Perspectives of abiotic resources

IV

1. A matter of Stocks

1.1. The stocks's stakes

a) Climate change – CO2 eq « stock »

[6] BP, 2020. BP Statistical Review of World Energy. [online].

[20] EIA, U.S. Energy Information Administration, 2016. Carbon Dioxide Emissions Coefficients. [online].

[21] IPCC. 2018. Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. . P. 82.

- Oil emissions of current reserves
    - Proven reserves :

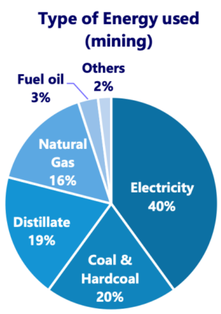
      -> 1733,9 billions barrels [6]
    - 53750,9 billion gallonsAverage on varied oil uses gives ≃ 10 kg CO2 emitted per gallon [20]

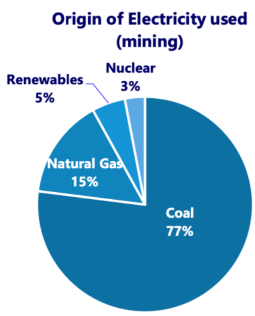
      -> 537,5 Gt CO2
- World CO2 eq budget, current estimations : [21]
    - 1170 Gt CO2 eq to stay <2°C of global warming
    - 420 Gt CO2 eq to stay <1,5°C of global warming
- Consumption of all current proven oil reserves is half of our total 2°C world budget and more than our total 1,5°C budget!
    - Without even considering natural gas, coal, or other emissions (CH4, for example) contributing to radiative forcing...
    - This considered, without changes, the 2°C threshold should be crossed in about 26 years

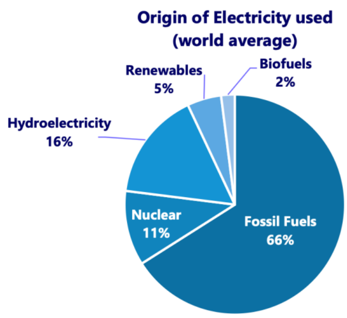
[3] BIHOUIX, P., GUILLEBON, B. ,2010. *Quel futur pour les métaux?*

[10] Data & Statistics,. *IEA*[online]. Available from : https://www.iea.org/data-and-statistics

And mining is very dependent of highly carbonated, non renewable energy vectors







Adapted from [3] .The values for World averages of Electricity origin were replaced by updated data rom [10]

b) Production peak

[6] BP, 2020. BP Statistical Review of World Energy. [online].

[15] JANCOVICI, J-M, 2019. Les Energies fossiles. *Ecole des Mines* [online].

[22] World Energy Outlook 2018. *IEA –International Energy Agency*.

- Hypothesis: we don't mind $CO_{2\ eq}$ emissions
  - Either we consider it's not a problem
  - Or we think innovation or start-ups will solve that

-> Exhaustion of Reserves through Production will still occur!

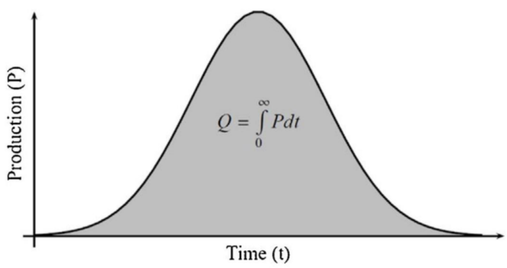
  - R/P ratio: most simplified model
  - Considering current reserves [6]
  - And 2019 rate of consomption [6] taken as constant for the years to come (quite unrealistic hypothesis of no flow reduction)

  -> No oil remaining in ≃ 50 years

[23] CALVO, G. et al.., 2017. Assessing maximum production peak and resource availability of non-fuel mineral resources.

[15] JANCOVICI, J-M, 2019. Les Energies fossiles. *Ecole des Mines* [online].

[22] World Energy Outlook 2018. *IEA – International Energy Agency.*



- A slightly better estimate: the Hubbert peak model (1956)
  - We know there is no production at t = 0 and t = t final
  - The area below the production curve must be equal to the reserve
  - Regarding conventionnal oil, several countries seems to have peaked already. A review can be found here [15]
  - It is commonly believed that world production peak of conventionnal oil already happened, in 2008 [22]

Extracted from [23]

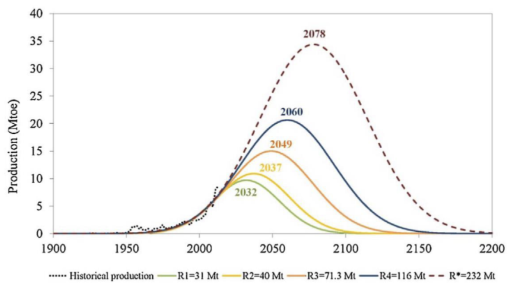


Fig. 4. The Hubbert peak applied to lithium with different resources estimations. The curve corresponding to R* values was calculated assuming that the most optimistic estimations (R4) were doubled.

