THE IMPACT OF SENSITIVE RAW MATERIALS ON GROUPE PSA ELECTRIFIED POWERTRAINS

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QUALITY AND ENGINEERING

POWERTRAIN & CHASSIS ENGINEERING DEPARTMENT
AUTOMOTIVE RESEARCH INNOVATION AND ADVANCED ENGINEERING DEPARTMENT

Conseil Français de l'Energie : « Les ressources non énergétiques : un frein aux transitions énergétiques ? » - Paris - January 23, 2019

AGENDA

- Context & Electrification’s strategy for GroupePSA
- Sensitive raw material: where are they ?
- Sensitive raw material: for Li-ion Batteries
- Sensitive raw materials for e-Machines
- Conclusion

Context &

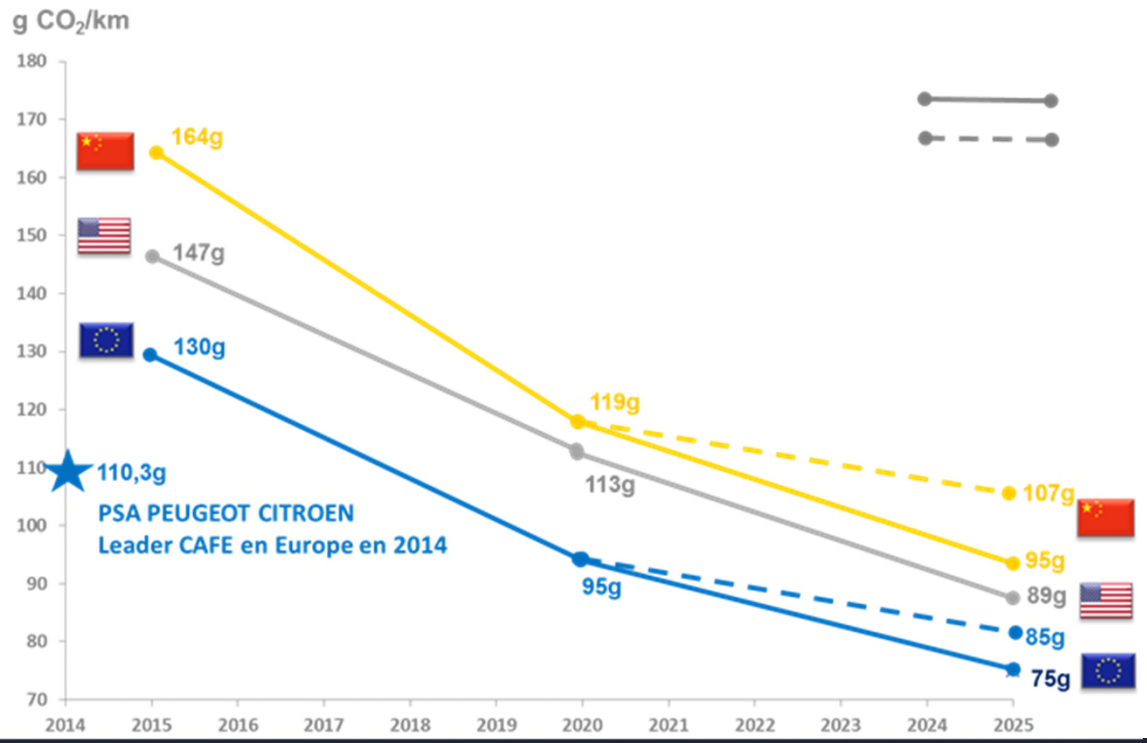
PSA Groupe electrification’s strategy

A DEEP MUTATION IMPACTING THE AUTOMOBILE

THE CAR WILL CHANGE MORE DURING THE NEXT 10 YEARS
THAN DURING THE 30 PAST YEARS

REGULATION CONSTRAINTS

PSA Groupe European Leader for CO_2 emissions with only **104,7g.CO2/km** (by end of 2017)



Major Driver = worldwide CO2 regulations

→ Need for deploying the electrification of powertrains to reach CO_2 emissions : 95g / km in 2020

