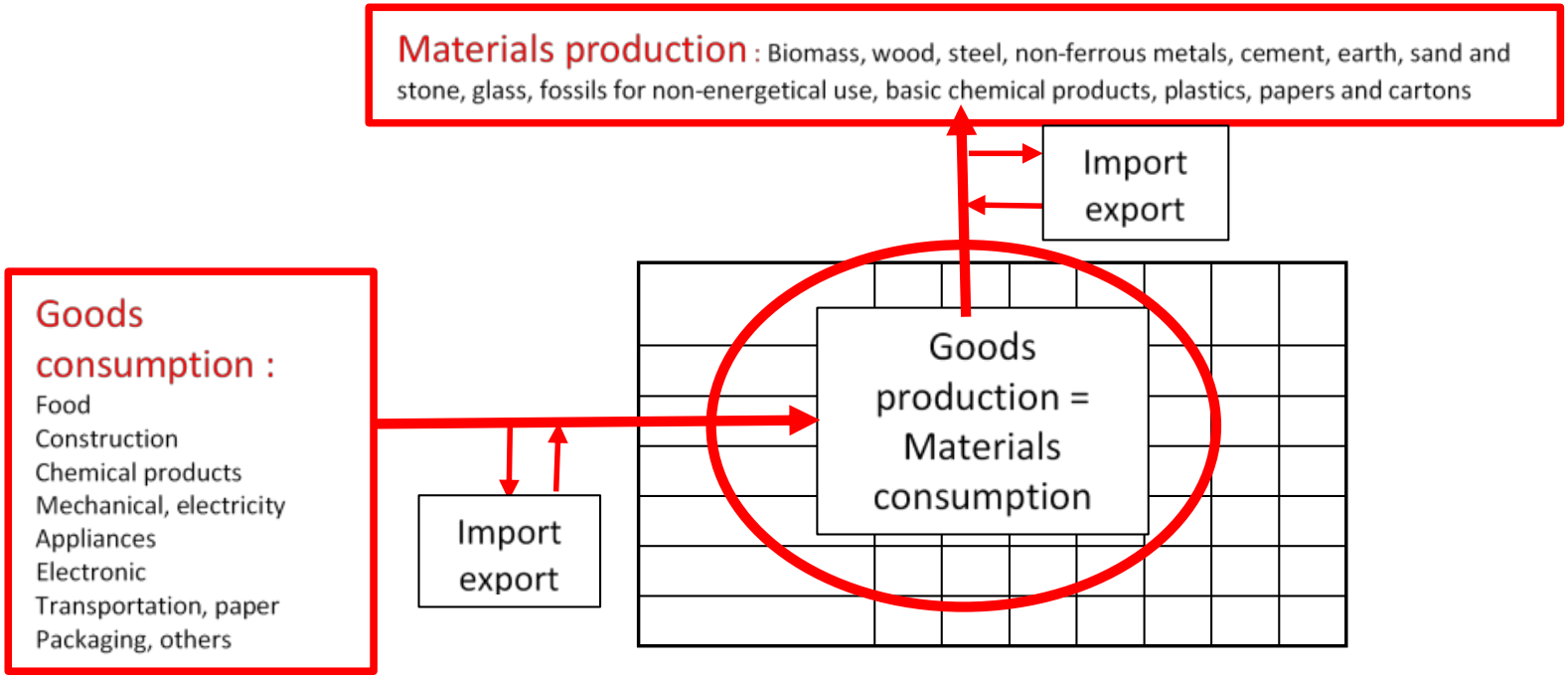


Step 2: How much are we going to produce?





Step 3: which materials for consumption goods?

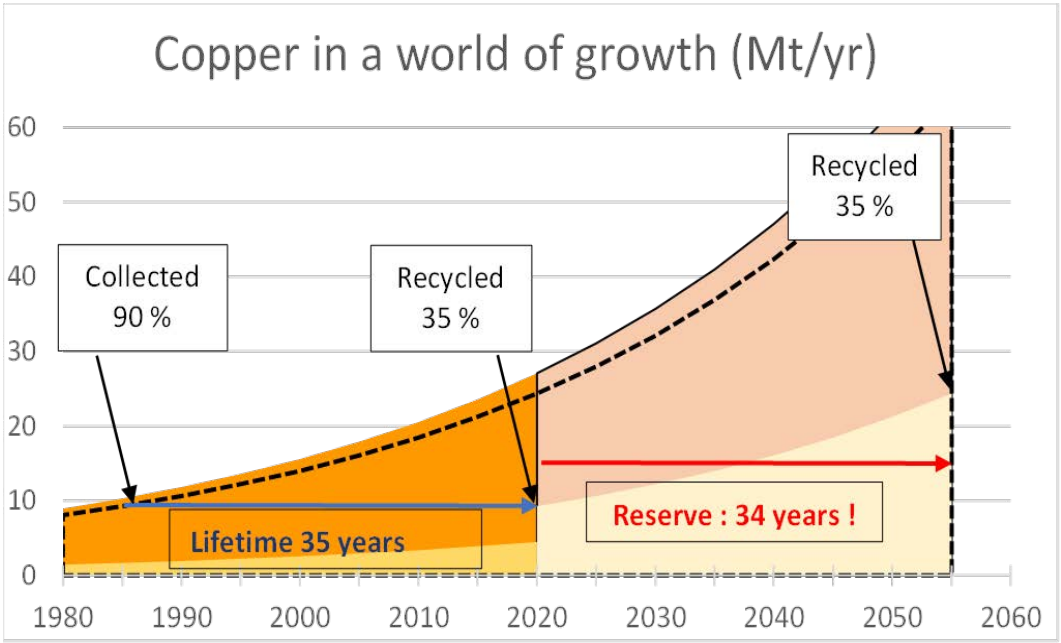


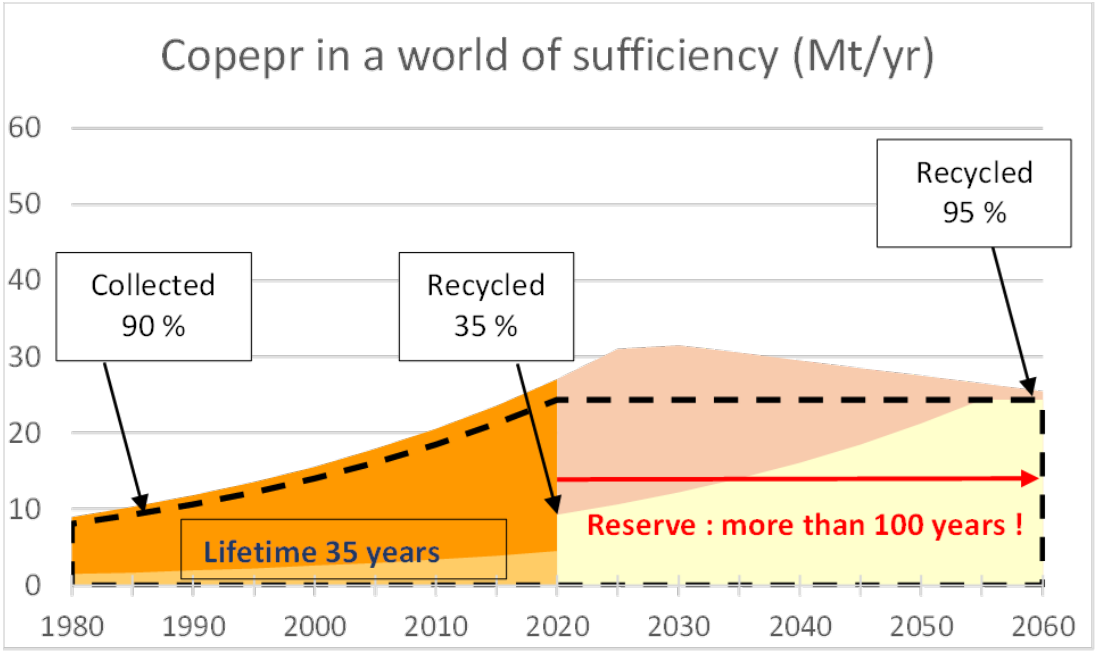
National **D**emand + **S**tock variation at year n =

Production + **I**mportations - **E**xportations

(avalaible for goods and materials)

Step 4: What can we expect from recycling?

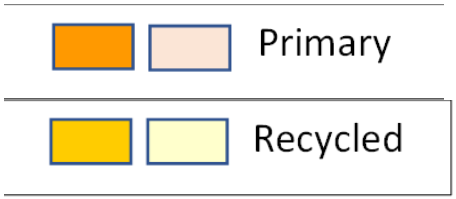




négaMat response :

In a worLd of growth, recycling rate cannot increase.

In a sufficient word, recycling becomes efficient



Step5: What is our print like on resources?

With negamat, we compare the cumulated print (2020-2070) and the reserve

Two structuring assumptions:

- The reserve is limited to the **proven reserve**

Ex. copper	**proven reserve**	**870 Mt**
	possible reserve	2 700 Mt
	ultimate resource	5 600 Mt

- The worldwide **quota** assigned to the designated country is **proportional to its population**

E;x. copper:	Million Inhabitants	%Pop	Res Mt Copper
World	7 870	100%	870 Mt
France	67.4	0,86%	0;86%*870 Mt = **7.5 Mt**