- Reliability is influenced by several parameters
  - Uncertainty regarding reserves information
  - Particular environmental issues: health, water use, ore grade
  - Sociopolitical issues: new objects, changes of regulation, or armed conflicts
  - Interdependencies of byproducts
  - Substitution & recycling

- That said, influence of reserves' variation is limited when rapported to the current trends in production and growth of production

  -> Li case study: estimated reserves x 8 only delayed the peak by 46 years

Extracted from [23]

- This recent try of systematic assessment is quite interesting to read[23] and accessible!
  - The time scaling is quite short, even for base metals

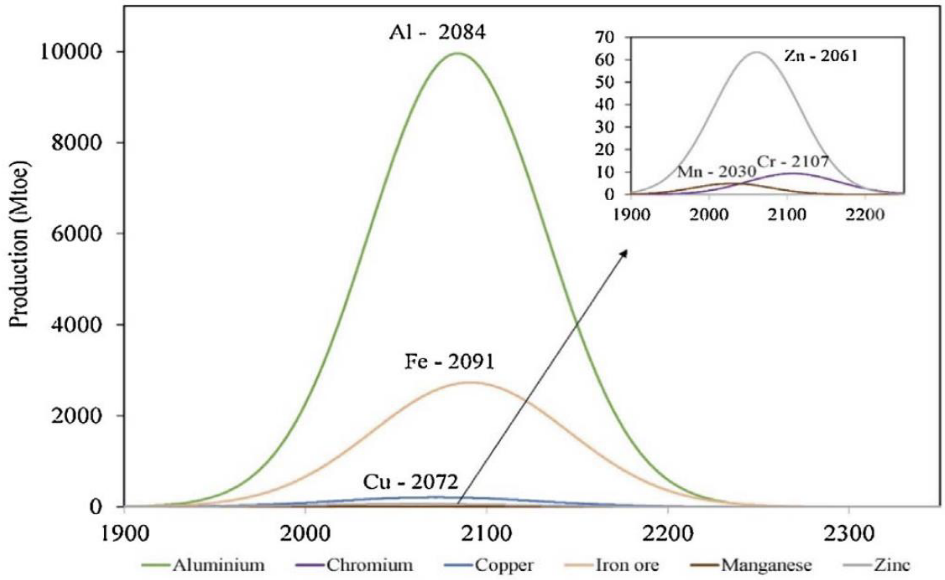
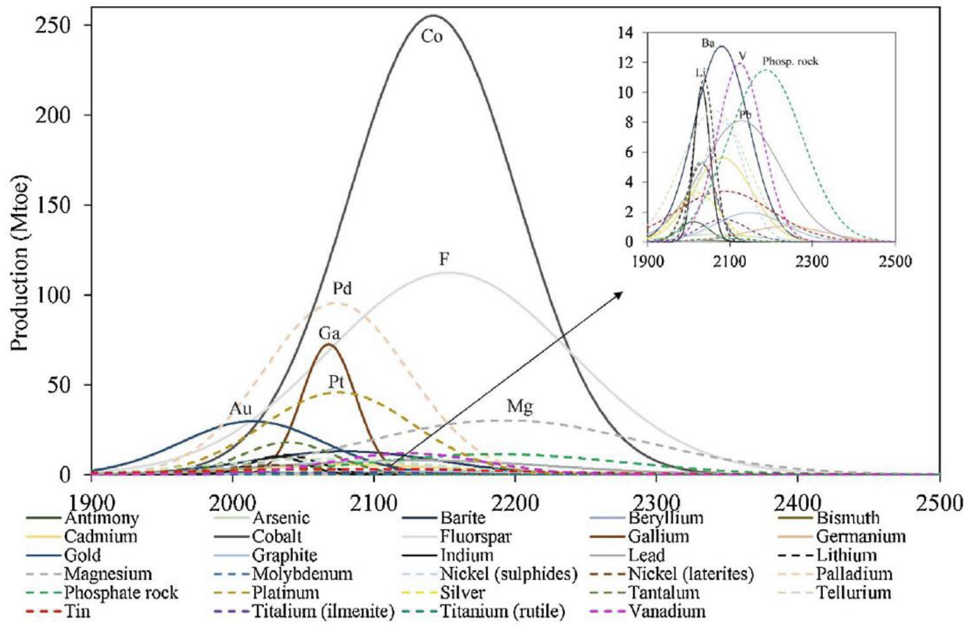


Fig. 5. The Hubbert peak applied to the "big six" resources.