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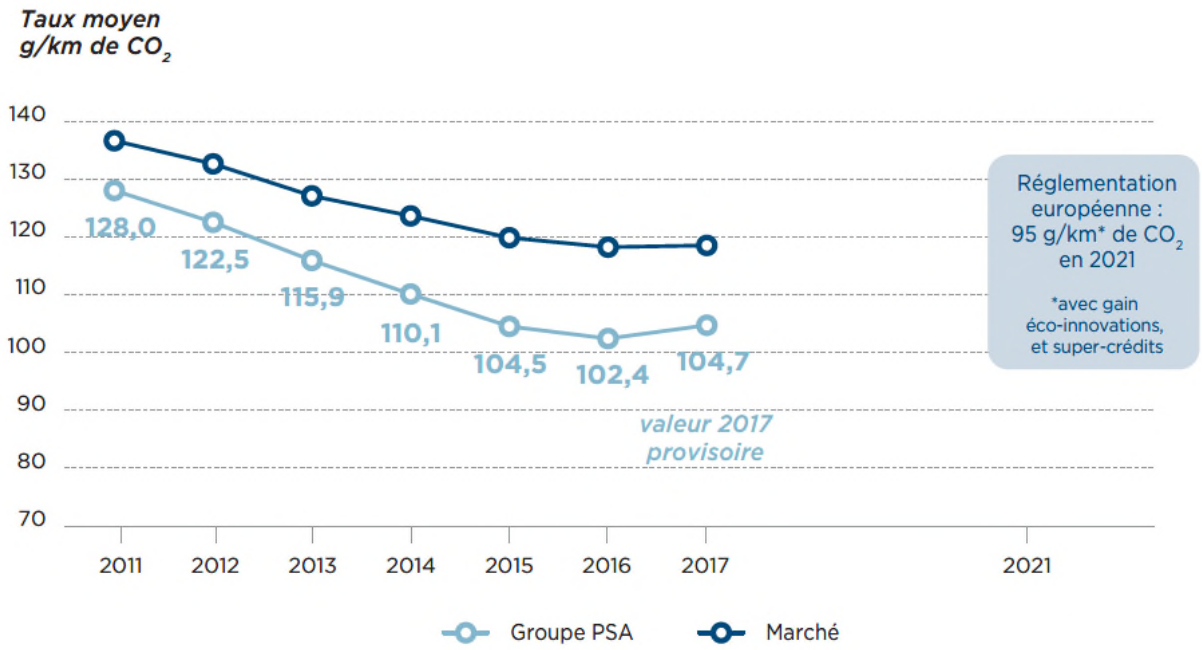


Major Driver = worldwide CO2 regulations

→ Need for deploying the electrification of powertrains to reach CO_2 emissions : 95g / km in 2020

GROUPE PSA ELECTRIC VEHICLES BLITZ FROM 2019

"100% OF OUR LINEUP WILL HAVE AN ELECTRIFIED VERSION BY 2025"

2 MULTI-ENERGY PLATFORMS

"CHOOSE THE MODEL YOU WANT WITH THE TECHNOLOGY YOU PREFER"

EMP2

ICE / PHEV

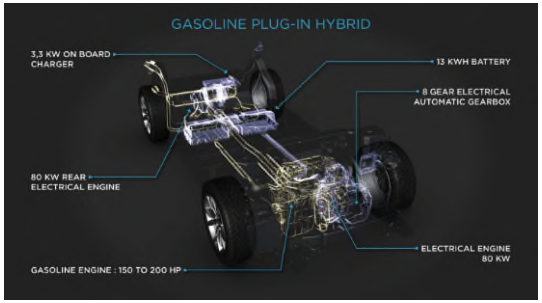
D SEGMENT

C SEGMENT

PHEV : PLUG-IN HYBRID

STARTING 2019

IN EUROPE & IN CHINA



CMP

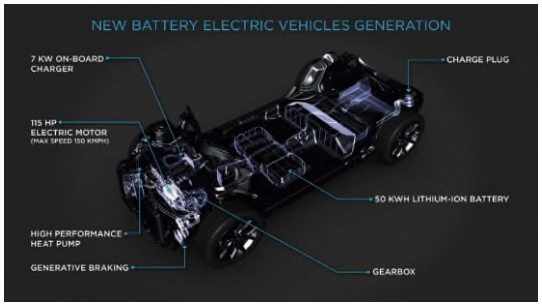
ICE / BEV

B SEGMENT

BEV : ELECTRIC VEHICLES

STARTING 2019

IN EUROPE & IN CHINA



GROUPE PSA ROADMAP FOR ELECTRIFICATION

"WE ARE DEVELOPING A COMPLETE OFFER TO MEET OUR CUSTOMERS' NEEDS ON A WORLDWIDE SCALE"