1. The négaMat approach
2. Some results

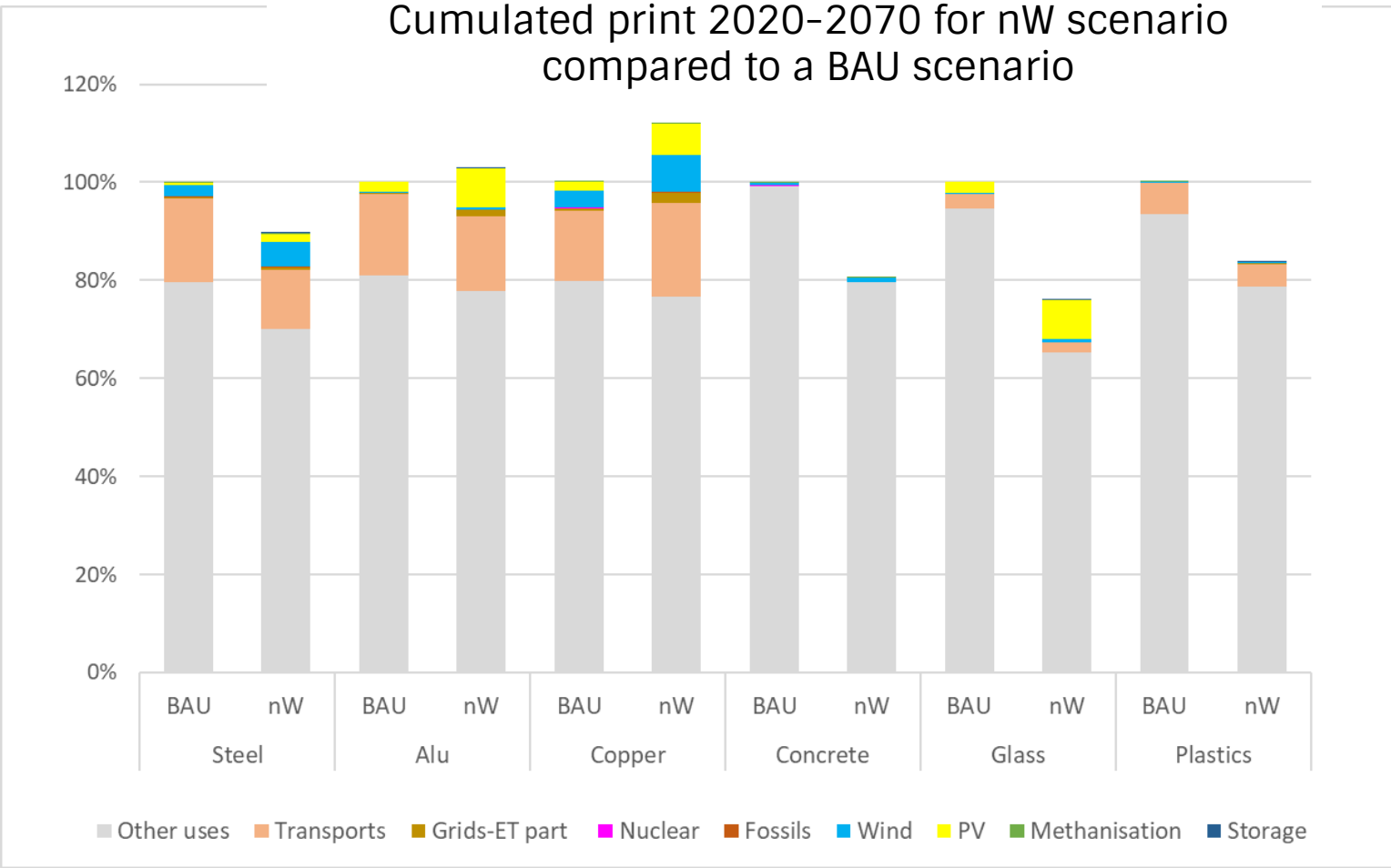
Many kinds of results

OPTIONS	A picture in one year The evolution for one period A comparison between two or more scenarii			
	CONSUMPTION	PRODUCTION	PRINT	OTHER
Consumption goods	X	X	X	Share of embodied materials
Basic and transformed materials	X	X	X	Share of uses
RPM incorporated	X	X	X	Theoretical and real incorporation rate
Raw materials	X	X	X	Cumulated print and comparison with reserve

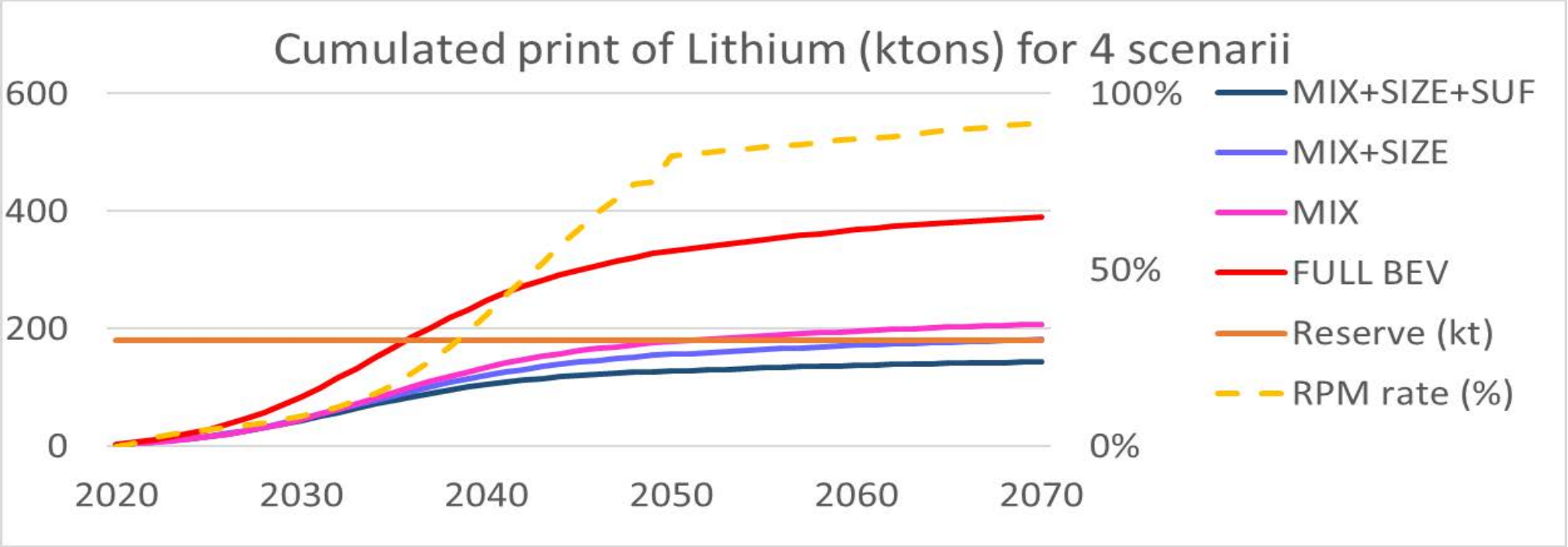
Example 1: Materials and energetical transition

Sufficiency and CE save more materials than require new technos

Renewable energy requires only **5 to 10%** all uses



Example 2: Li reserve and comparative print for 4 simulations

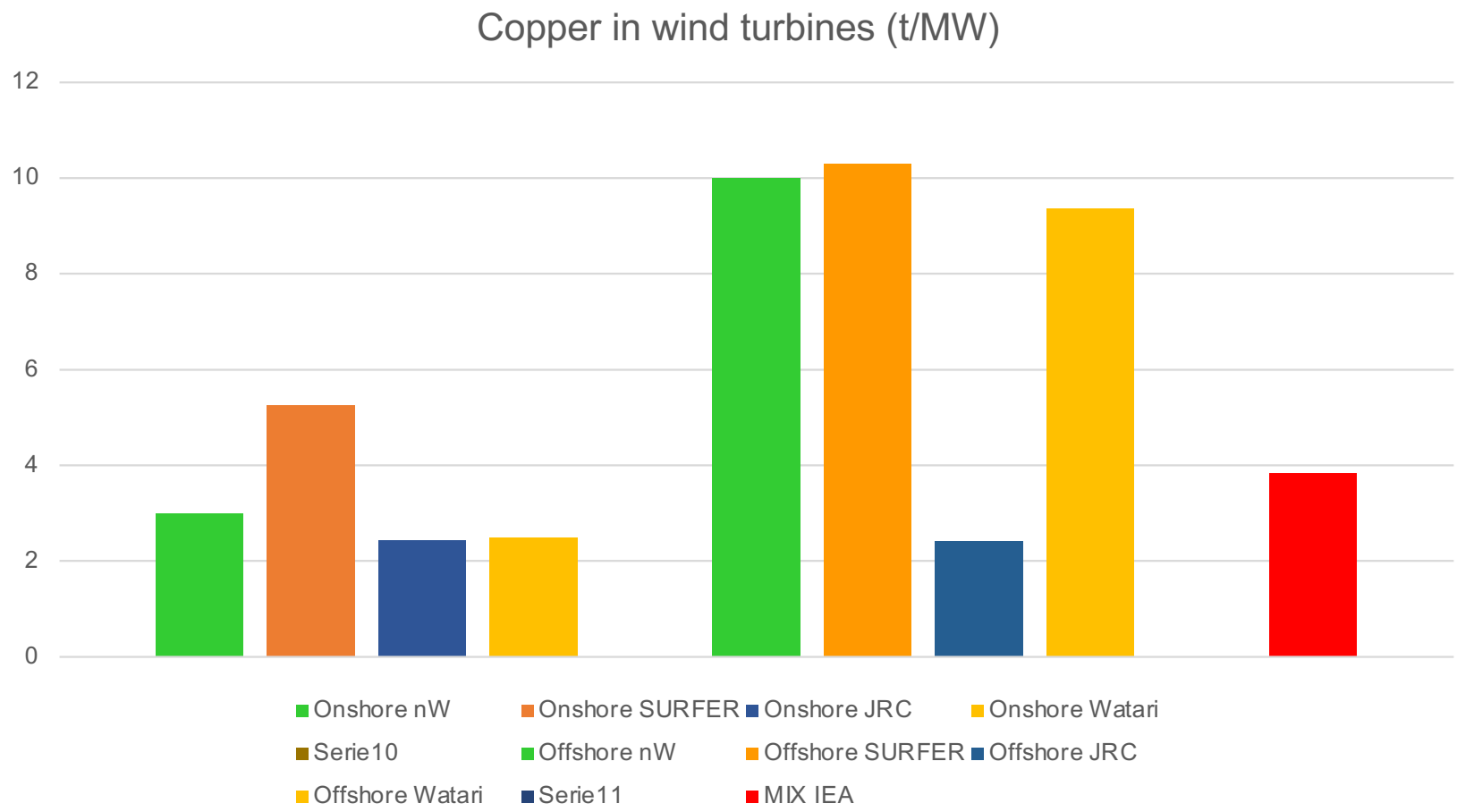


FULL BEV = 100% Battery Electric Véhicules
MIX = part of hybrid with biogas
SIZE = Adjust car size with use
SUF = sufficiency

