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**EXPLORONS  
LES POSSIBLES**

Pour une **Transition Énergétique  
Soutenable et Économique**

“Critical” minerals and the ecological transitions in Europe and the global south.  
Supply chains, policies, & markets seen from the social sciences

Brussels, 10/04-05/2023

ANTLIA: ANTicipation of Lithium Amount for the energy transition  
Insight for a methodological approach for the construction of critical minerals  
modelling and delivering scenarios

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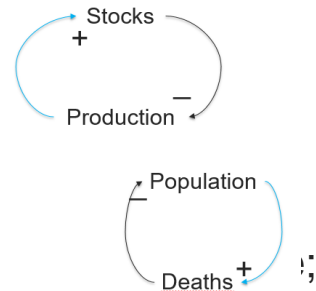
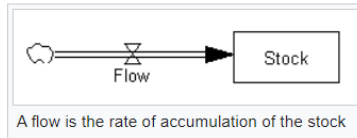
# System Dynamics (SD) or Complex System Dynamics

## Methodological insights

Both an approach and a visual modelling technique to represent and to understand complex systems over time.

It uses:

- stocks,
- flows,
- internal feedback loops,
- table functions
- time delays



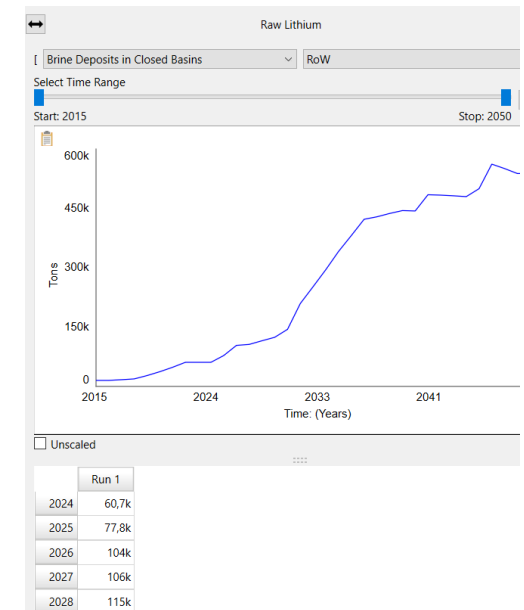
And obtains:

- dynamic simulation results

To understand the factors that create or

To help better understanding phenomenon and their causes.

Ex. The physical availability of critical materials based on growing demands.





Both an approach and a modelling technique to represent and to understand complex systems over time.

Originally used in a managerial perspective (50', MIT, J. Forrester), it is well known for being the based-model technique used for the Meadow's Report *The Limits to Growth* in 1972, actualized in 2004 (Model World3).

Sverdrup H.U (Univ. of Iceland) develops models for the global cycle of minerals for economic uses. (Li in 2016).

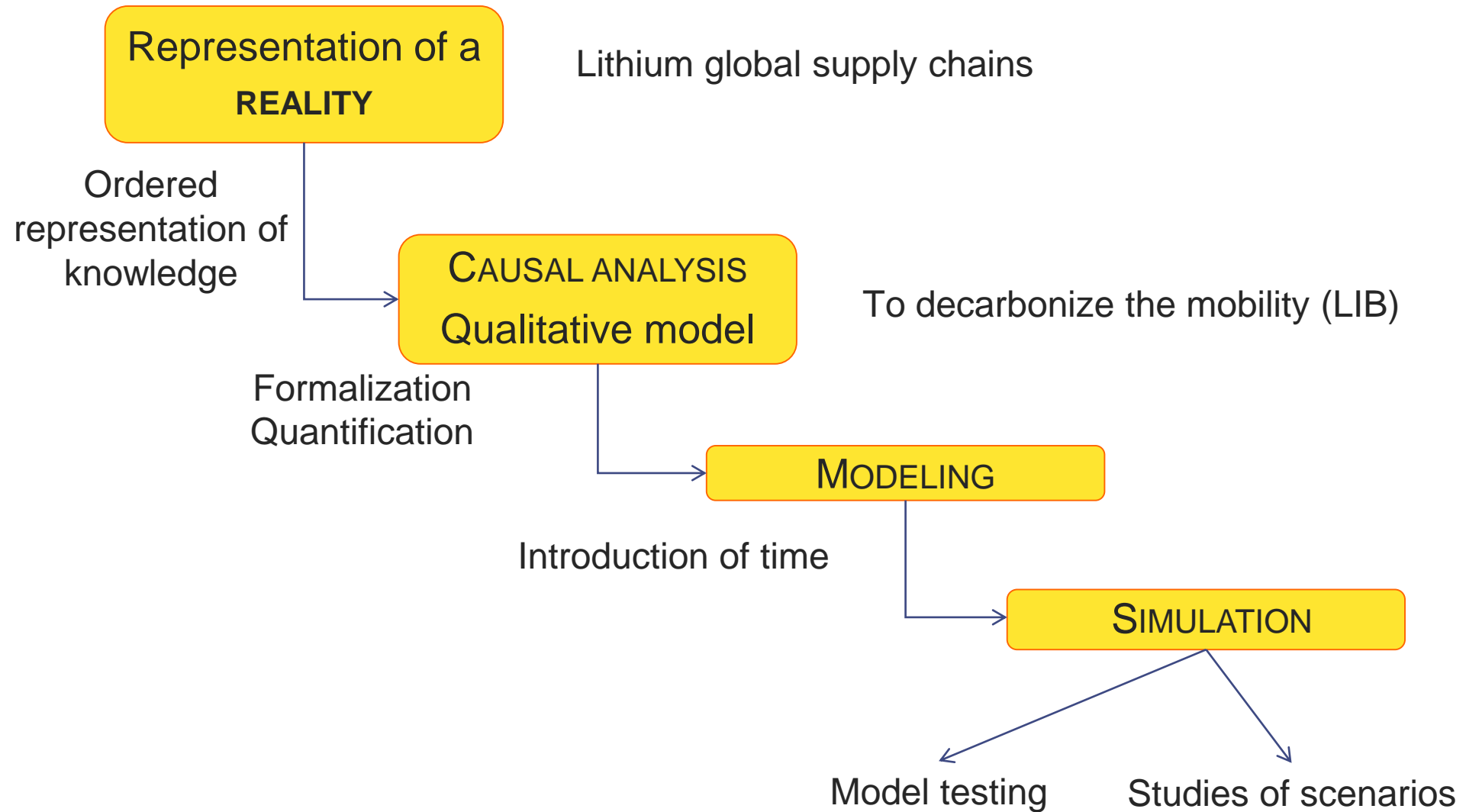
The model POLES - Prospective Outlook on Long term Energy Systems (P. Criqui, CNRS) : economic analysis of energy-climate policies. POLES is used and developed by Enerdata in collaboration with the European Commission's JRC IPTS and University of Grenoble-CNRS (GAEL).