Extracted from [23]

- Expected peak in the next 50 years : 12 metals over 47 studied: As, Bi, In, Li, Mn, Mo, Ni, Ag, Ta, Te, Zn
- 30 metals over 47 have their expected peak in the next 100 years
- Gold & Antimony peaked arround 2015 (agreement for Gold with [3])



Extracted from [23]

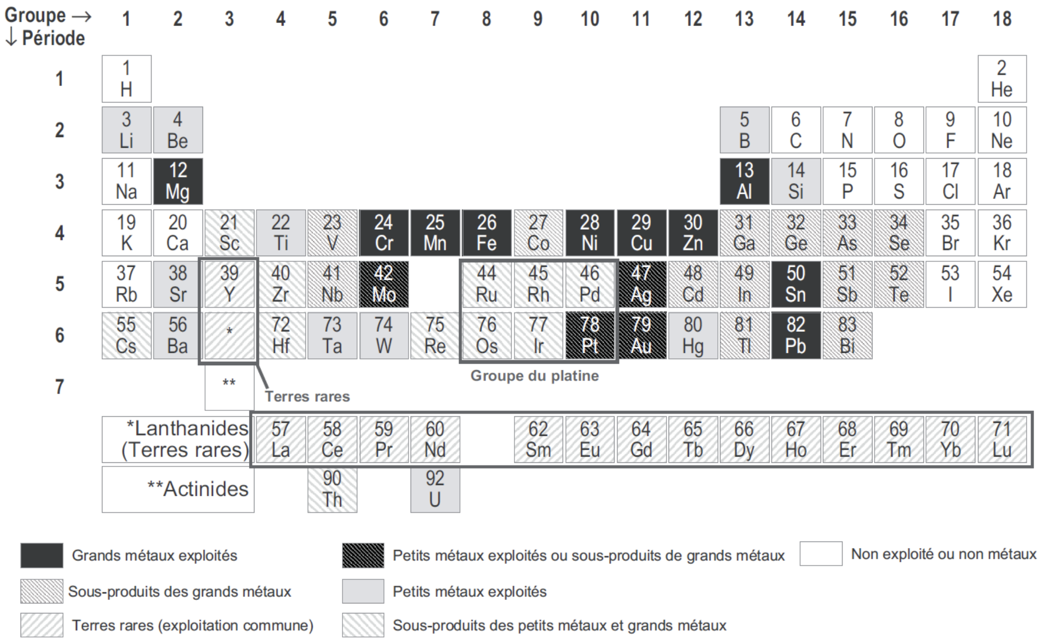
- Taking into account the interdependencies of metals
  - Bold indicates it is the main production process of said **metal**

Major metals exploited	Main non-dependent byproducts	Main dependent byproducts
Fe	Zb, Pb	
Al		**Ga**, V
Cr	Pd, Pt	
Cu	Ag, Au, Mo, Pd, Pt, Zn	**As**, Bi, Co, Ir, Os, **Re**, Rh, Ru, **Se**, **Te**
Ti		Zr, Hf
Pb/Zn	Ag	As, **Bi**, **Cd**, Co, Ga, **Ge**, **In**, **Sb**, **Tl**
Ni	Ag, Au, Cu, Pd, Pt	**Co**, Ir, Os, Rh, Ru, Se, Te
Sn	Ag	In, Nb

Extracted from [3]

[3] BIHOUIX, P., GUILLEBON, B. 2010. *Quel futur pour les métaux?*

- Nearly a half of metals today exploited are interlinked



Sources : E. Verhoef, G. Dijkema and M.A. Reuter (2004), USGS, BRGM

Extracted from [3]

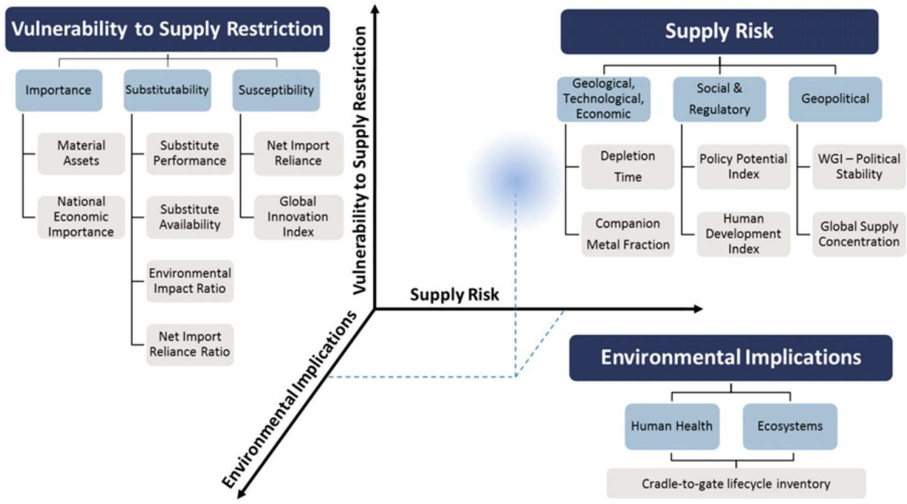
c) Criticality

[26] GRAEDEL, T. et al., 2015. Criticality of metals and metalloids. DOI 10.1073/pnas.1500415112[1].