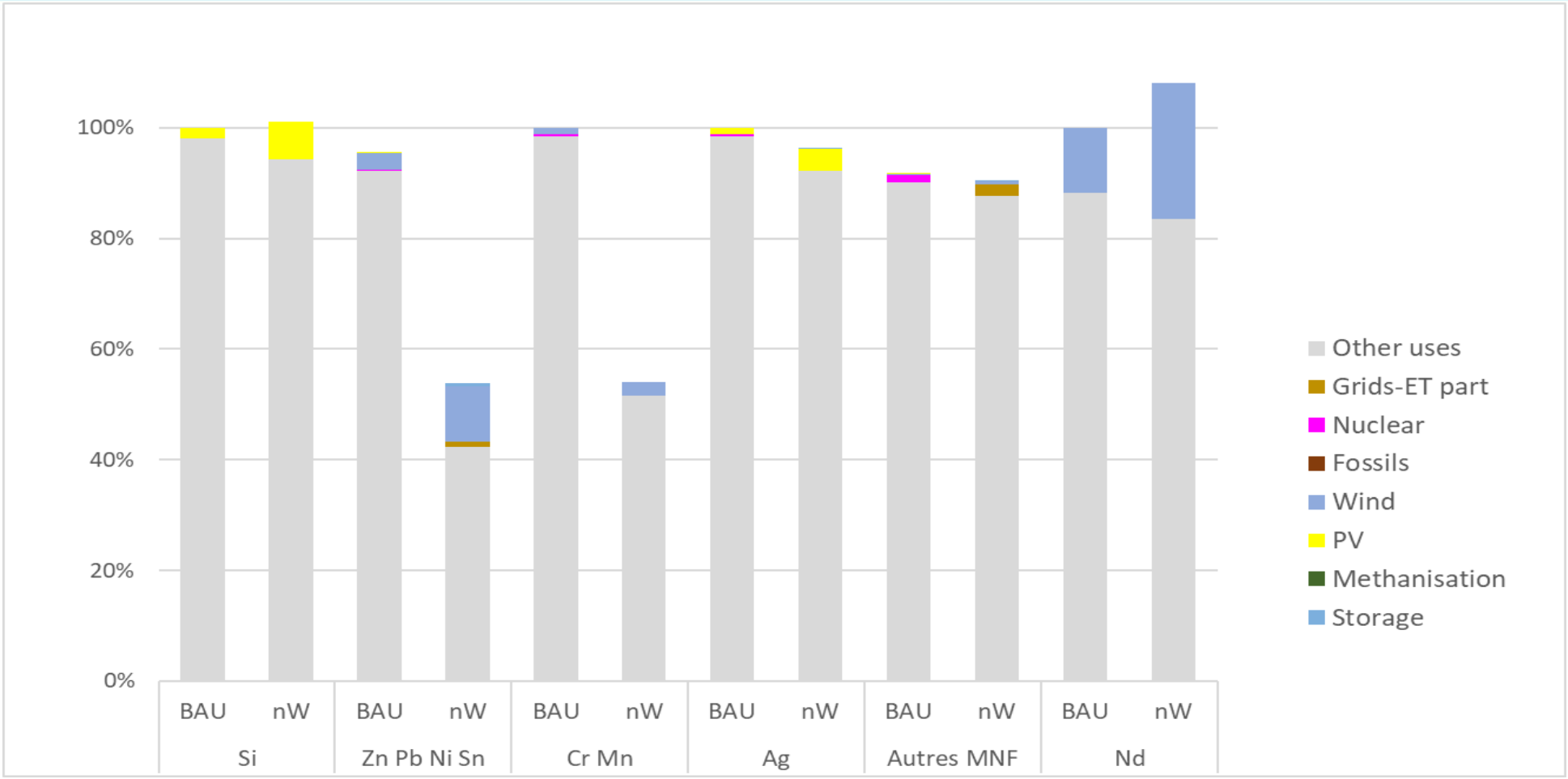

We have only one planet :
Save it …
Thank you for your kind attention…

ADDITIONAL SLIDES FOR A POSSIBLE WORKSHOP

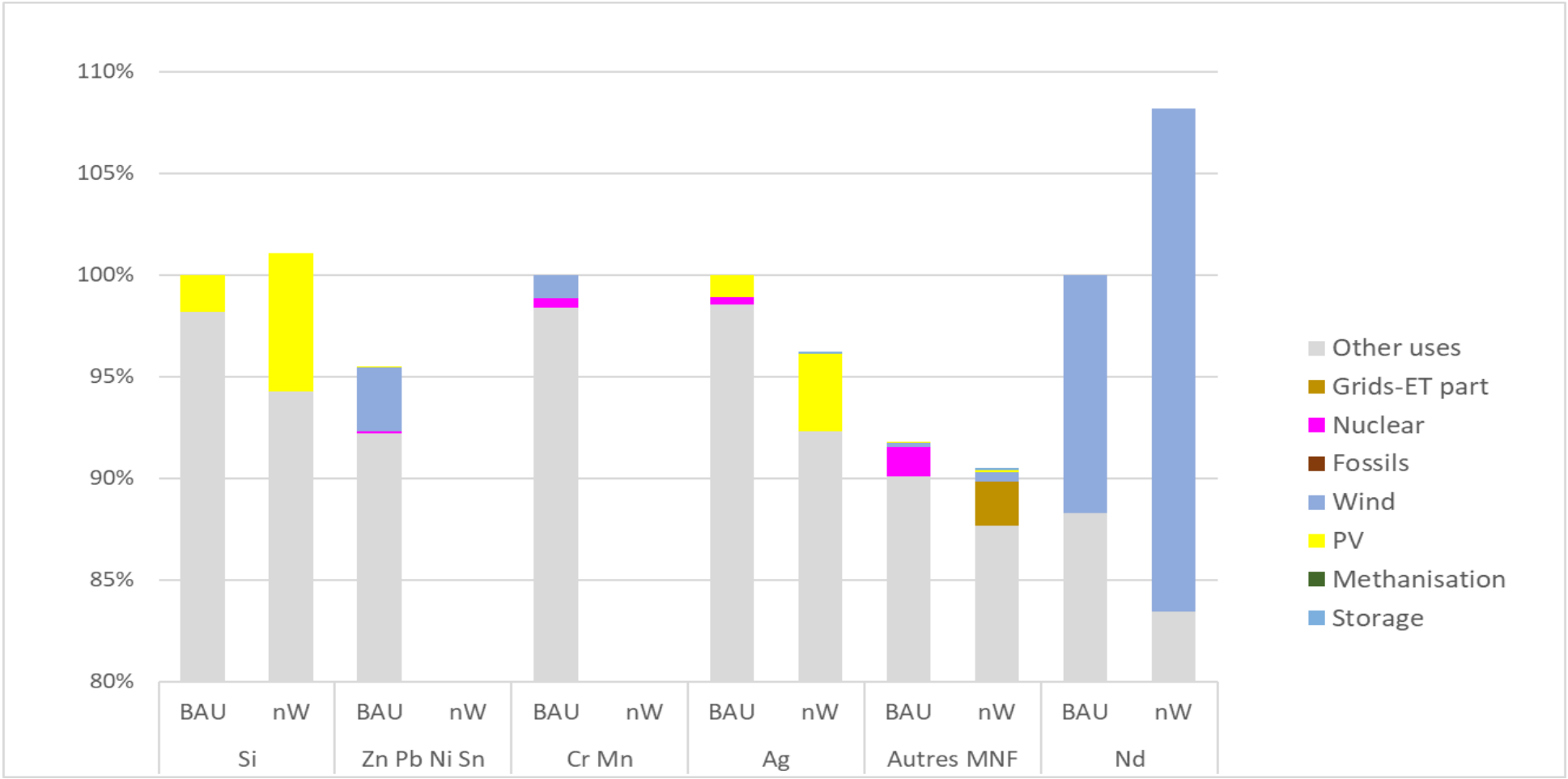
Sources comparison



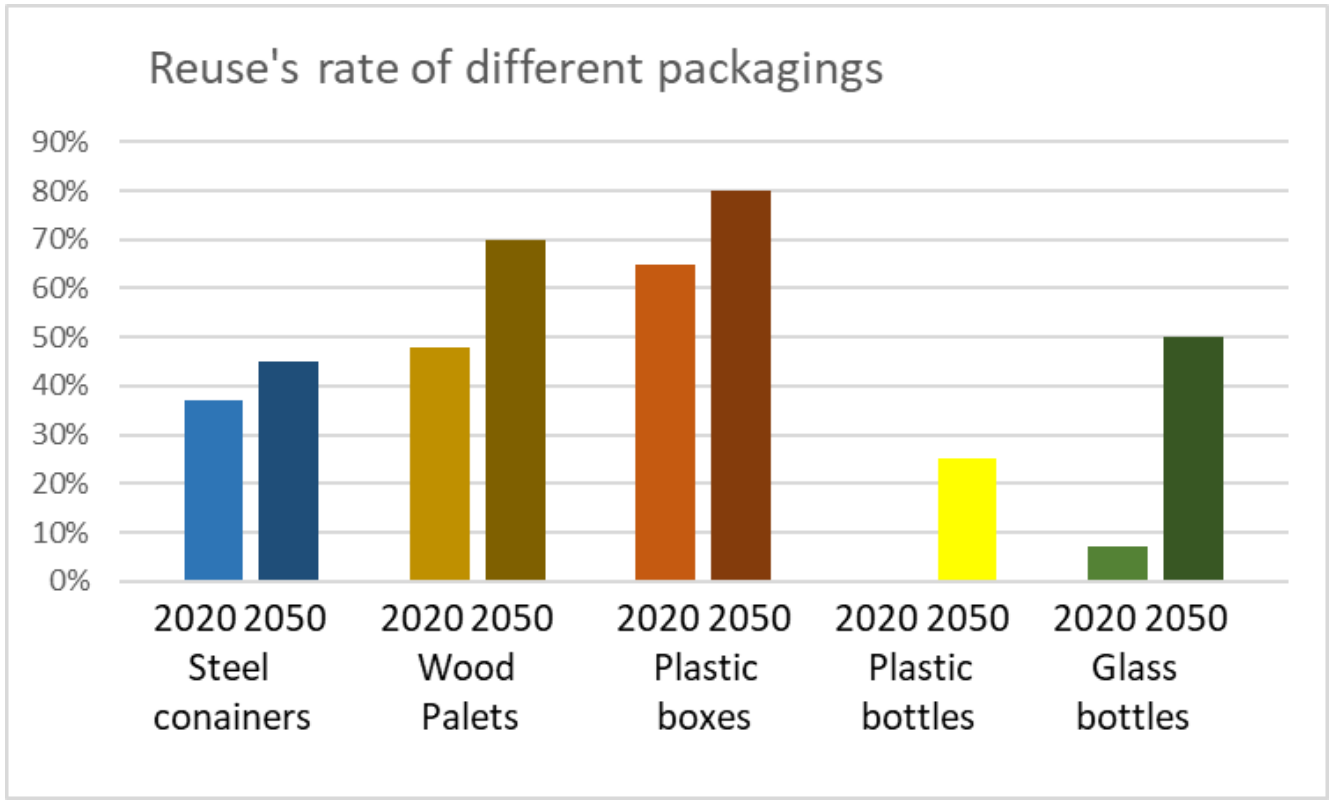
Example 1: Materials and energetical transition