Currently | 2019 | 2020 | 2021 | 2022 | … | 2025


Citroën E-Mehari


Citroën C-ZERO


Peugeot ION


Citroën BERLINGO *PC & LCV*


Peugeot PARTNER *PC & LCV*


Opel e-AMPERA


PHEV on EMP2


8 MODELS BEFORE 2021


BEV on CMP

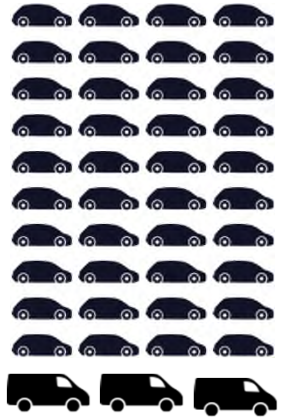

7 MODELS BEFORE 2021

From 2022

New Electrified Powertrains

&

e-components integration

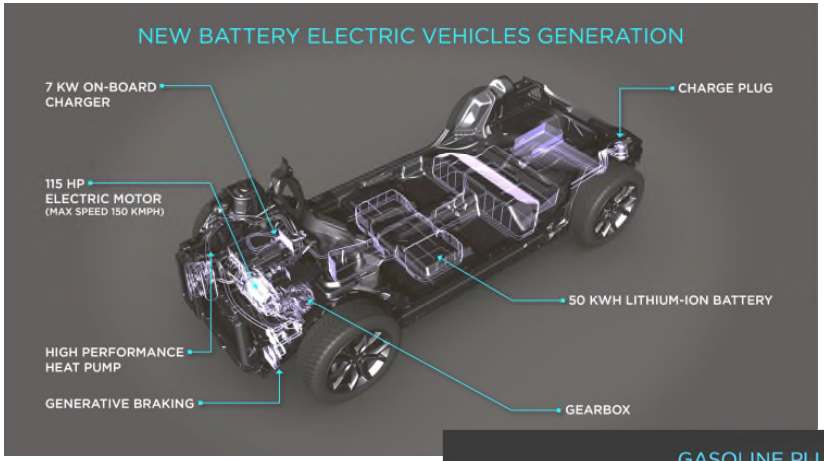

40 MODELS OF THE 5 BRANDS

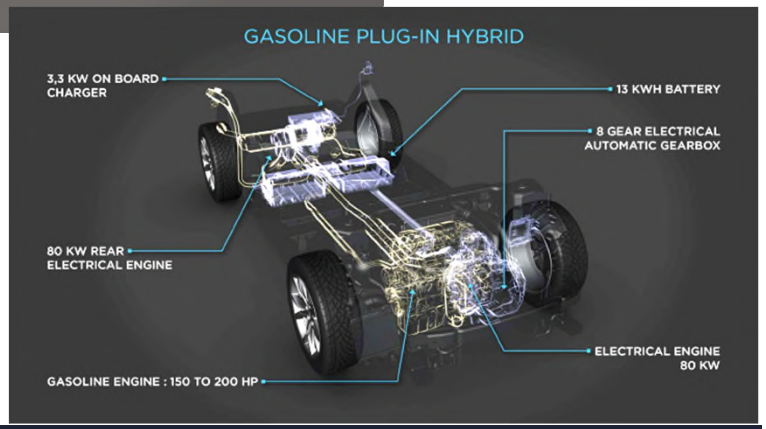
Sensitive raw materials

Where are they ?