O. Vidal (CNRS, ISTERre) focuses on the mineral resources-energy nexus in connection with the transition toward low-carbon energy, and the dynamic modelling of reserve-production-recycling-demand-cost-price at the global scale on the long term. Ex. Carbon & Water cycles.

Nuclear sector (CEA): the GRUS Model: Gestion des Ressources en Uranium sous Environnement Stella.

To analyze the system's response to a demand for electricity as a function of certain parameters (physical, economical, etc.).

# The process and steps for modeling



# ANTLIA

**ANT**icipation of **LI**thium **A**mount for the energy transition

A lithium system dynamic modelling

- A **research project** DGALN/CEA
- One of the actions : to develop a **model in system dynamics** to bring elements of discussion for **public policies** on:
  - raw materials supplies;
  - sovereignty.

A value chain perspective: crossing global lithium-based energy transition policies (decarbonized mobility in particular) to offer methodological insights for the forecast of critical minerals through modelling and the constitution of resource intensive energy transition scenarios.

**2 scales:** World and Europe

**Timeline:** 2050 and over

**Approach:** stocks and flows

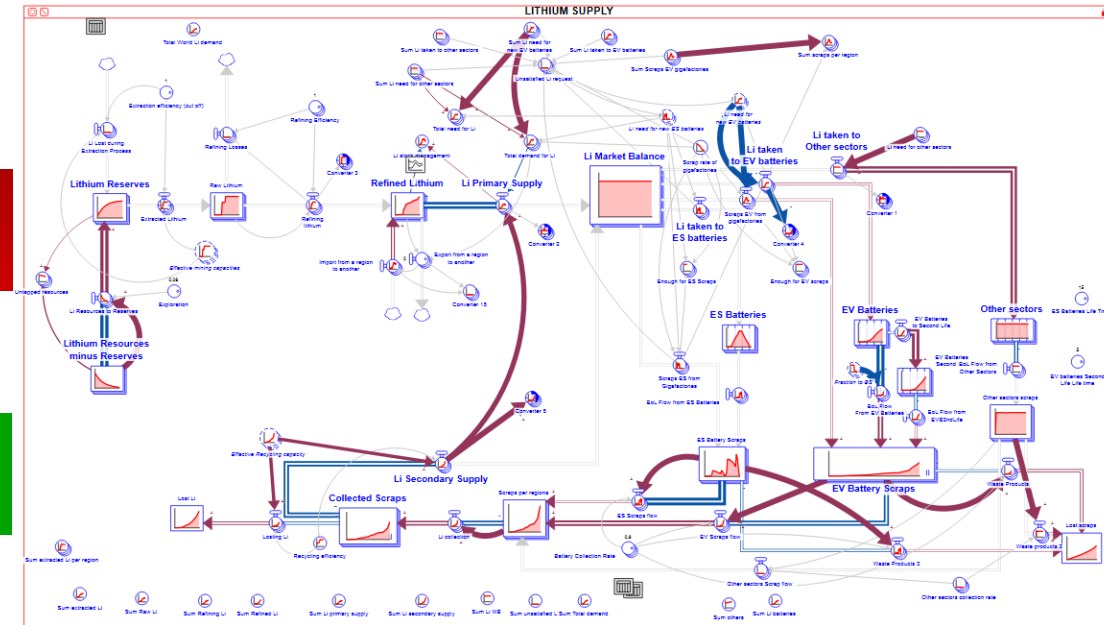
# 4 modules = value chains (stocks, flows, supply, demand)