- Notion related to the attempt to assess the relative risks concerning the availability of resources
  - Relatively recent preoccupation
  - As availability is an already complex notion, its risk analysis is also complex

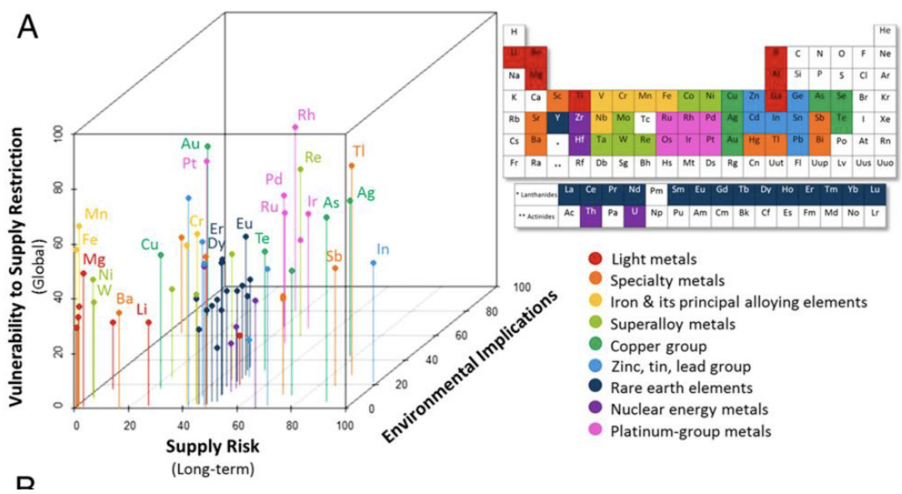
[1] https://www.pnas.org/doi/full/10.1073/pnas.1500415112

        - Geological abondance & concentrations
        - Potential for substitution
        - State of the art of mining technology
        - Amount of regulatory oversight
        - Geopolitical initiatives
        - Governmental instability
        - Economic policy
    - As reserves are part of the assessment, it is also dynamic
- Several methodologies
    - At different scales of organizations
    - For different scales of time
    - With then varied results difficult to compare between each other



Extracted from [26]

- Criticality space: a first step is to get an overall idea
    - A number of metals are concentrated on the middle: moderately high on at least 2 axis (rare earths, Cr, Te, etc.)
    - Some are regrouped toward lower left: relatively low criticality (Fe, Mg, Ni, Mn, etc.)
    - The right side: high supply risk (In, Ag, Tl, As, Sb)
    - The particular case of Au & Pt



Extracted from [23]

- This methodology allow the comparison of varid elements for (here at global level) :
    1. Supply risk
    2. Environmental implications
    3. Vulnerability to supply restriction
- Keep in mind it is a relative assessment
    - Per kg comparison
- Results may be underestimated
    - Database of 2008 (they were in the process ofupdating up to 2012 at publication in 2015)
    - As data revisions are not frequent & major technology changes occurs slowly, they recommand reassessment on a 5 years basis