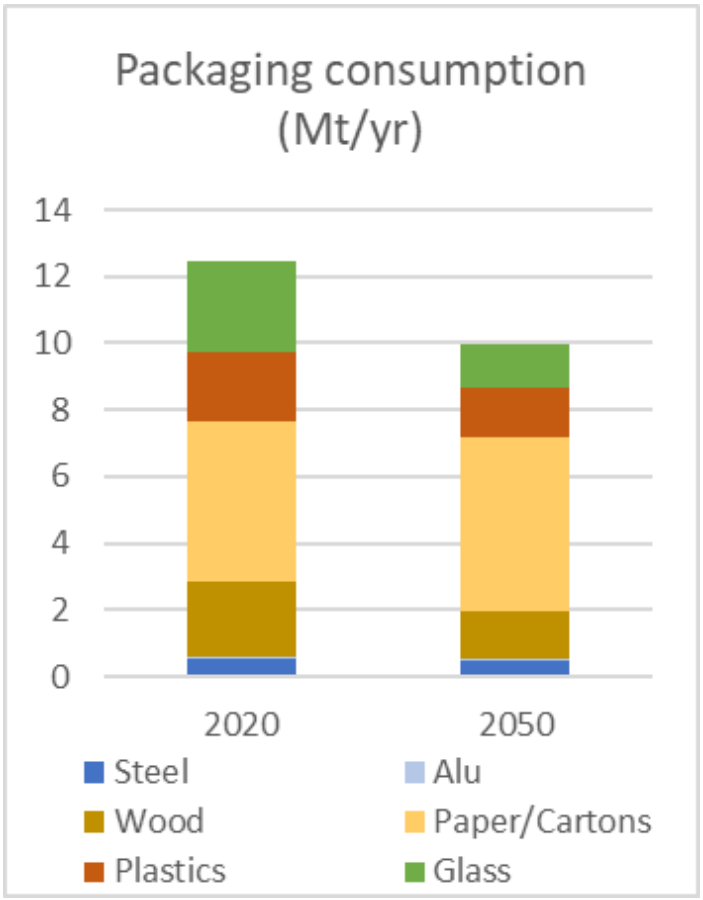


Example 1: Materials and energetical transition

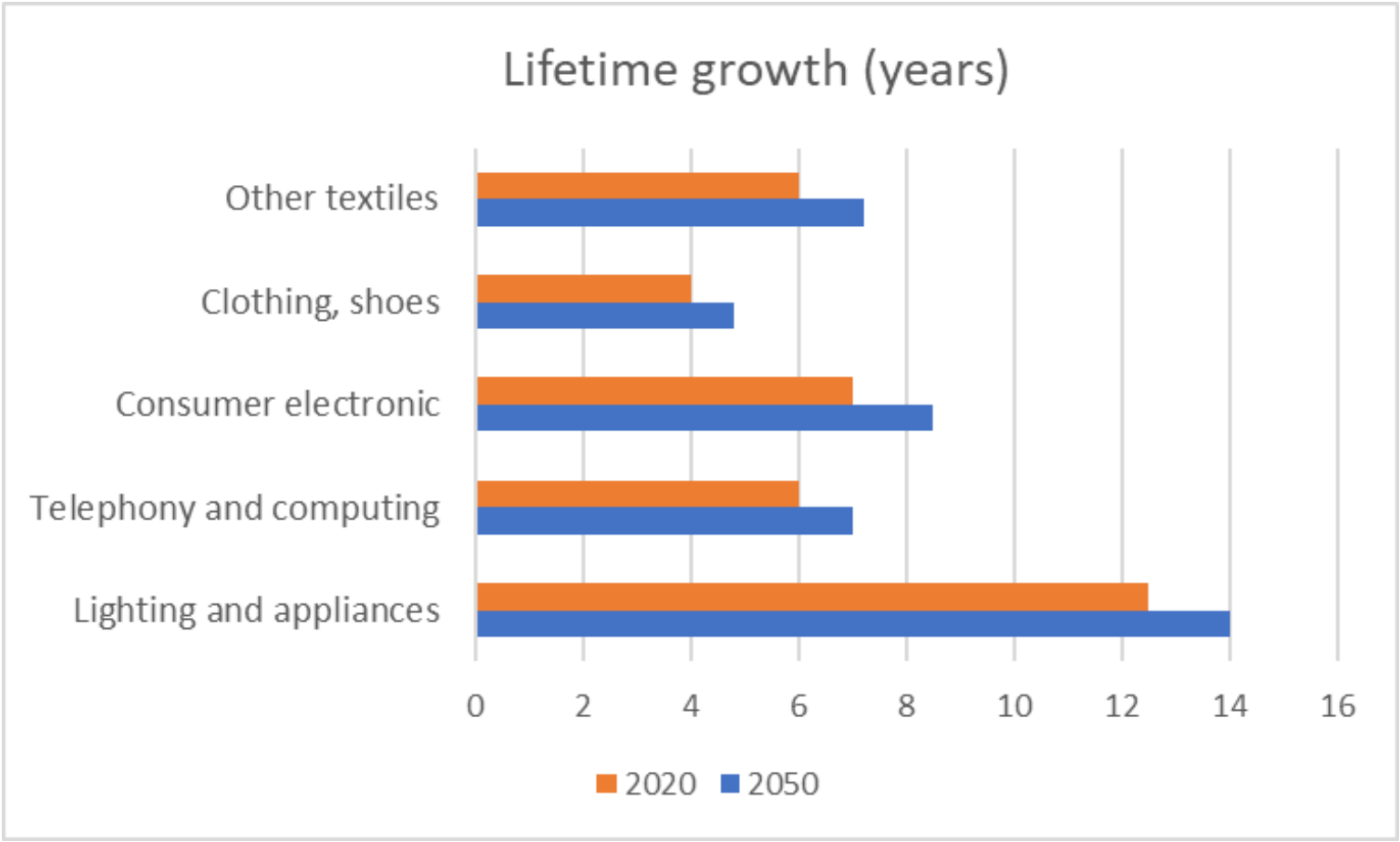


Reuse for packaging

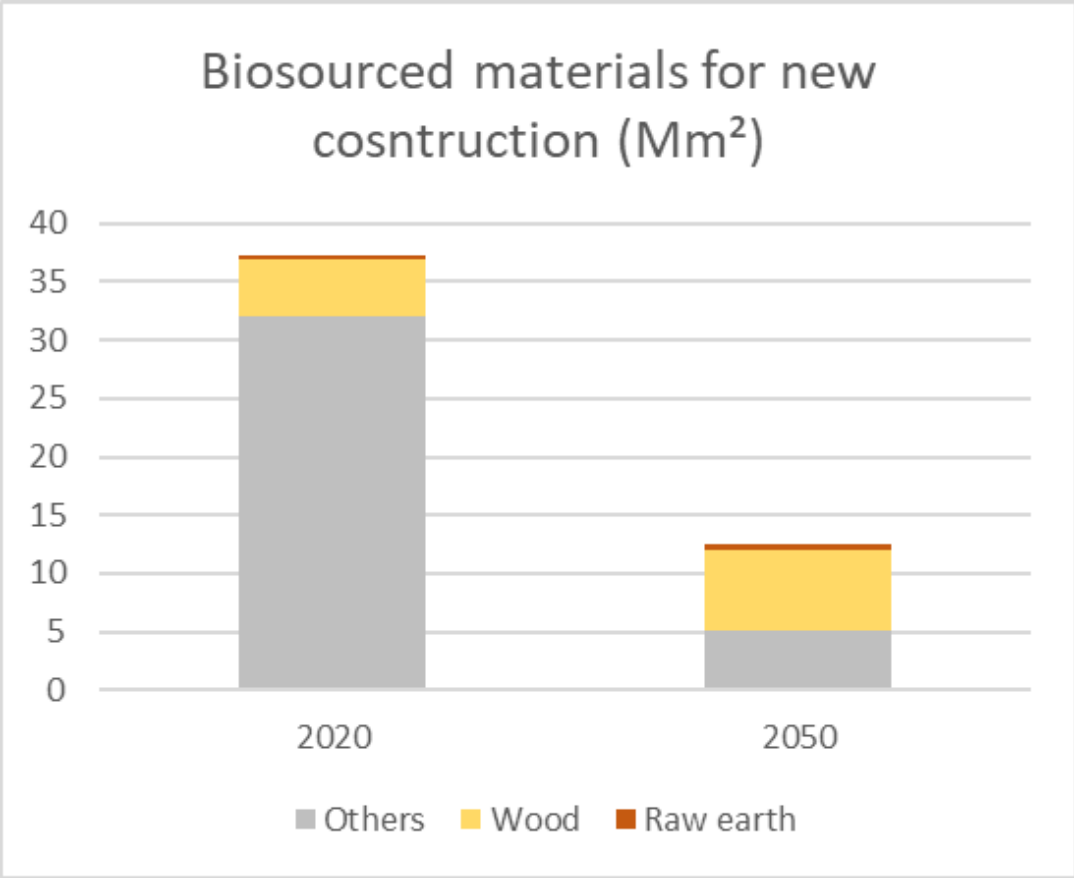


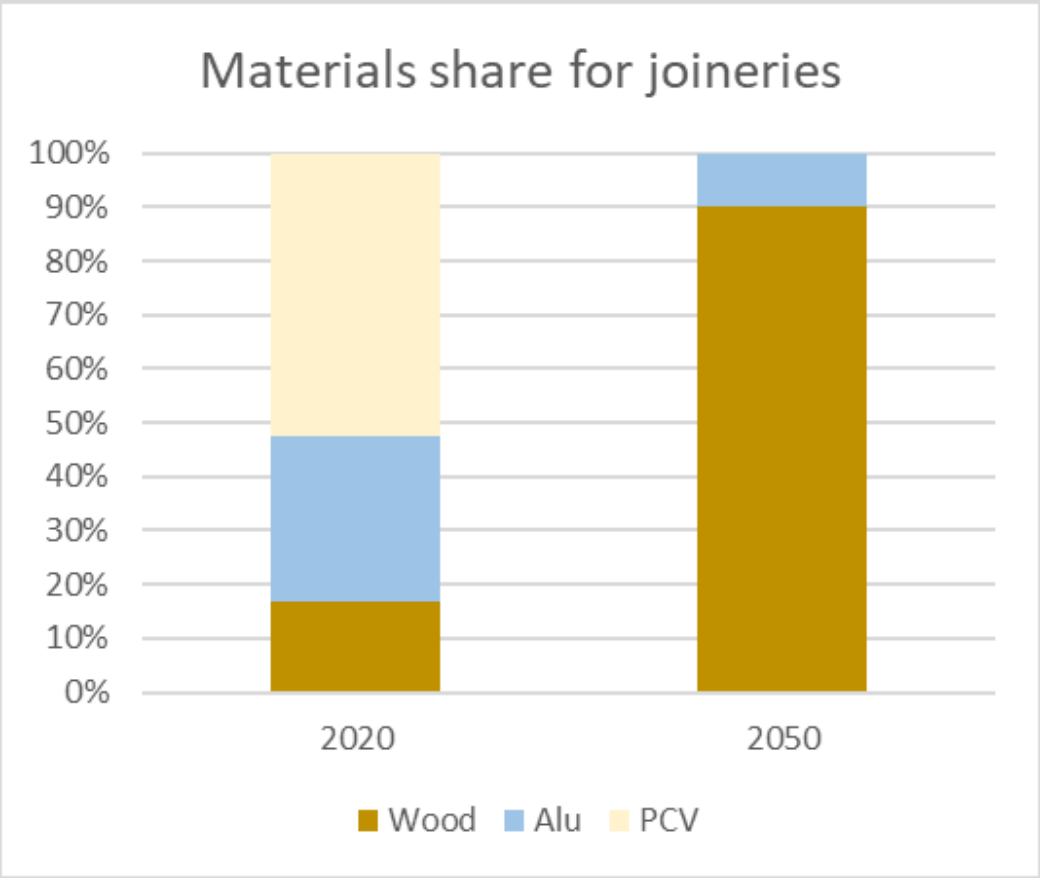


Lifetime growth

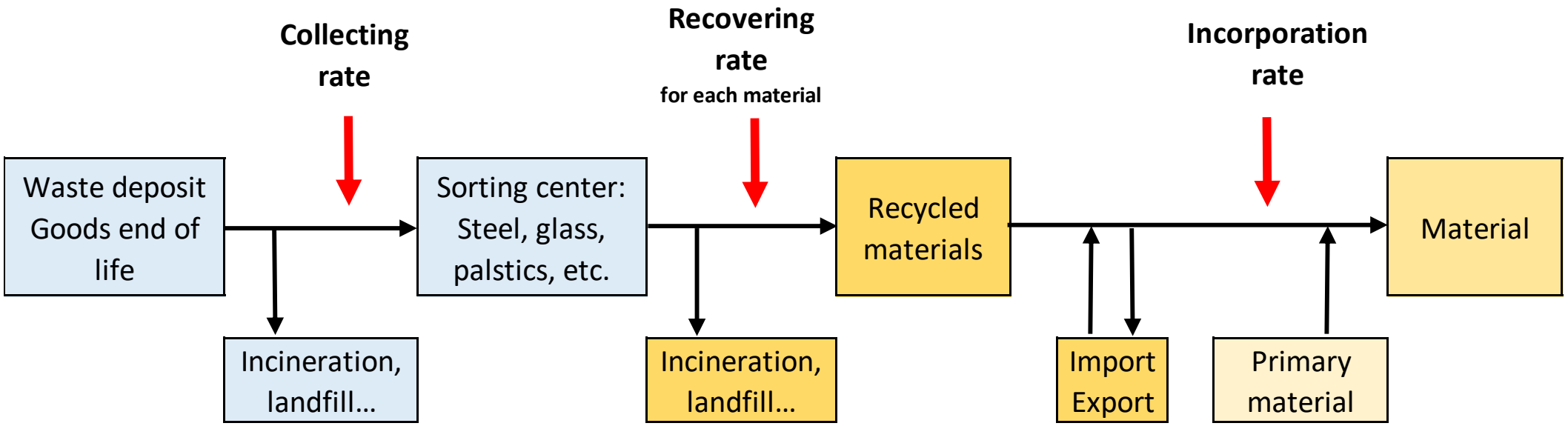


Biosourced materials for buildings





Step 4: recycling materials



Example of plastics

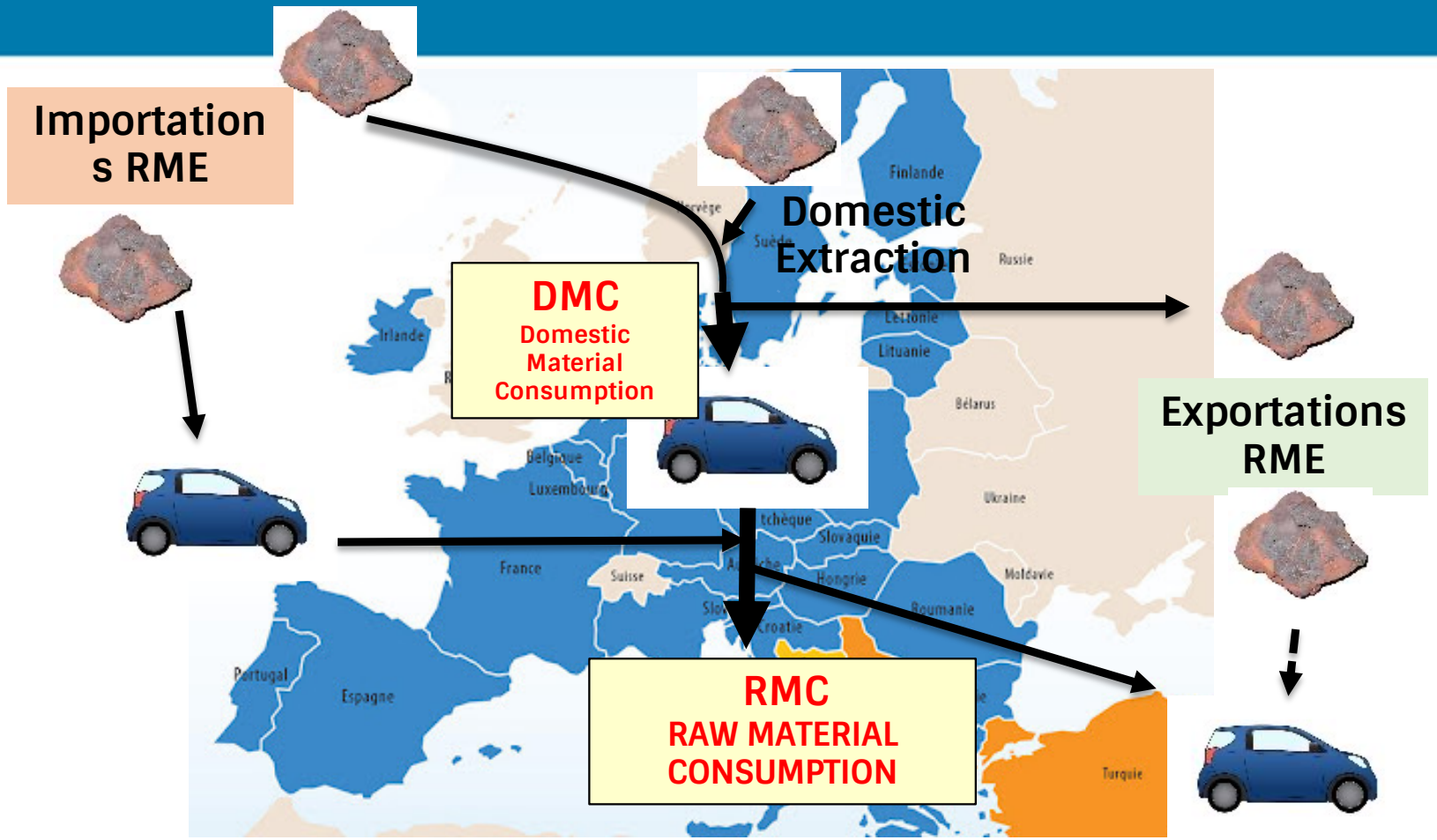
Mt 2014	Global waste	Collect rate	Collected for recycl.	Embodied Plastics	Recover rate	RPM
SUM				**3,104**		**0,712**
Mechanicals EEE	5,215	**72%**	3,773	0,584	18%	0,104
Others	3,849	**18%**	0,682	0,225	14%	0,032
Packaging	2,060	**35%**	0,711	0,695	52%	0,363
Transports	4,954	**95%**	4,706	0,450	12%	0,055
Buildings	222,327	**46%**	102,24	1,150	14%	0,158

	RPM
SUM	**0,712**
Export	0,339
Prod RPM	0,373
Prod plastics	5,476
Incorpo RPM	7%

Mt 2050	Global waste	Collect rate	Collected for recycl.	Embodied Plastics	Recover rate	RPM
SUM				**3,956**		**2,606**
Mechanicals EEE	4,792	**87%**	4,167	0,650	57%	0,372
Others	4,485	**80%**	3,588	1,353	55%	0,741
Packaging	1,515	**80%**	1,212	1,186	85%	1,010
Transports	2,746	**100%**	2,746	0,265	67%	0,176
Buildings	109,950	**57%**	62,78	0,503	61%	0,306

	RPM
SUM	**2,606**
Export	0,244
Prod RPM	2,362
Prod plastics	5,050
Incorpo RPM	47%

What is material footprint ?