Primary Supply: resources & mining capacities

Final uses : mobility, storage, other uses

Secondary Supply : waste, scraps and recycling capacities

Resource's demand : technologies, batteries



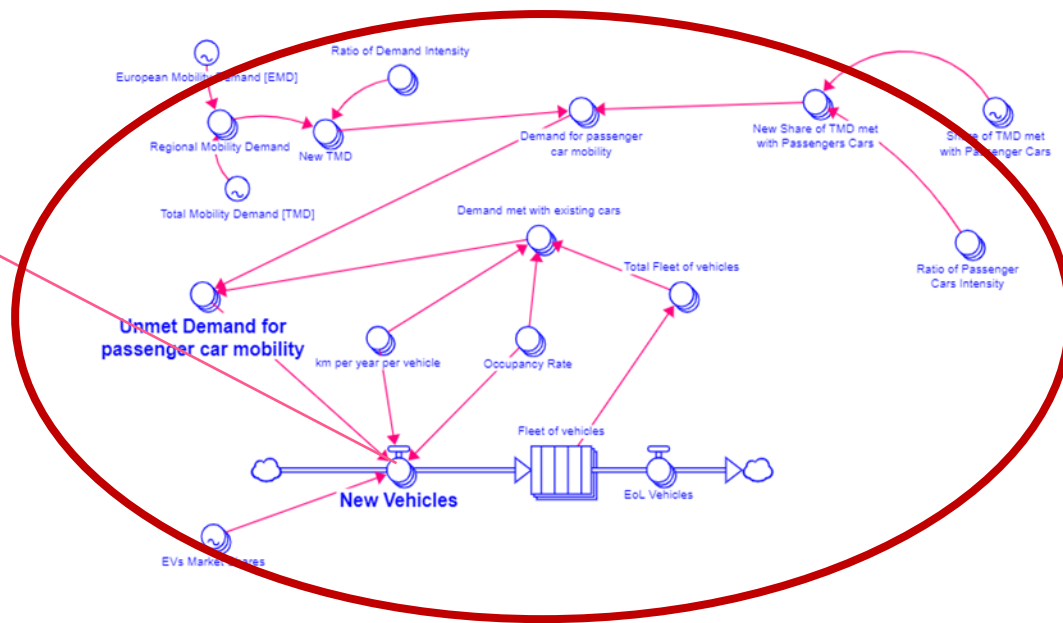
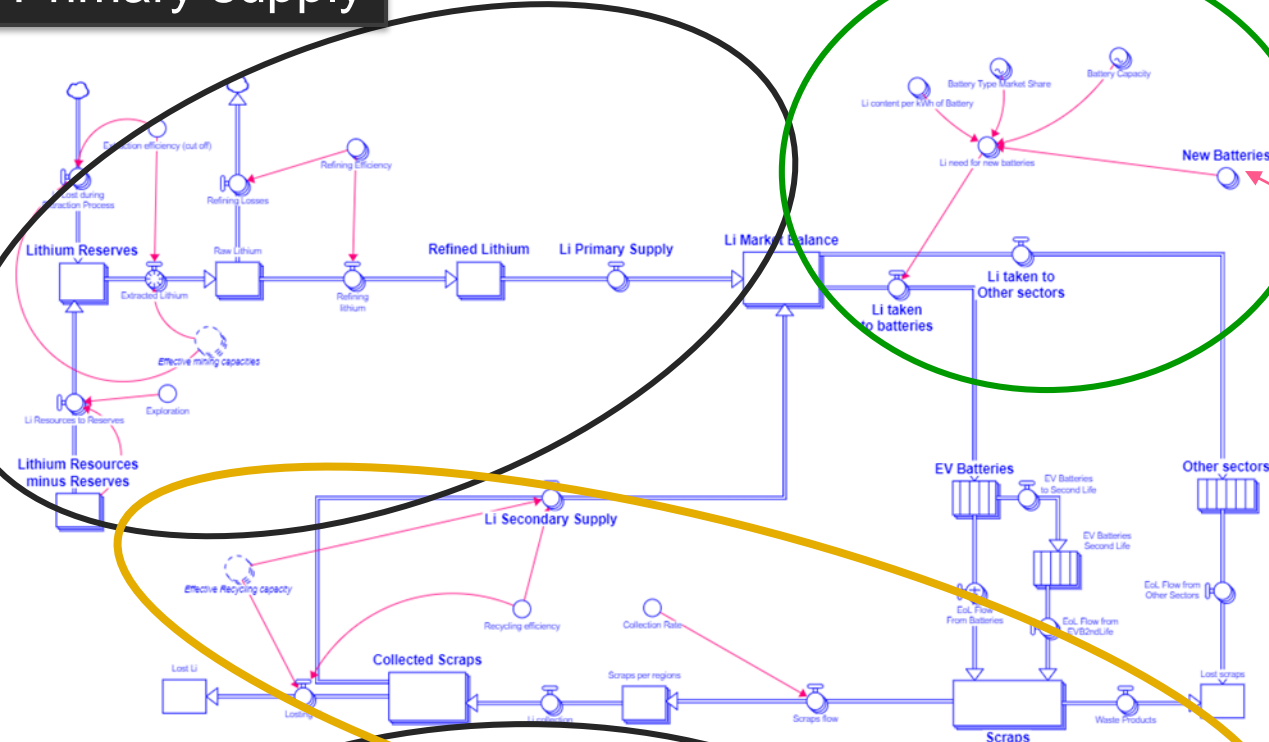
This modeling is based on a physical approach of the lithium chains (flows and stocks) with a relatively macroscopic granulometry in order to understand the phenomena and the levers that can be directly or indirectly derived from public policies.