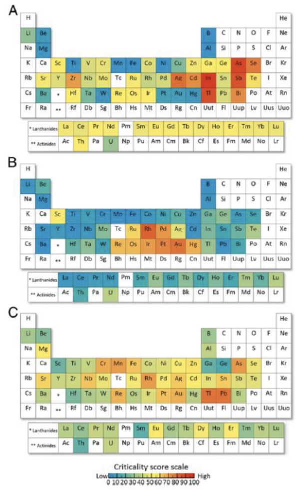
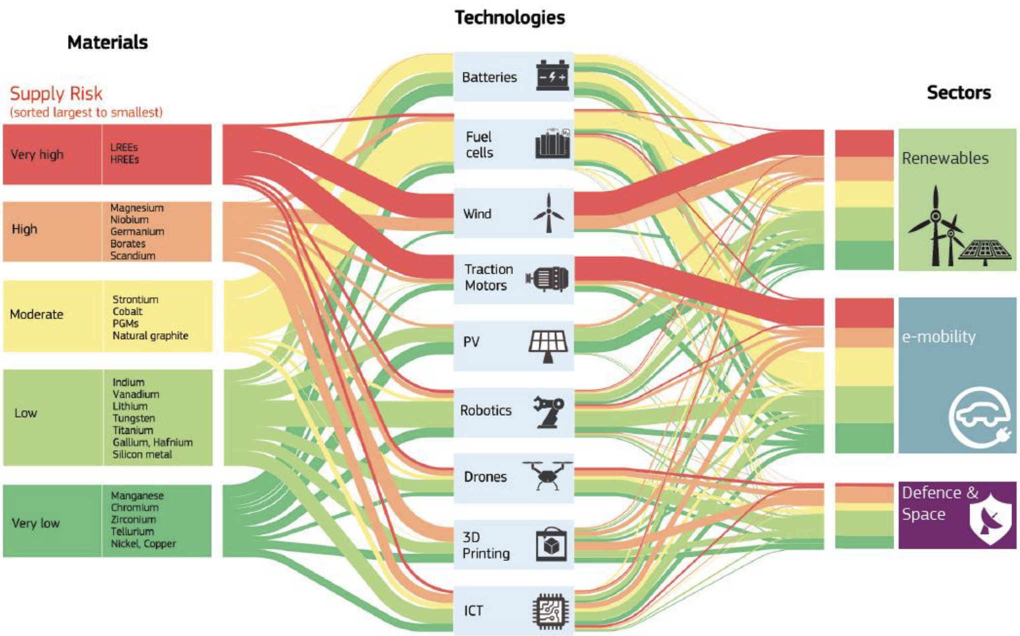


Fig. 6. Periodic tables of criticality for 62 metals, 2008 epoch, global level for (A) supply risk, (B) environmental implications, and (C) vulnerability to supply restriction.

Extracted from [23]

[25] HUISMAN, J., PAVEL, C., *et al. 2020. Critical Raw Materials in Technologies and Sectors - Foresight* [online].

Figure 2. Semi-quantitative representation of flows of raw materials and their current supply risks to the nine selected technologies and three sectors (based on 25 selected raw materials, see Annex 1 – Methodological notes)



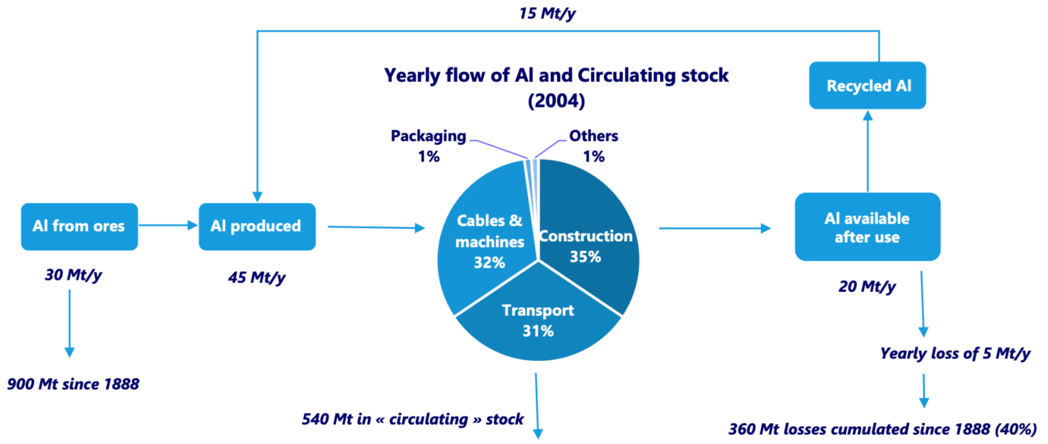
1.2. Preserving stocks

a) Necessity & Limits of Recycling

[3] BIHOUIX, P., GUILLEBON, B. 2010. *Quel futur pour les métaux?*

- Major difference between oil (energy resources) and metals (mineral ressources) :
    - Oil, Coal & Natural Gas -> mostly burned -> The flow is not retrievable
    - Metals -> mostly materially conserved -> The flow is retrievable + there is a stock in circulation!

- Each year, stocks of metals :
  - Increases of the producted quantity
  - Decreases of the lost quantity
    - Dispersive uses (metals used as dyes or fertilizers)
    - No recycling (incineration or landfill disposal)
- Current recycling
  - Precious metals (Au) or with moderately high value (Cu): few losses
  - Less noble metals (Al, Zn) have more important loss rates
  - No data for a lot of metals used in specific applications (electronics...)