THE E-POWERTRAINS: THE COMPOSITION

- The e-Powertrains
  - **A Battery**
  - **An e-Machine**
  - Power electronic parts
  - Reducer
  - Wires
  - Control & Command laws





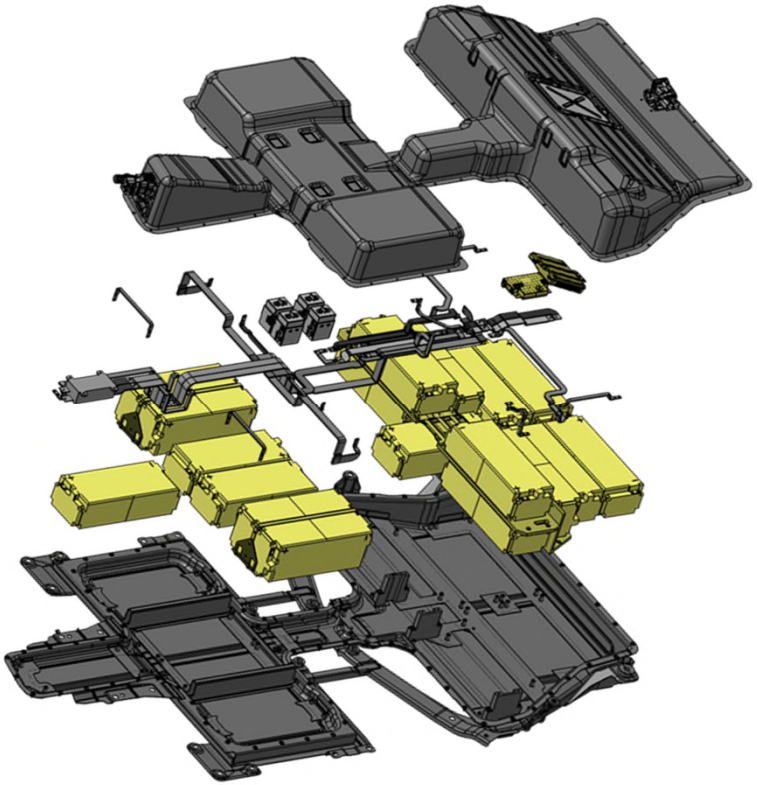
THE BATTERY SYSTEM

- Battery = complex system

  Different type of raw materials are used

  - Non electrochemical parts
    - Aluminium
    - Copper
    - Polymers

  - Electrochemical cells
    - Electrodes raw materials
    - Electrolyte
    - Separator (polymers w/wo ceramic)



THE E-MACHINE SYSTEM

- E Machine = complex system

  Different type of raw materials are used

  - Electromagnetic parts
    - Rare earths (magnets) 
    - Copper (winding) 

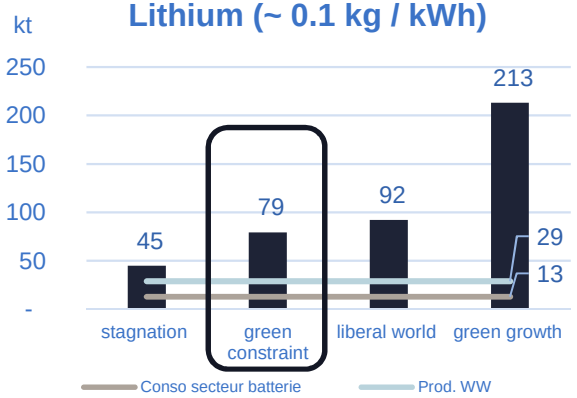
  - Non electromagnetic parts
    - Aluminium 
    - Steel 

Sensitive raw materials

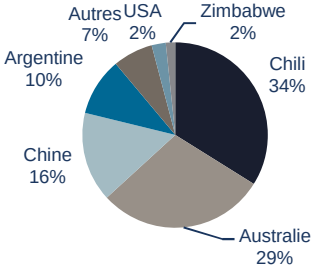
for Li-ion Batteries

LI-ION BATTERIES: ELECTRODES RAW MATERIAL STAKES (WW – 2030)

Lithium (~ 0.1 kg / kWh)