# ANTLIA : 4 modules

## Li Demand

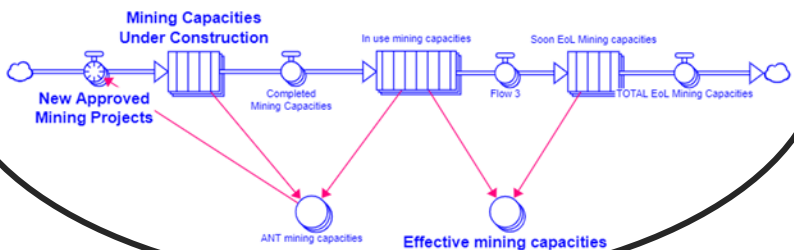
## Final uses

### Primary supply

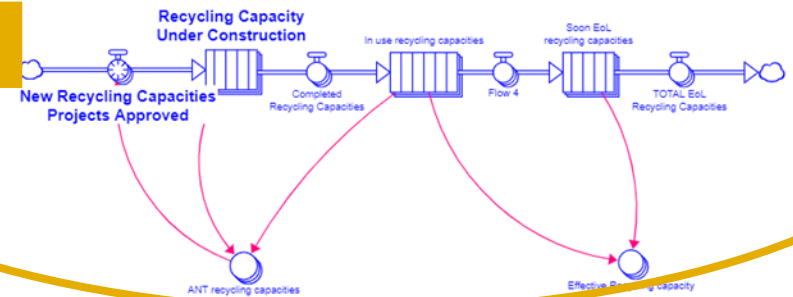


### Secondary supply

### Mining capacities

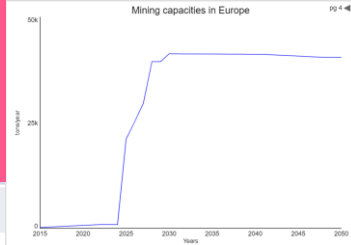


### Recycling capacities





Parameter	Source	Reference value
Current resources & reserves	CEA's expertise	
Existing mines		
Panned European mines		Opening according to announced projects
Mine opening time		
Extraction efficiency (cut off)		
Refining Efficiency		
Mine lifetime		25 years

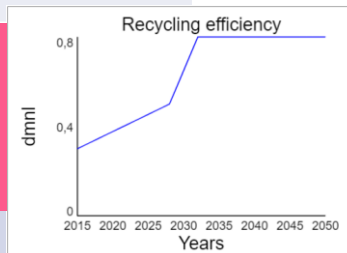


# Base case scenario

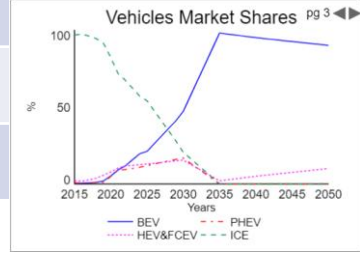
**Primary Offer: resources & mining capacities**      **Final uses : mobility, storage, other uses**

**Secondary offer : waste and recycling capacities**      **Resource's demand : technologies, batteries**

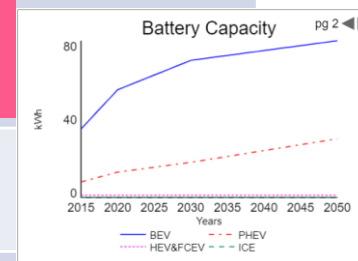
Parameter	Source	Reference value
Collecte rate of EV and ESS batteries	Battery directive	90 %
Waste collection rate for portable batteries and batteries for light-duty vehicles	Directive batteries	
Opening time of a recycling plant		
Recycling efficiency	Metals recovery rate from recycling (battery directive)	
Lifetime of recycling plants	CEA's expertise	25 years



Parameter	Source	Reference value
Demand for mobility in pkm	Recover Scenario OECD	
Share of passenger vehicles	Recover Scenario OECD	In 2015 ≈ 40% vs. In 2050 ≈ 30%
Vehicle occupancy rate	Recover Scenario OECD	
Km/vehicule/y	Recover Scenario OECD	
Vehicle lifetime	CEA's expertise	15 years
Shares of different types of vehicles	APS Scenario OECD + 0% of ICE in Europe in 2035	
Perfect anticipation of the demand (10y)	CEA's expertise	Yes



Parameter	Source	Reference Value
Market shares of the different types of batteries	Goldman Sachs	
Vehicle battery capacities	IEA	
Li content in kg/kWh	CEA's expertise	0,1 kg/kWh for NMC & NCA (+ before 2030) 0,08 kg/kWh for LFP 0,455 kg/kWh for SSB (solid)
Batteries lifetime		15 years
Batteries 2 <sup>nd</sup> e lifetime		
Dv des batteries stationnaires		
Rate of gigafactories' scraps	« Transport & Environnement »	



# Demand, Needs and Consumption for Li

## Definitions

### Demand for Li:

#### 4 constitutive elements:

- ✓ Needs for new electric batteries for EV
- ✓ Needs for new Energy Storage Systems
- ✓ Needs of the 9 other sectors (glass and ceramics; lubricating greases; flexible powders for continuous casting molds; polymer production; aluminum production; air treatment; rechargeable batteries for electronics; other consumer batteries; other uses)
- ✓ « Needs » of scraps

### Need for Li:

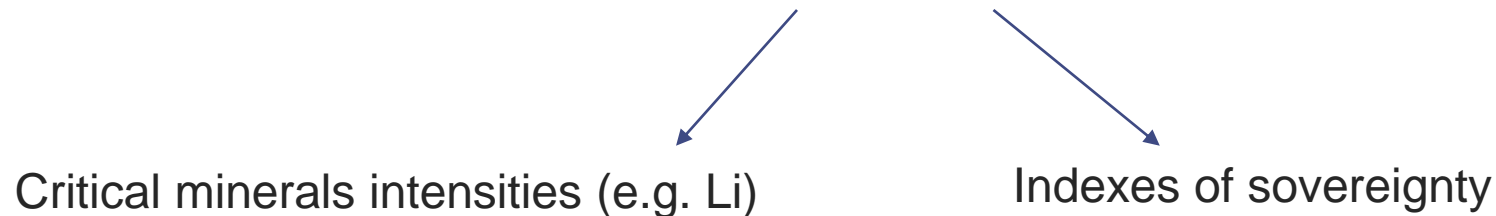
The three elements minus scraps



**Consumption: part of the Need that is satisfied**  
**If the Li anticipation (10 y) is good: consumption=need**

# Methodology

- To define a base-case scenario: entry parameters (input data)
- To observe dynamic results
- To define analyses of sensitivity by varying the entry parameters
  - ↳ To determine the most influent parameters
  - ↳ To elaborate distinctive scenarios associated with different stories / paths