- Metals are one of the most interesting category of materials for recycling
  - Theoretically recyclable an infinite amount of time without diminishing their properties
  - Have high yield for stock preservation
    - 40% recycling rate -> 80% recycling rate <-> Reserves x 3
    - 50% recycling rate -> 99,9% recycling rate <-> Reserves x 500
- Rich countries show that recycling rate can reach high levels for base metals
  - France (2010): 85% for Fe ; 80% for Al & Cu ; 70% Pb ; 50% Zn [3]
- But it cannot do everything
  - No industrial process have a 100% efficiency -> same for recycling (remelt Al generate a dispersed loss of 1-2%)
  - A lot of our uses are not compatible with recycling
- The trend of higher complexity
  - > 30 metals in a computer
  - > 10 alloys of Steel in a car
  - Prevent us from retrieving the resources: not easy and sometimes techically impossible to detect or separate metals of an allow
- This phenomena exist for a lot of our metarials
  - Glass: mix of transparent & colored glasses -> no more use in most of construction or cars, only bottles
  - Plastic: often reused in less demanding uses (technically or aestetically)

-> Important to rethink life-cycles of products, raw materials, and mostly uses

- -> Integrate less performant or pretty materials & more recycled materials
- -> Organize recovery channels to boost recycling rate
- -> But also question the trend of high tech solutions instead of low tech ones
- -> That is, question the needs
- The trend of direct dispersive uses
  - Dyes (98% of Ti used as TiO_2 for white dyes)
  - Fertilizers (P, Zn, etc.)
  - Additives (Cr in Glass)
  - Pesticides ($CuSO_4$ in some organic farming plants)
- And « indirecty » dispersive uses (very difficult to recover)
  - 33% of Sn is used in welding
  - 50% of Zn is used in galvanizing
- Some metals like Co or Mb are nearly exclusively used in dispersive uses or alloys
- The socioeconomic limits
  - Economical incentives to constructors are not present or sufficient
  - Lack of reglementation and means to enforce it
  - Complexity of products and recovery channels does not help

b) Substitution

- Limit the use in rare or noble metals in favor of abondant metals
  - Critical lens on « innovation »
  - Aim to maximize a low tech approach as much as possible at the level of product and technology

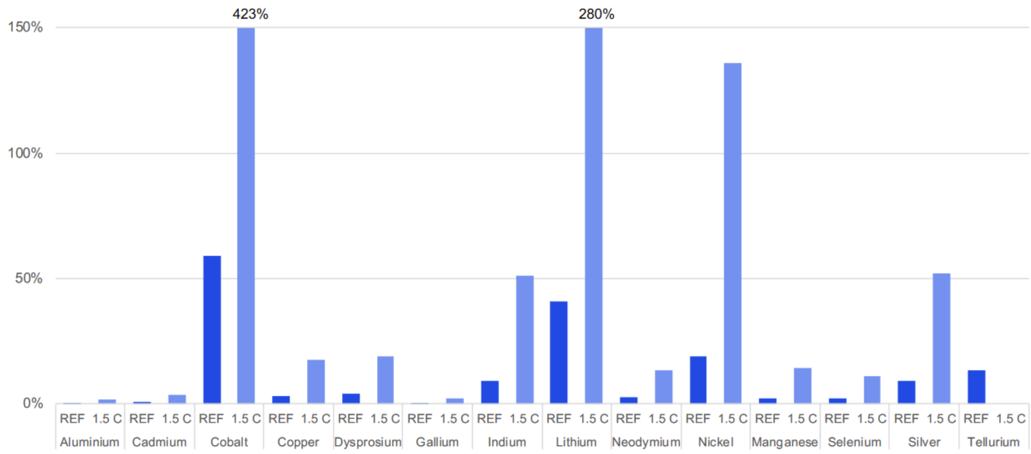
  -> For inorganic solar pannels, Si should be prefered to GaAs, CIGS, and others, even if the conversion efficiency is less important
- For critical cases, possibilities needs to be carefully explored :
  - Cr nearly indispensible for anti-corrosion

    -> Ti can replace Cr in certain cases but its energy footprint is 4-5 times higher
  - Cu nearly indispensible for electrical applications

    -> Al can replace Cu in certain cases but its energy footprint is 2-3 times higher

- Substitute oil by electrification? [27]
  - Li-ion batteries represented 37% of Li consumption in 2016 (and 40% of Co)
  - Batteries for electric vehicules were only 10% of Li-ion consumption in 2018
  - Most elements at disposal indicates that strong choices of resources's uses will have to be made in the years to come :

Figure 6: Cumulative total demand from renewable energy and storage by 2050 compared to reserves in the 1.5 degree and Reference scenarios



[27] Responsible minerals sourcing for renewable energy, 2019. *University of Technology Sydney* [online].