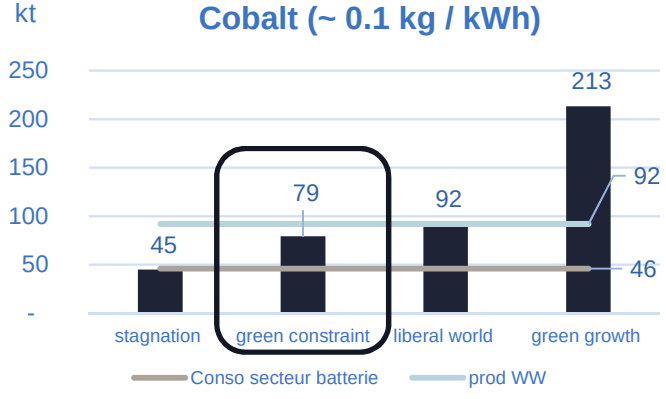


Stock : 32.5 Mt

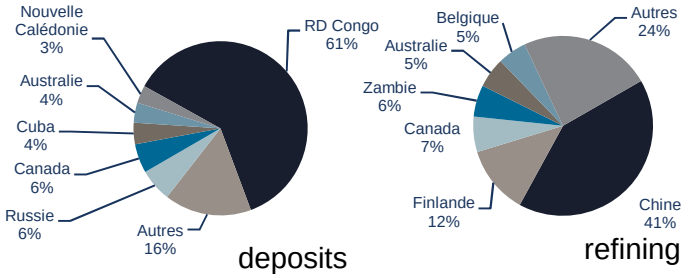


- Moderate geopolitical risk
- Volatile stock price (7 kUS$/t)

Cobalt (~ 0.1 kg / kWh)

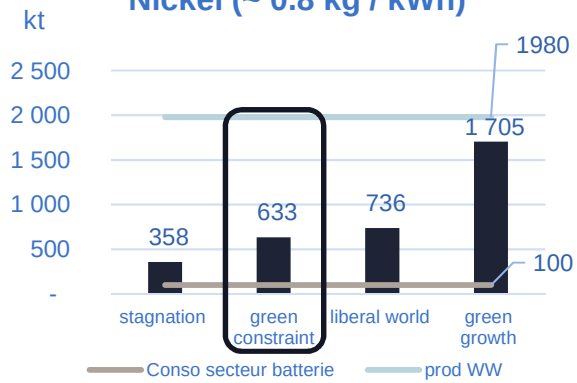


Stock : 7.2 Mt



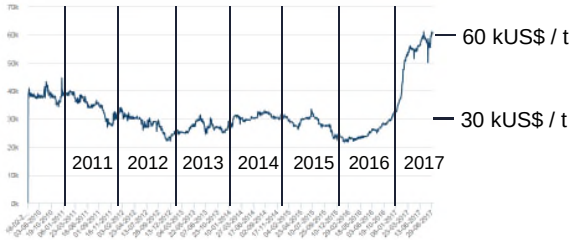
- **High geopolitical risk**
- **Limited stock**
- **Volatile stock price (10 kUS$/t)**

Nickel (~ 0.8 kg / kWh)



Stock : 69 Mt

- Moderate geopolitical risk
- Volatile stock price



- **Monitoring priority on Cobalt**, then Nickel and Lithium
- Copper and Graphite : weak signals

OPPORTUNITIES TO REDUCE DEPENDANCE ON SENSITIVE RAW MATERIALS

- Electrochemical cells
  - Cathode raw materials
    - Less Cobalt as possible

Abbreviation	Formula	Abbreviation	Formula
LCO	$LiCoO_2$	NCM523	$Li[Ni_{0,5}Co_{0,2}Mn_{0,3}]O_2$
LFP	$LiFePO_4$	NCM622	$Li[Ni_{0,6}Co_{0,2}Mn_{0,2}]O_2$
LMO	$LiMn_2O_4$	NCM811	$Li[Ni_{0,8}Co_{0,1}Mn_{0,1}]O_2$
NCM	$Li[Ni_xCo_yMn_z]O_2$	NCA	$Li[Ni_xCo_yAl_z]O_2$, x >0,8
		NMCA	LiNixMnyCozAl(1-x-y-z)O2

    - Even “Cobalt free” electrode (still low maturity level)
    - Recycling & reuse

LI-ION BATTERIES: RAW MATERIALS RISKS AND STRATEGIES

- Raw material access : geopolitical risks
  - Democratic Republic of Congo 
  - Pirate mining 

➡ Everyone wants Cobalt, but nobody wants to open new mines … except in China ?