What will be the quota for France / Europe?

What scenario do we envisage for the future?

Typical scenario SSP1

SSP1: strong international cooperation **prioritising sustainable development**, population stabilised in 2050

Typical SSP3 scenario

SSP3: fragmented world affected by competition between countries, **slow economic growth**, and policies oriented towards security and industrial production with little concern for the environment

Response from the negaWatt scenario:

In an egalitarian world, France / Europe is entitled to a percentage of the reserve proportional to its population

Example for copper:	Million Inhabitants	%Pop	Res Mt Copper
World population	7 000	100%	770 Mt
France	70	1%	1%*770 Mt = 7.7 Mt
EU28	500	7%	7%*770 Mt = 55 Mt

Current or predicted proven reserve?

Example for copper:

Typology	Description	e.g. Copper
Proven reserve	Proven and cost-effective technology	770 Mt*.
Possible reserve	Geologically identified, technically possible but may not be economically feasible	2,720 Mt
Ultimate Resource	Geologically identified but technically and economically uncertain	5,600 Mt

In 1996, the proven reserve was 310 Mt, in 2011, 690 Mt

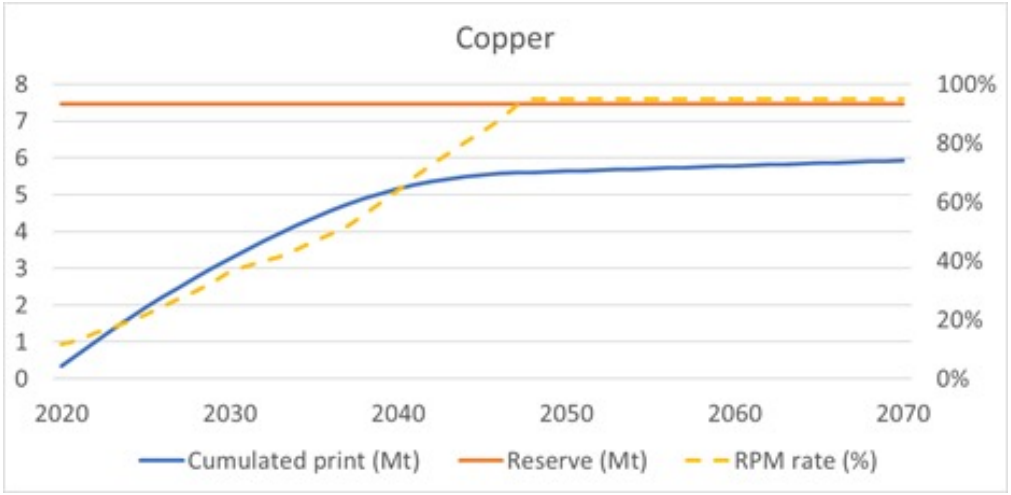
Questions:

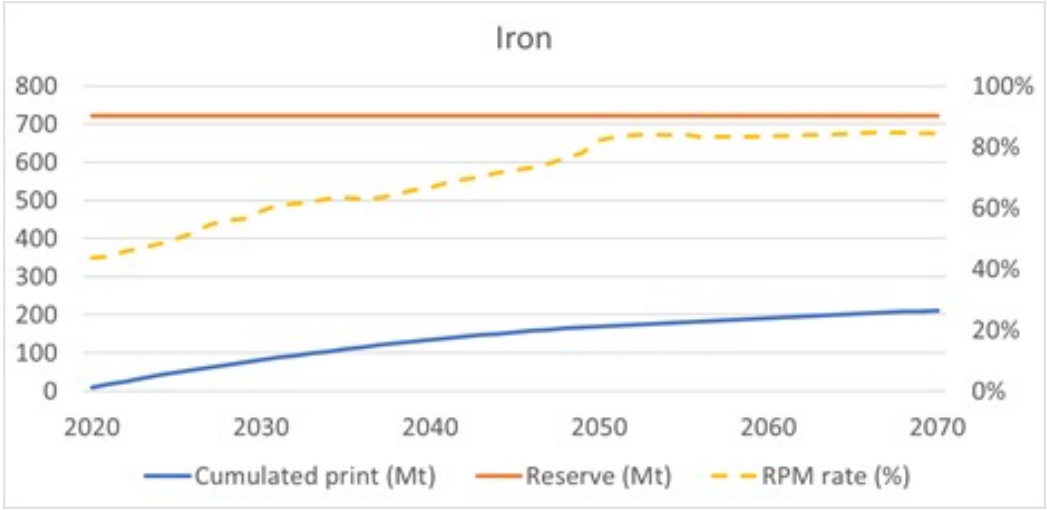
- ✓ What is a profitable mine in 2050?
- ✓ What about the environment? Is that what we want?