[28] ABDALLA, A. *et al.*, 2018. Hydrogen production, storage, transportation and key challenges with applications: A review. DOI 10.1016/j.enconman.2018.03.088[1]

[29] SCHMIDT, O., *et al.*, 2017. Future cost and performance of water electrolysis: An expert elicitation study. DOI 10.1016/j.ijhydene.2017.10.045[2].

- Substitute oil by « hydrogen »?
  - Currently > 90% of H_2 is produced by steam reforming (10 kg CO_2 per kg of H_2 produced) [28]
  - Water electrolysis / fuel cells have problems of their own [29]
    - Alkaline electrolysis is not adapted for electric cars
    - New technologies currently depends either on Pt and are not industrially mature (PEM) or rare earths and are at the state of demonstrators (SO)
- In need of a big & new infrastructure for supply of cars

-> We are back to the vicious circle of energy & material footprint

c) Challenging needs

[30] BIHOUIX, Philippe, 2014. *L'Age des low techs : vers une civilisation techniquement soutenable.* Seuil.

- The often most efficient stategy to preserve abiotic resources stock
  - House thermally isolated + put on a sweater >>> room heating technical solution
  - Most transport on bicycle (short distance) + train (long distance) with minimal use of a car (occasional rental) >>> electric cars replacing current diesel and petrol cars
  - Simple dismountable and repairable electronics >>> computer assembly with glue with digital prints technology

[1] https://www.sciencedirect.com/science/article/pii/S0196890418303170?via%3Dihub
[2] https://www.sciencedirect.com/science/article/pii/S0360319917339435?via%3Dihub

- It is the first of the 7 principles of low-techs [30]
    1. Challenging needs
    2. Design and produce truly sustainable
    3. Orienting knowledge to resources' savings
    4. Striking a technical balance between performance & conviviality
    5. Relocalize without losing the right scale effects
    6. De-machinizing services
    7. Knowing to remain modest
- Indeed this kind of transition imply numerous socioeconomical consequences
    - As any kind of transition, it is also a matter of flows and their evolution

1.3. Medias

https://pod.utt.fr/video/3948-ev14-abiotic-resources-61-stakes-of-the-stocks/

https://pod.utt.fr/video/3949-ev14-abiotic-resources-62-preserving-stocks/

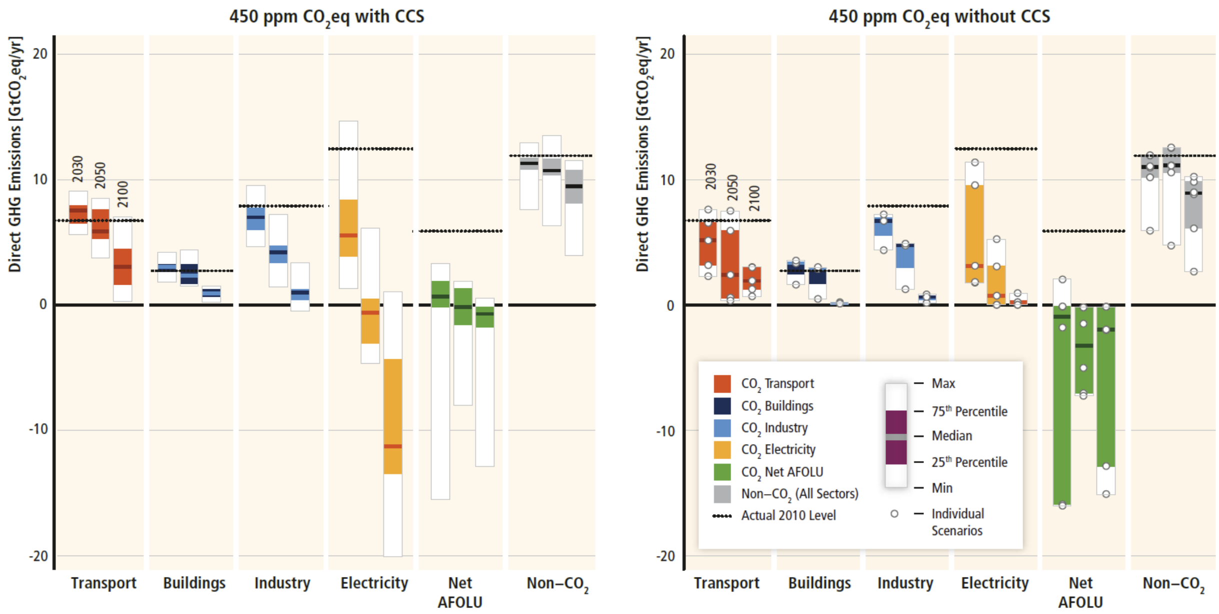
2. A matter of Flow

2.1. The flows's stakes

a) Climate change

[31] IPCC. *2014: mitigation of climate change: Working Group III contribution to the 5th Assessment Report of the IPCC.*