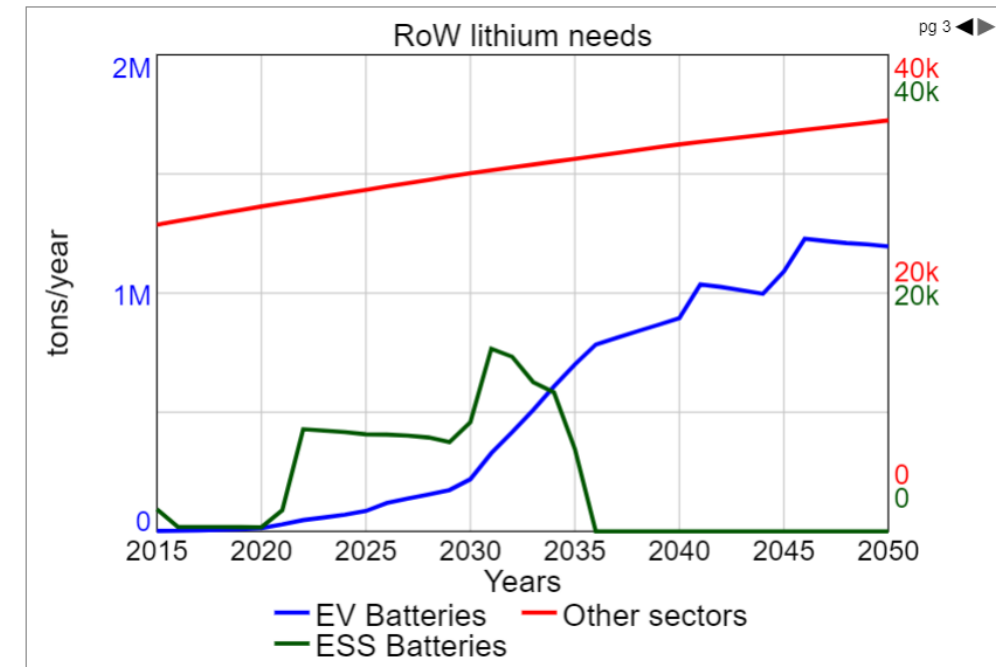
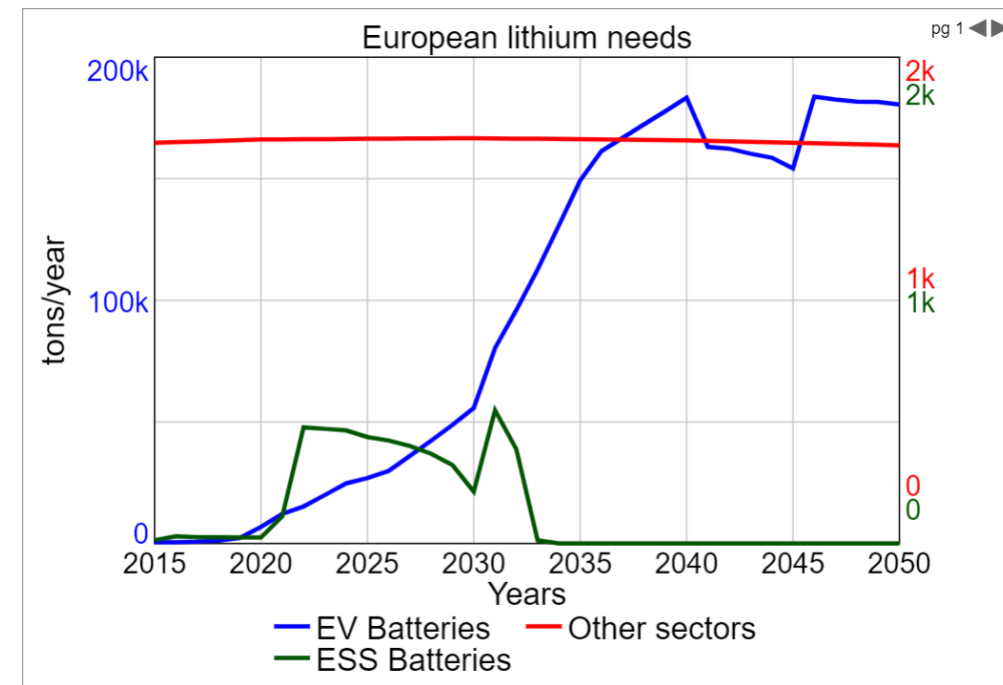


# Base-case scenario

- Based on the most reliable data available
- Representing an average trajectory
- Taking into account existing measures (e.g. Battery Directive, ICE ban, etc.)