Response from the negaWatt scenario:
We limit ourselves to the current proven reserve and do not try to open new mines

Two examples for current materials

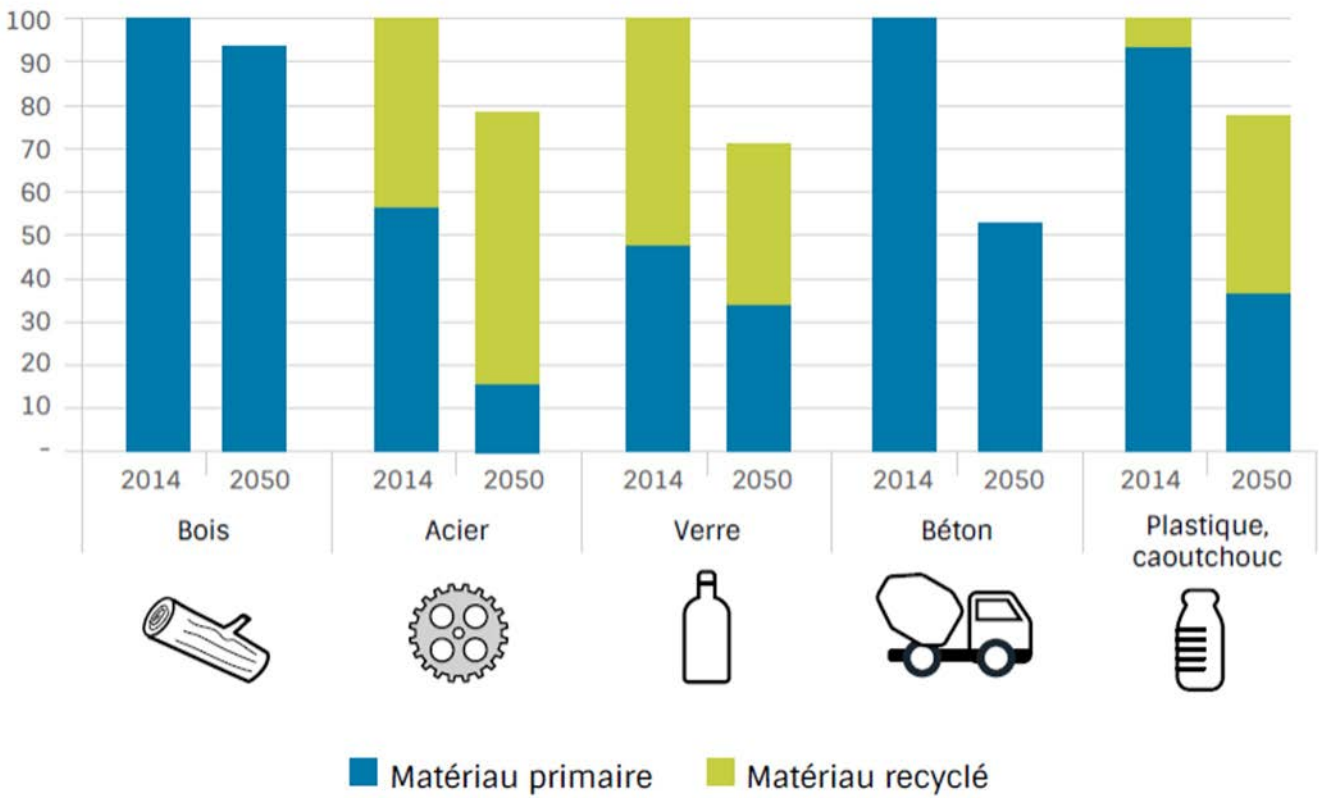
Iron: high recycling and decreasing demand,
Copper: high recycling, necessary efficiency and substitution by alumina





Primary materials decreasing consumption

Evolution de la consommation de matériaux primaires et recyclés



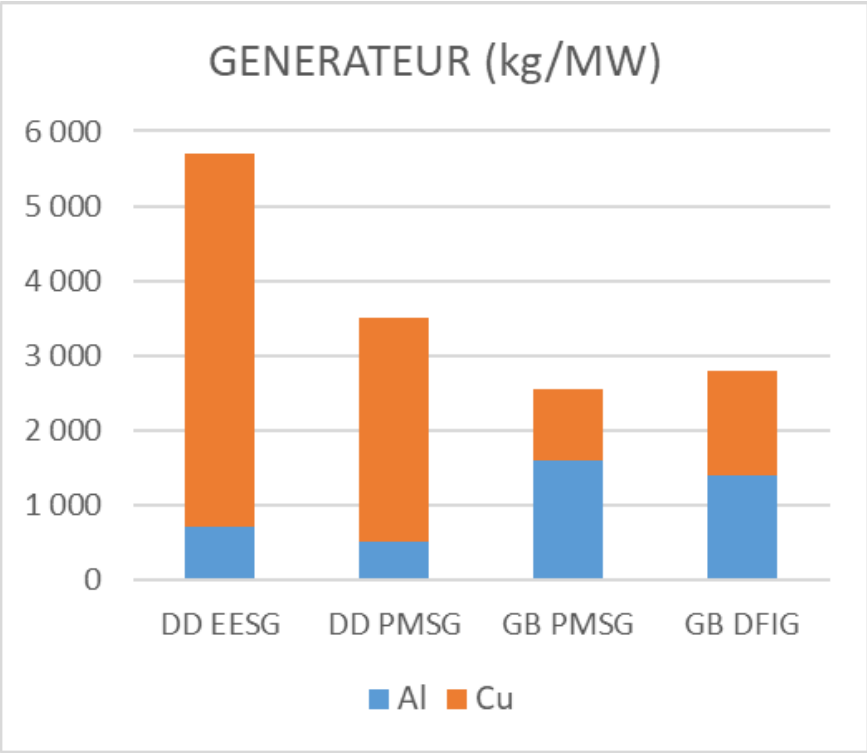
Various technologies for wind turbines

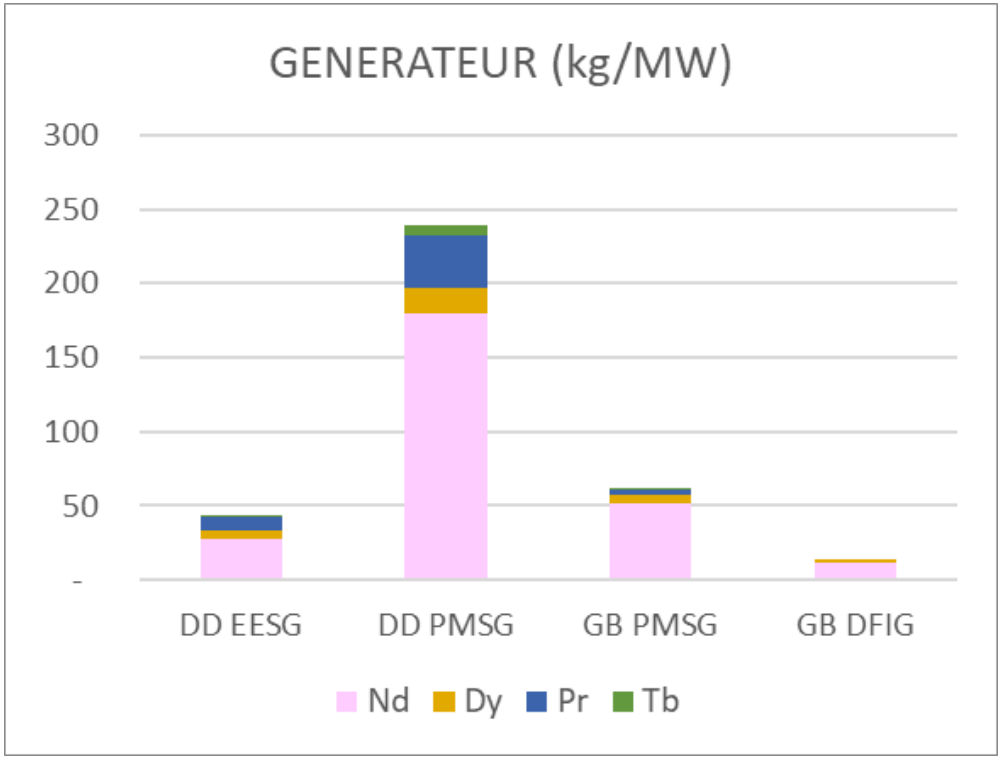
		Terrestre	Offshore
Foundations		embase poids	gravity base
		colonnes balastées	monopile
		Rigid inclusions	tripod
		piles	gravity weak twinge
		mixt	jacket
		composites	floting TLP
			floating semiisub
			floating spar
Tower		Steel, concrete	Steel
Nacelle			
Generator	Gear box	GB DFIG Asynchrone induction	
		GB SCIG Synchrone	
		GB PMSG Synchrone	
	Direct driving	DD EESG Synchrone	
		DD PMSG	
		DD HTS Supraconductors	
Transformer			
Cables			
Sub station			

Materials amount depends strongly on technology

- Foundations and tower : almost steel and concrete
- Generator : metals and copper.
- Network and connecting : copper and alu

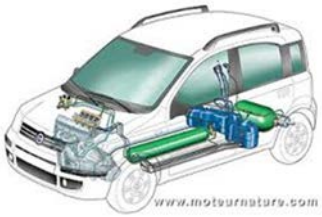
Wind turbines : The generators





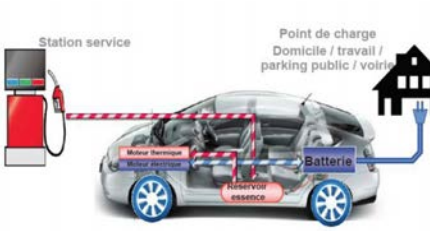
What will replace fossil fuel car ?