- Raw material access : two main strategies available
  - Keep agility (no strategic partnership): to use the best “up to date” technology 
  - To have a strategic partnership, to secure raw material access

    Ex : Glencore and CATL (2017) : ~ 15% of the world's Cobalt production 

Sensitive raw materials

for e-Machines

E-MACHINE: COPPER

- Copper have a wide range of use in cars

  - ICE vehicle : ~ 20 kg
  - HEV : ~ 40 kg
  - EV : ~80 kg

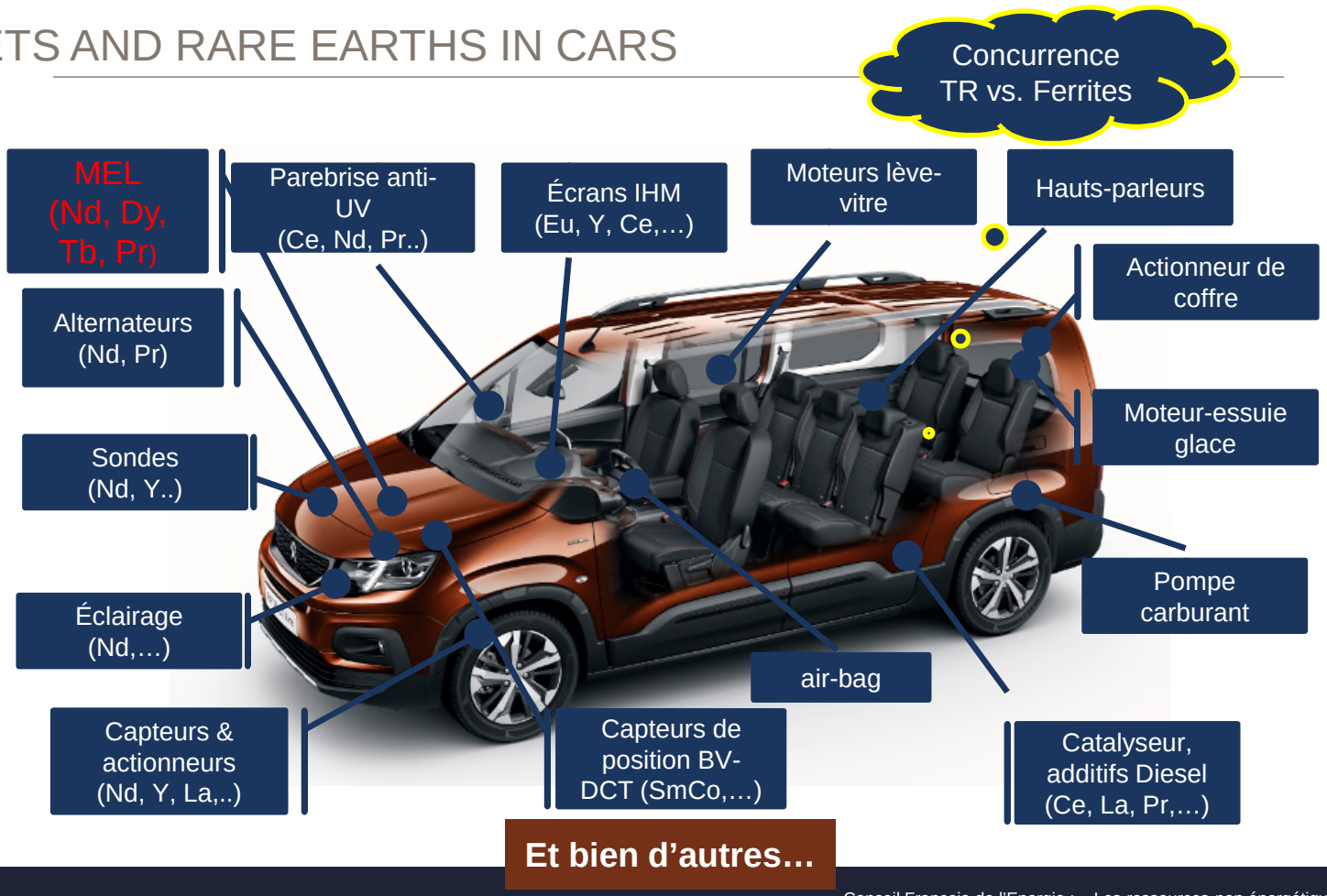
comes
Comité pour les métaux stratégiques

  - ➢ No main issue until 2021.
  - ➢ From 2022, real risk, due to higher needs for automotive applications
    - ➢ One reason : no recent investment in new mines, to close the gap between automotive demand and supply

    Nota : it is more difficult to open new mines, while respecting environmental constraints