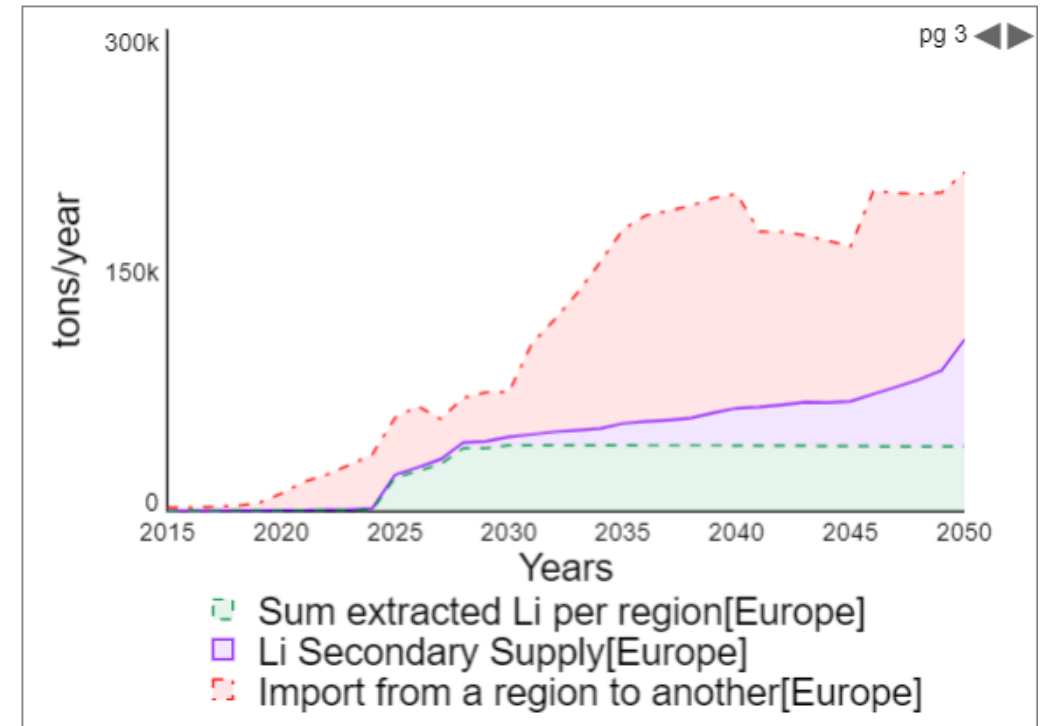
# Base case scenario

- The **need for Li for EV** is higher than other needs ( $\approx 100$  times higher in Europe & 50 times higher in the RoW)
- Fast-growing **need for Li for EV**, higher growth in Europe (ICE ban from 2035).
- The **need for Li for other sectors** correspond to the evolution of the population
- The **need for Li for ESS** exists until  $\approx 2035$



# Base case scenario: Annual Li quantities in Europe

- European extraction & recycling do not prevent from importing lithium but local production strongly reduces the dependency (2025-2030)
- The recycling boom and its positive effects will mainly be seen in the long term (2050 and beyond)