Fossil fuel car



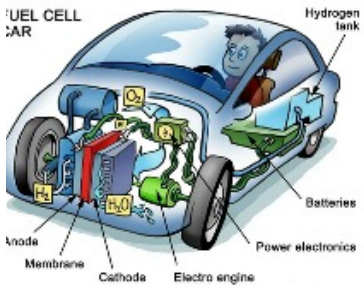
Bio NGV Bio Natural gas Vehicle

HEV Hybrid Electric Vehicle



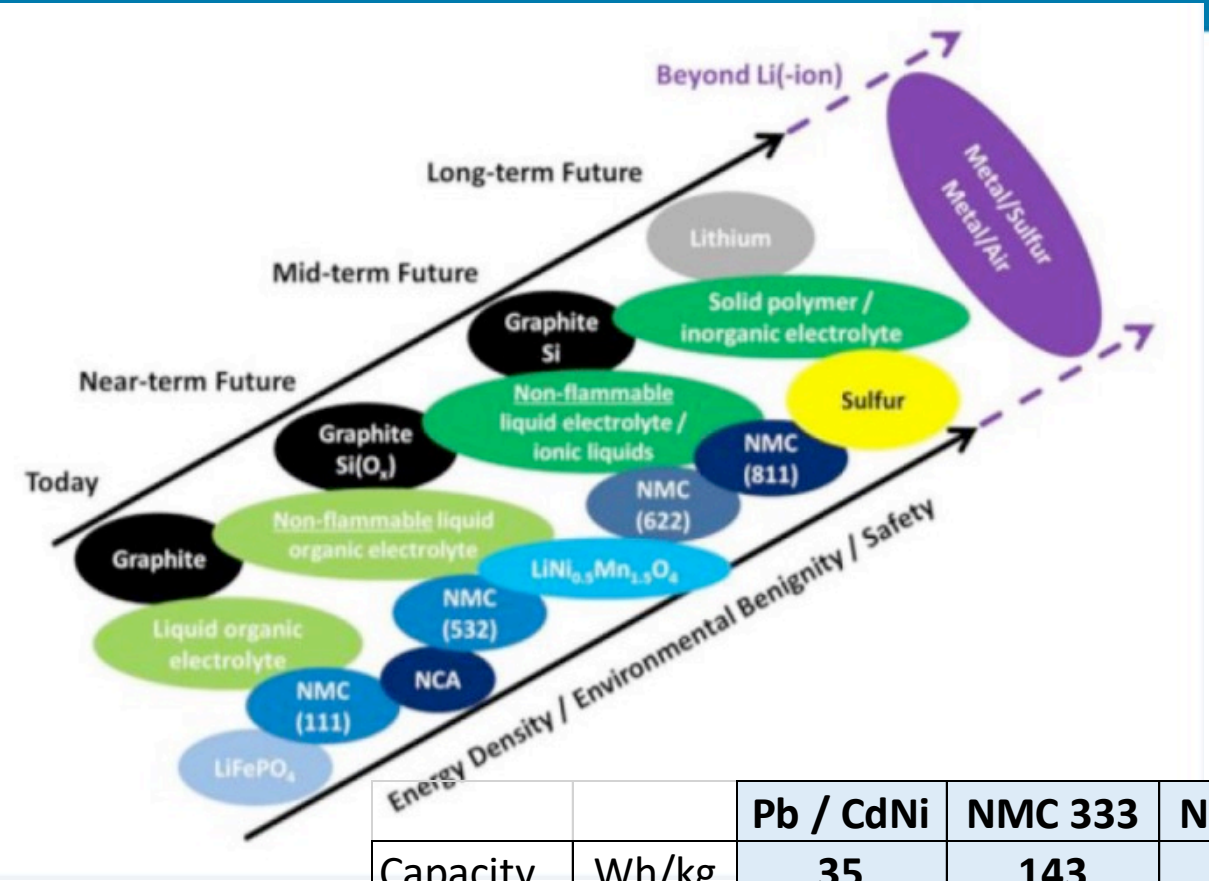
PHEV Plug In Hybrid Electric Vehicle

BEV Battery Electric Vehicle



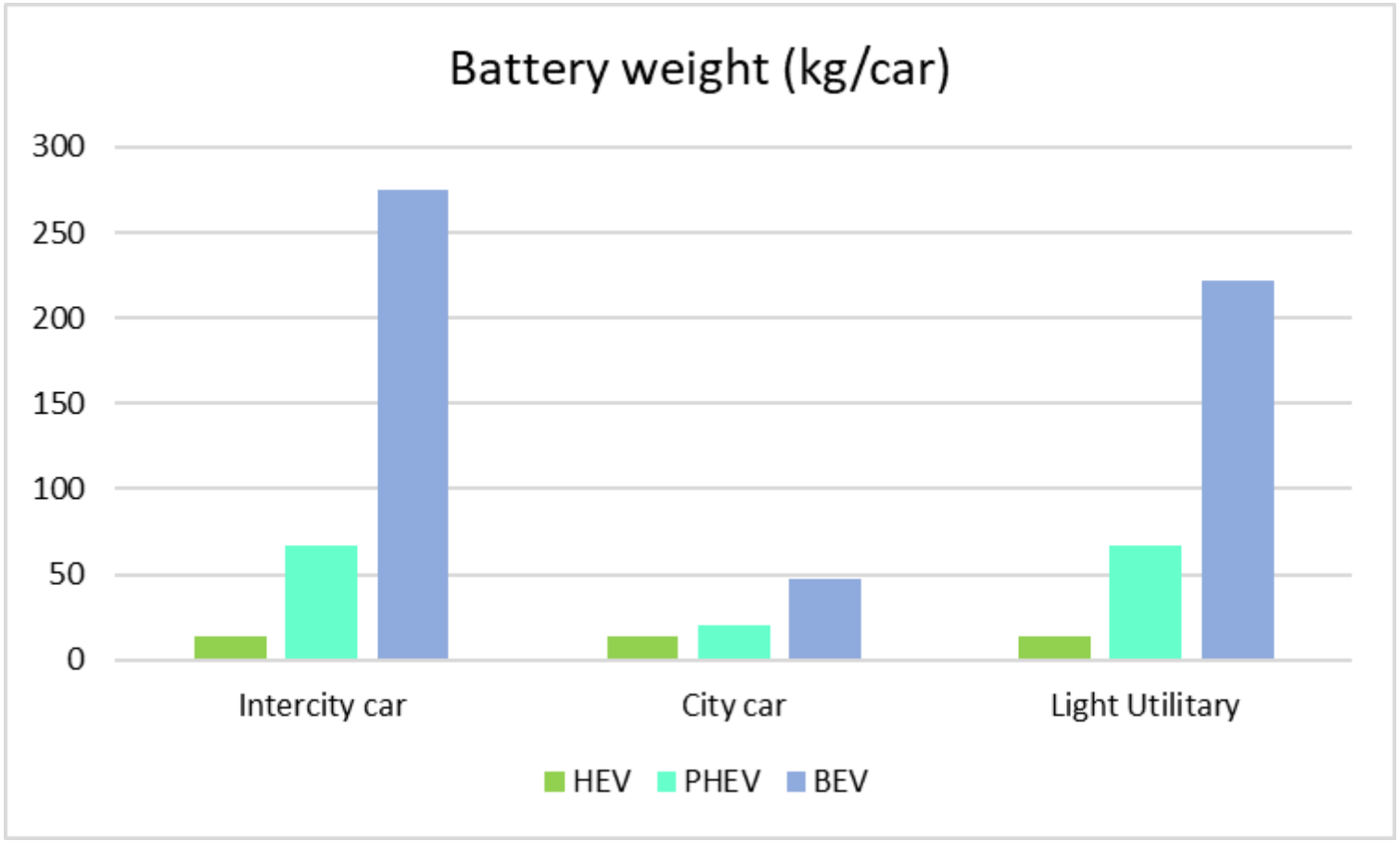
H2V Hydrogen Vehicle

What kind of battery for the future ?

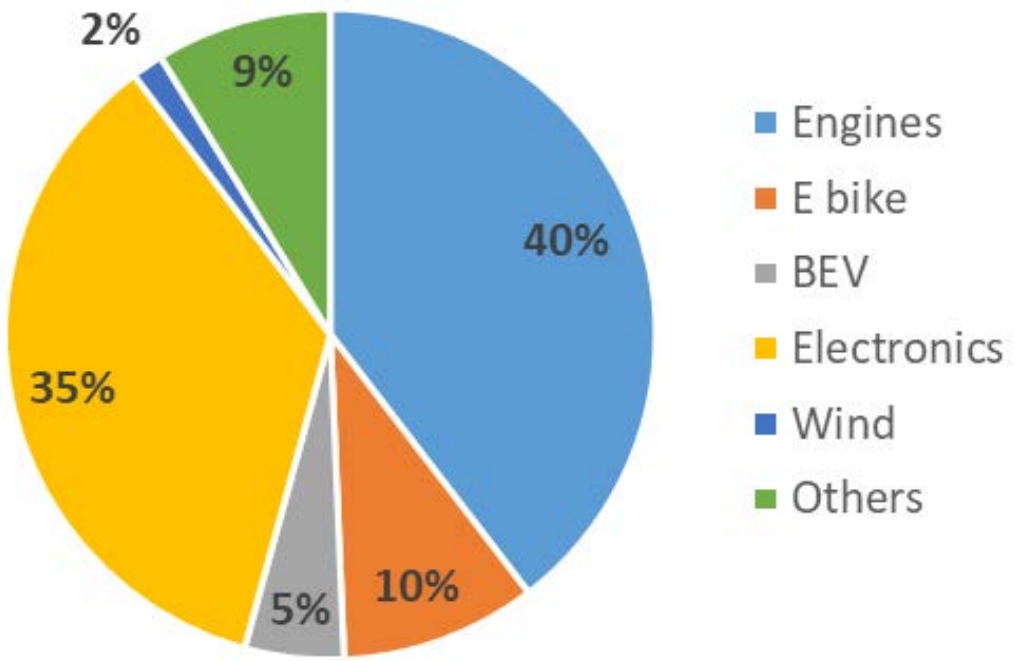


		Pb / CdNi	NMC 333	NMC 811	LFP
Capacity	Wh/kg	35	143	149	116
Lithium	kg/kg	-	2,50%	2,10%	1,50%
Cobalt	kg/kg	-	6,60%	1,50%	-