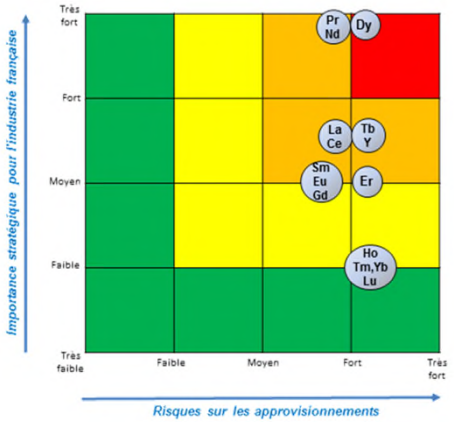
➡ Another risk for availability from 2040: SPECULATION (COMES source)

MAGNETS AND RARE EARTHS IN CARS



E-MACHINE: MAGNETS

- Rare earths in cars
  - ICE vehicles : in the range of 1/2 kg
  - HEV : in the range of 3 kg (mainly e-machine and NiMH battery)
  - EV (Li-ion): in the range of 1 kg (mainly e-machine)

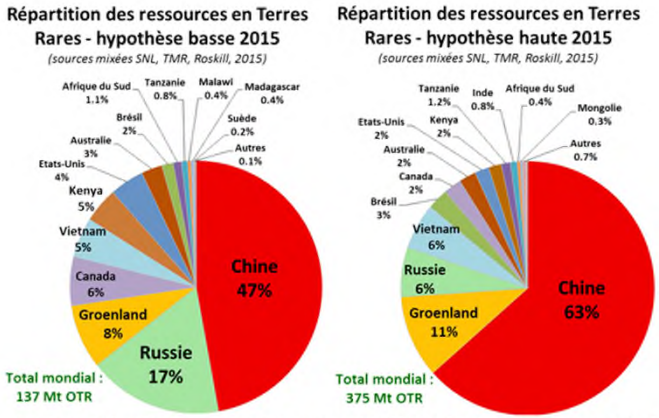


(Source : BRGM 2015)

- Main risks (that influences their cost !)
  - Main mines location: China

China = ~ 85 % of rare earths produced (extraction + refining)

(~ 95% for heavy RE / ~75% for light RE)



(Source : BRGM 2015)

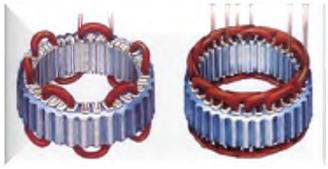
Figure 36 - Répartition par pays des ressources identifiées en Terres Rares, à des degrés divers de fiabilité. Hypothèses basses et hautes selon les sources (cf. tab. 16).

OPPORTUNITIES TO REDUCE DEPENDANCE ON SENSITIVE RAW MATERIALS

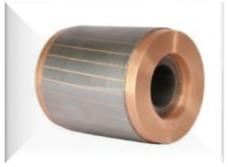
- Systemic approach
  - Raw materials : Rare earths / Copper / Metal sheets
  - Industrial investments
  - Geopolitic sensitivity
  - Financial sensitivity (speculation)