Demand= Consumption/Need + Scraps

# Index of sovereignty for Europe

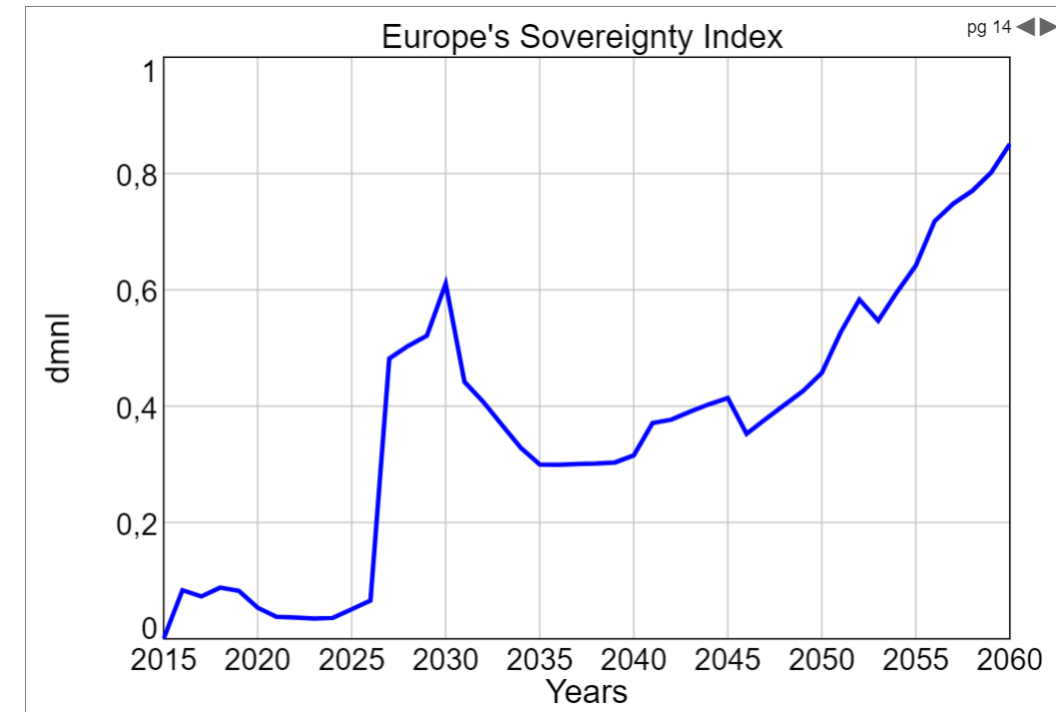
## Definition

Sovereignty = industrial sovereignty → long-term technological choices

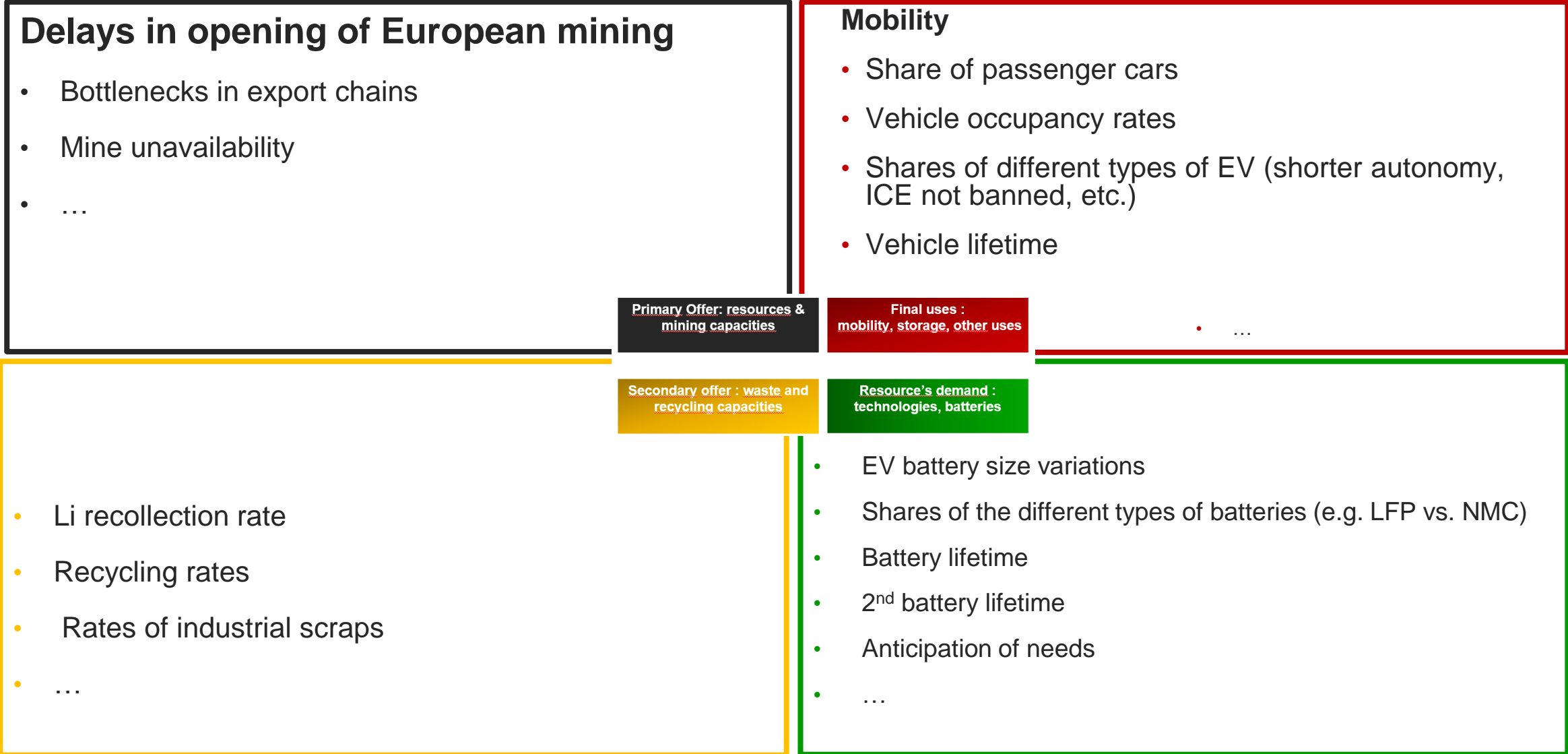
The index expresses the ratio for a given year between what Europe produces in primary and secondary lithium and the European demand for Li.

### Index of sovereignty:

- Grows with the opening of mines
- Decreases with the growing demand and rises again because of the opening of recycling plants and the stabilization of the demand ( $\approx 0,45$  in 2050)
- Can grow with an extended sovereignty (raw materials diplomacy)



# Sensibility and input variations





# Alternative scenarios

## Scenario 3

### Decarbonization without Eu. mines

- **0 mine opening in Europe**
- **Very good collection rate** (95% v. 90% for the base case)
- **Very good recycling rate** (95% v. 80% for the base case)

## Scenario 1

### Premium decarbonization

- **Mostly NMC in Europe**
- **Very good collection** (95% v. 90% for the base case)

## Scenario 2

### « External » decarbonization and global dependency

- **European recycling of European Li only**
- **Smaller batteries** (70 kWh v. 80 kWh for the base case)