Type of vehicle comparison



Metals and rare earths



Worldwide permanent magnets USES by 2019

SnW France 2070

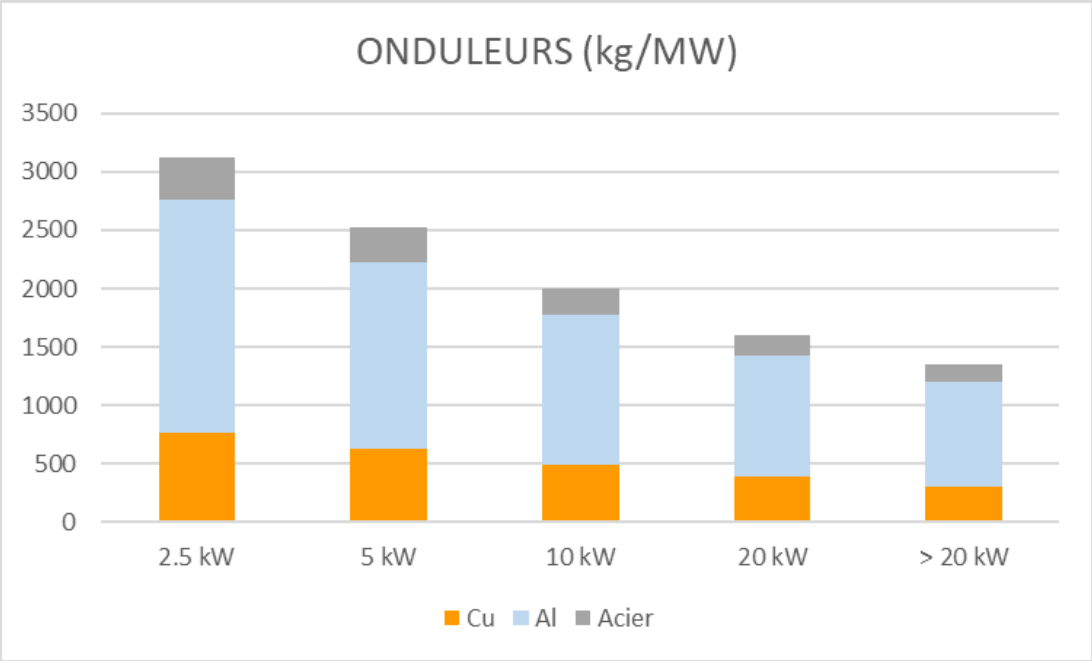
Onsshore wind turbines :
90% with no permanent magnets

Offshore wind turbines
Néodyme 6% of reserve
Dysprosium 3% of reserve

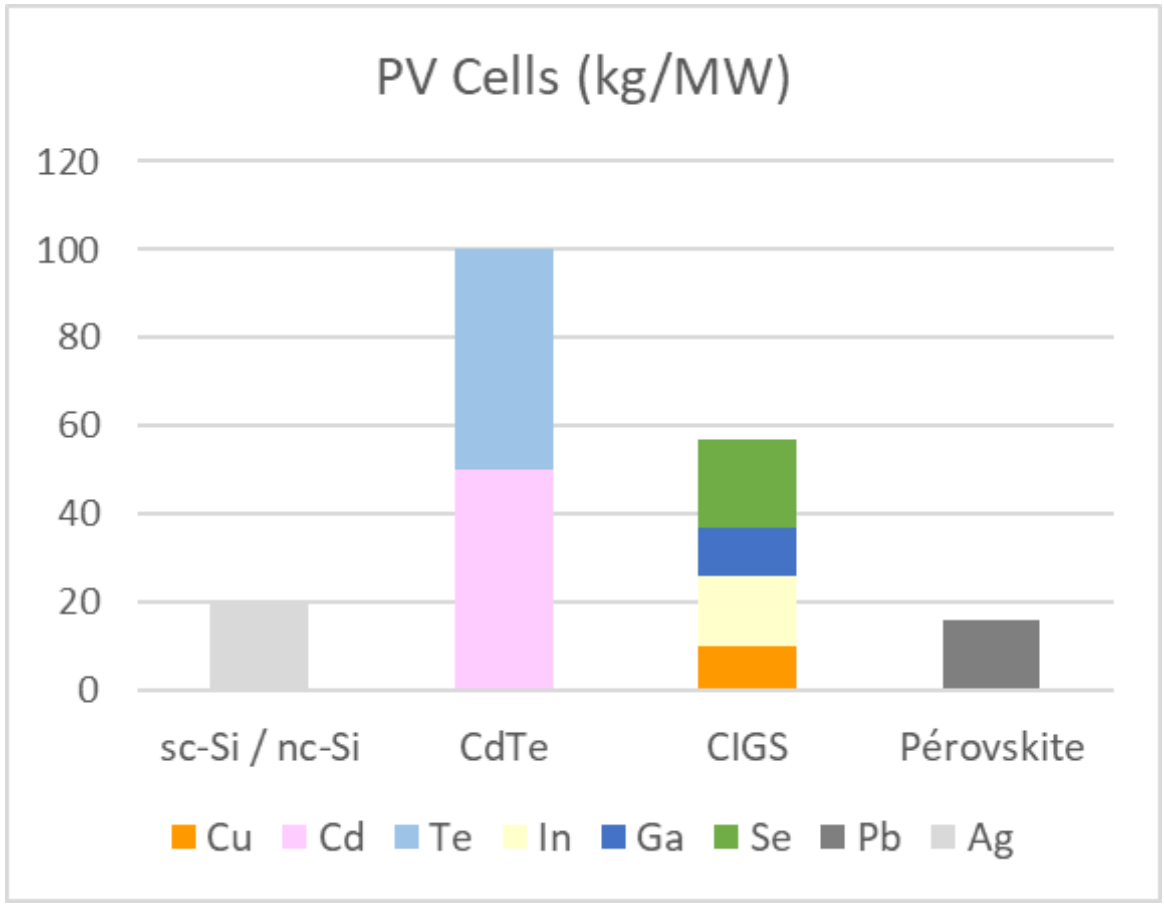
Photovoltaic 100% sillicon
No rare earth
Silver 6% of the reserve

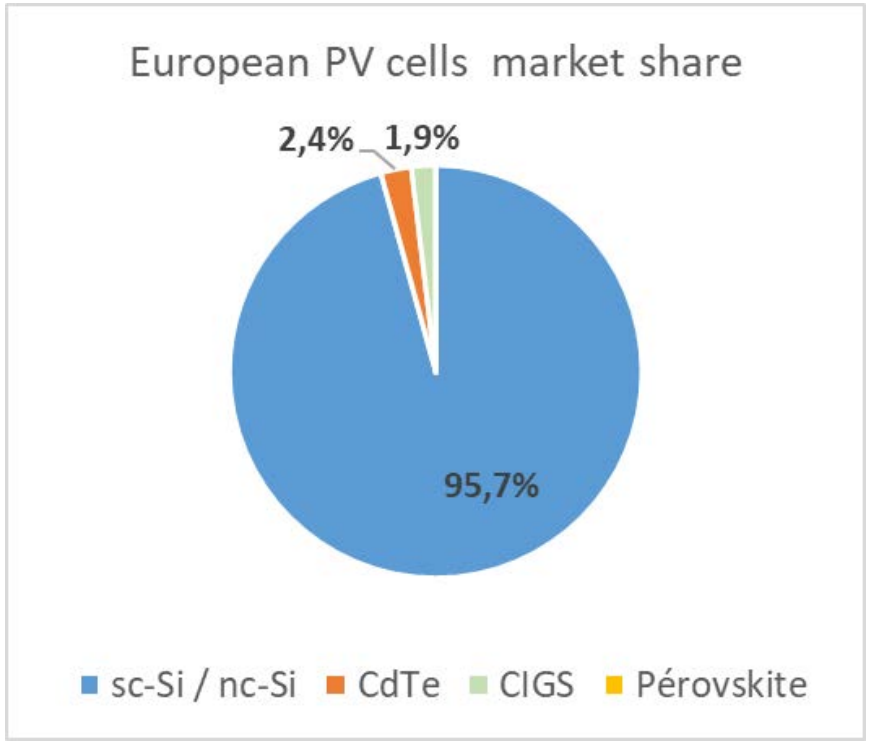
PV : The size inxidence

	Ground	Roof
CELS	Mono sc-Si	
	Poly mc-Si	
	CdTe	
	CIGS	
	Perovskite	
SUPPORT		Static
		Tracker 1
		Tracker 2
INVERTER	2,5 kW	
	5 kW	
	10 kW	
	20 kW	
	> 20 kW	

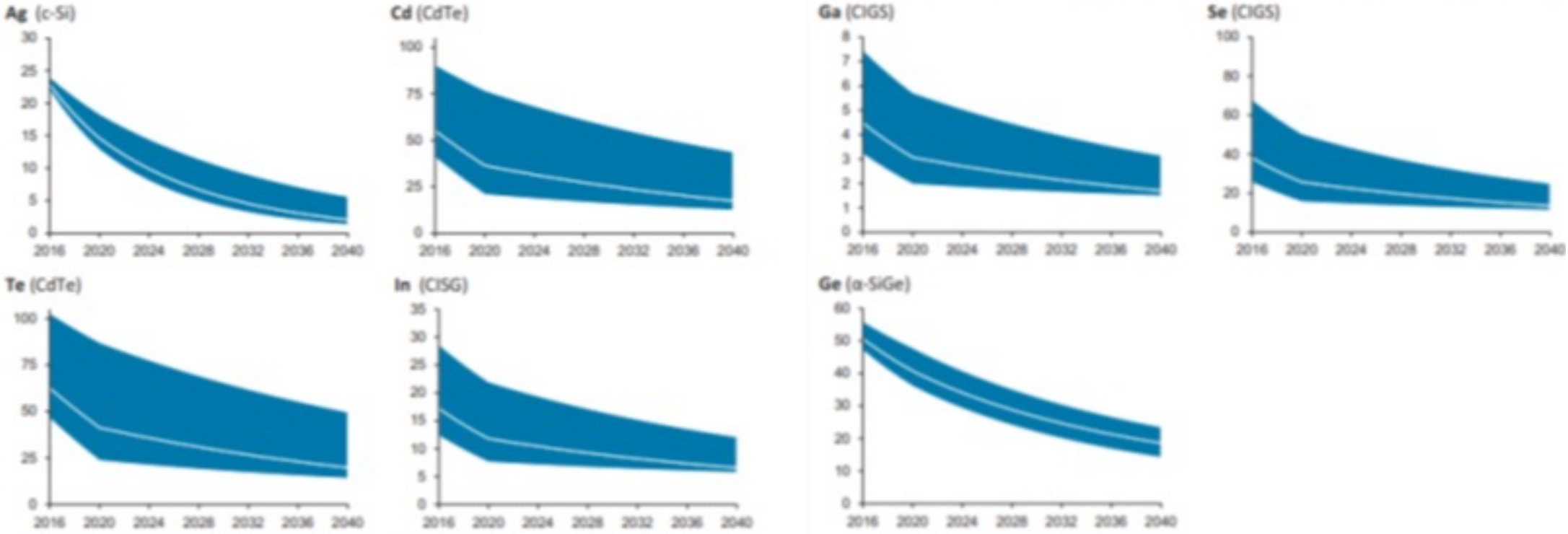


PV : huge majority of silica technology





Decreasing rates for many materials



Example 1: Materials for renewable energies and grids