OPPORTUNITIES TO REDUCE DEPENDANCE ON SENSITIVE RAW MATERIALS

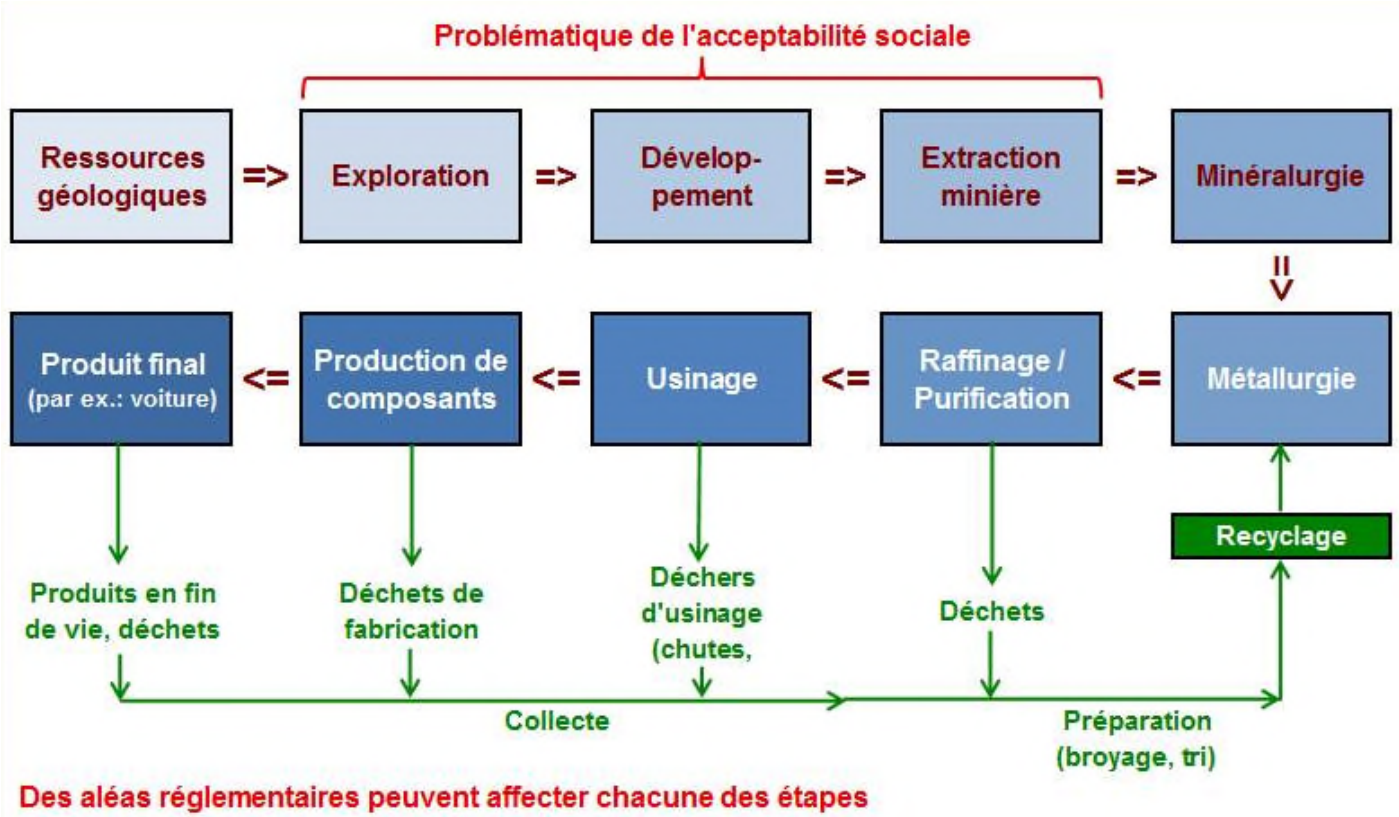
- Rare earths in e-Machines alternatives
  - Magnet free solution : winding for the rotor
    - Less expensive
    - Higher volume (difficult for platform integration)
    - More Copper
  - Ferrite magnets
    - Lower performances
    - Less expensive
  - Free heavy rare earth magnets
    - Same performances
    - Still compact
    - Lowest dependence to China



(Source : Alibaba)



ANNEXES



Source : Mineral Info (http://www.mineralinfo.fr)

Sensitive raw materials

Conclusions

CONCLUSION: E-POWERTRAINS RAW MATERIALS SENSITIVITY

Through its strategy, the PSA Groupe is aware of the **Company's Social Responsibility**. To this end, it works in a network with public authorities, partners and suppliers in order to offer its customers environmentally friendly solutions.

Our actions in promoting sustainable development, take into account in particular the raw materials used in our vehicles, as well as the processes necessary for their implementation.

From the extraction of raw materials to the recycling of its vehicles, the PSA Group deploys a policy of responsible development, and this implies rigorous management of the products used in the manufacture of its automobiles.

CONCLUSION: E-POWERTRAINS RAW MATERIALS SENSITIVITY

- Main raw materials to be closely monitored and/or replaced
  - Cobalt for Li-ion batteries
  - Heavy rare earths for e-machines
  - Copper

(Source : Hawaii industrial supplies)

- Main difficulties in ensuring an adequate supply of sensitive raw materials
  - Timings are really different
    - Public authorities : a few months to define regulations
    - Industrials (manufacturers/integrators) : 4 to 7 years
    - Mining and refining : up to 10 years


Thank you for your attention
UNBORING
THE FUTURE
Any questions ?