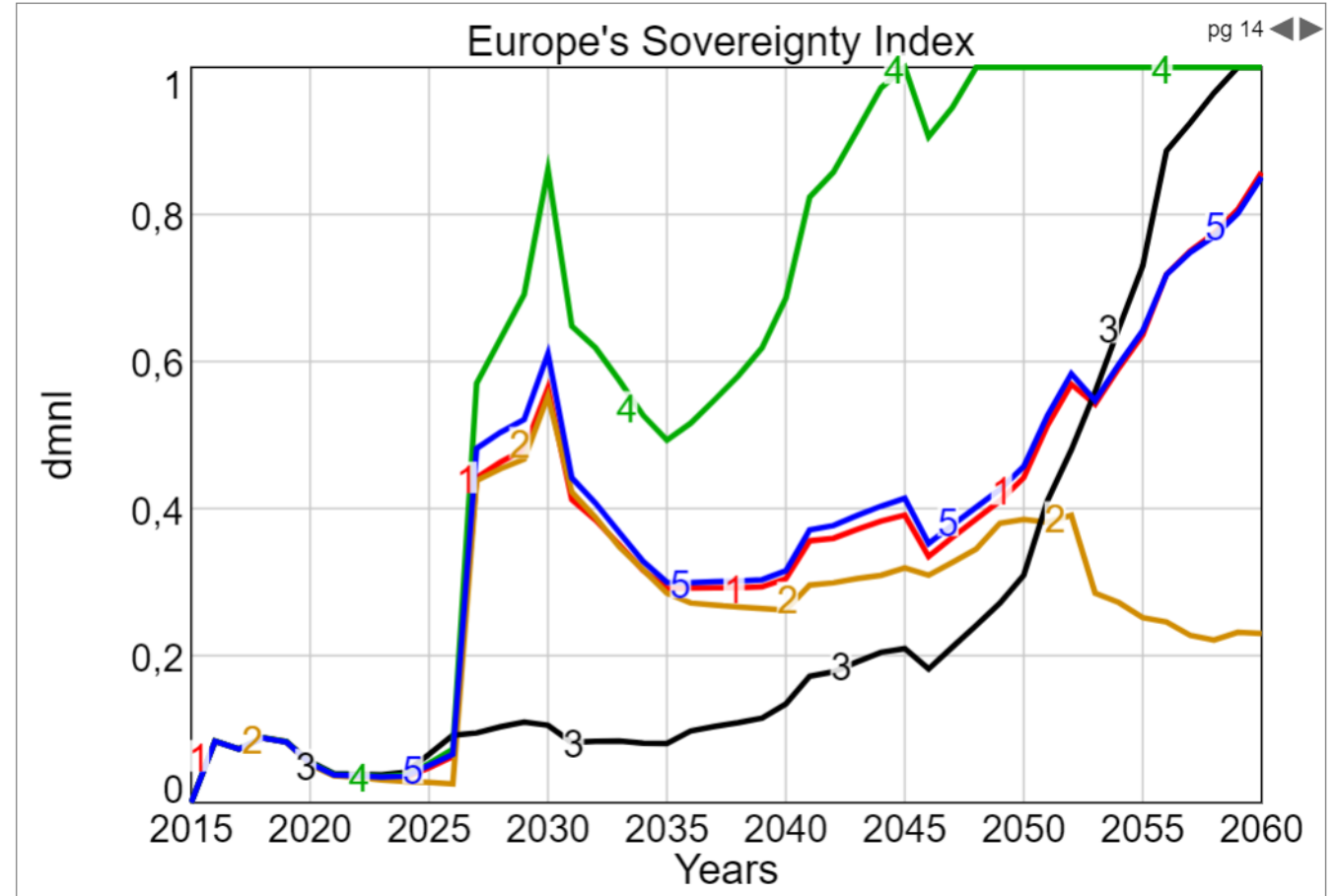
## Scenario 4

### Sober and internal decarbonization

- **Smaller batteries** (50 kWh v. 80 kWh for the base case)
- **Growing share of free Li batteries, reduction of SSB**

# European sovereignty

- Until 2050, the Eu. Sovereignty depends on Eu. Mines therefore the absence of Eu. Mines (Sc. 3) would be critical
- Combining with a technical focus (small batteries & less Li intensity) – Sc. 4- increases the sovereignty at medium term
- After 2050, recycling is a key factor :  
↳ Sc. 2, the EU is dependent because the Eu. Battery supply does not take over the transition period.



# Conclusions

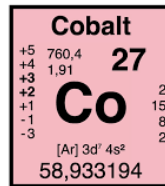
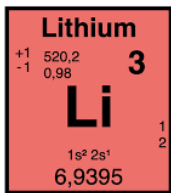
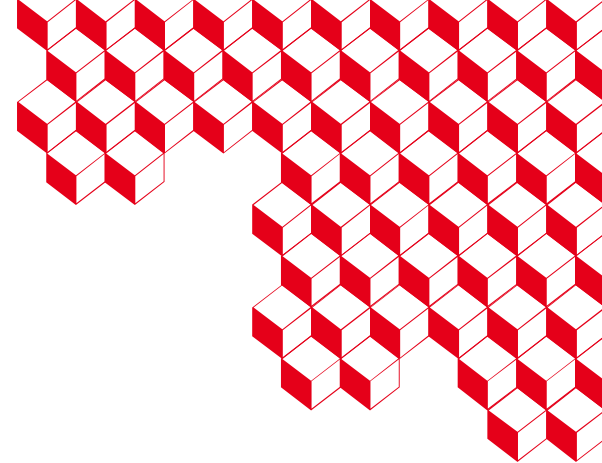


## The SD :

- Favors the study of movement and the behavior of complex systems ⇒ **useful to study the dynamism and the cycles of energy transition**
- Is a visual technique and allows the production of qualitative and quantitative models  
⇒ **modular and agile**
- Allows to develop a prospective analyses and to describe different scenarios based on different hypotheses ⇒ **complementary with other approaches**
- Is fit to anticipate critical material needs and offer supply risk analyses
- Is a useful tool for stakeholders to simulate options



# Perspectives



**Les 17 terres rares**

SCANDIUM 21 Sc	LANTHANUM 57 La	CERIUM 58 Ce	PRASEODYMIUM 59 Pr	NEODYMIUM 60 Nd	PROMETHIUM 61 Pm	SAMARIUM 62 Sm	EUROPIUM 63 Eu	GADOLINIUM 64 Gd
YTRIUM 39 Y	TERBIUM 65 Tb	DYSPROSIUM 66 Dy	HOLMIUM 67 Ho	ERBIUM 68 Er	THULIUM 69 Tm	YTTÉRIUM 70 Yb	LUTÉTIUM 71 Lu	

**Des propriétés exceptionnelles**

- Électromagnétiques
- Optiques
- Chimiques
- Mécaniques
- Semi-conductrices

**Les principaux domaines d'utilisation**

- Numérique
- Technologies vertes
- Domaine médical
- Armement

# Thank you

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