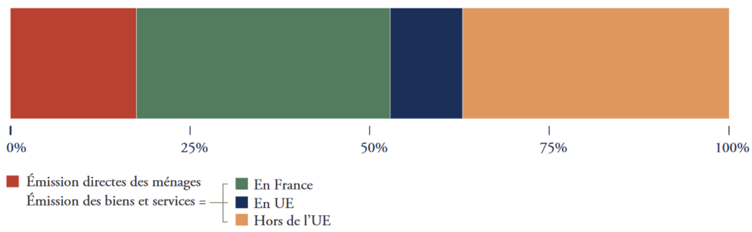
- Trajectories mitigating climate change all require a global limitation of material & energy flows
    - Even with the hypothesis of a high developpment of the use of carbon capture and storage (CCS) technologies



[32] HCC, 2020. Maîtriser l'empreinte carbone de la France. *Haut Conseil pour le Climat* [online].

- The French carbon footprint
    - A large part of our carbon footprint comes from importations

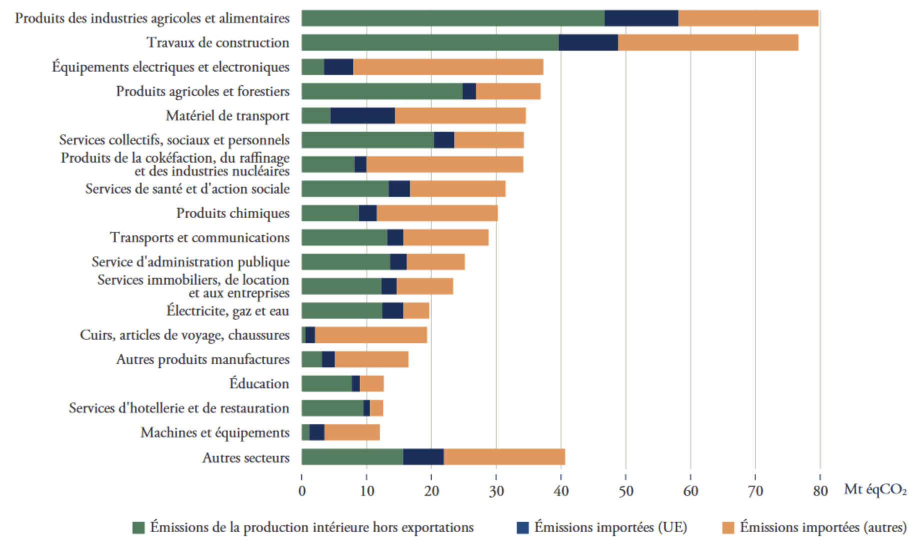
Figure 8 – Localisation des émissions
qui composent l'empreinte carbone de la France en 2011



Source : Traitements HCC 2020 d'après Malliet (2020)

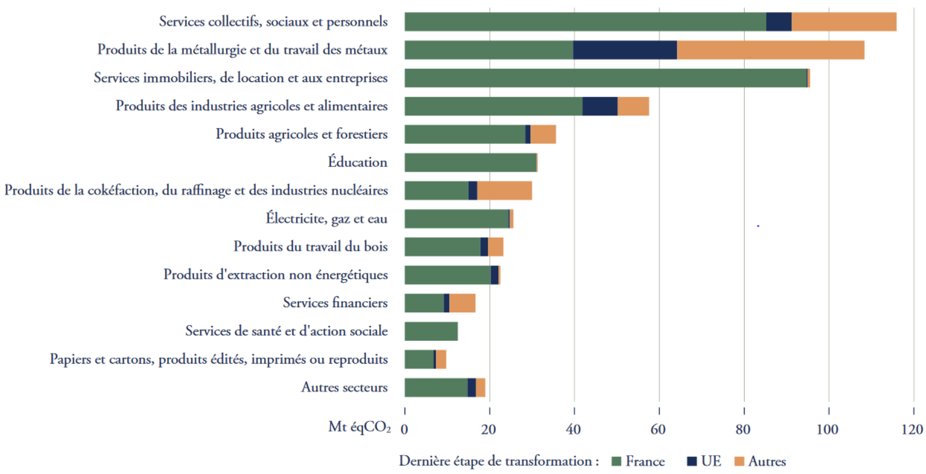
- The French situation
  - Mineral resources: metals & cement
  - Energy resources & chemical products: oil
  - Abiotic resources are a large part of it, metals in particular!
  - In terms of weight of abiotic resources in domestic emissions: oil is dominant through transport (direct emissions), followed by metals & cement (indirect and distributed emissions)

Figure 10 – Secteur et localisation des émissions qui composent l'empreinte carbone,
hors émissions directes des ménages, en 2011



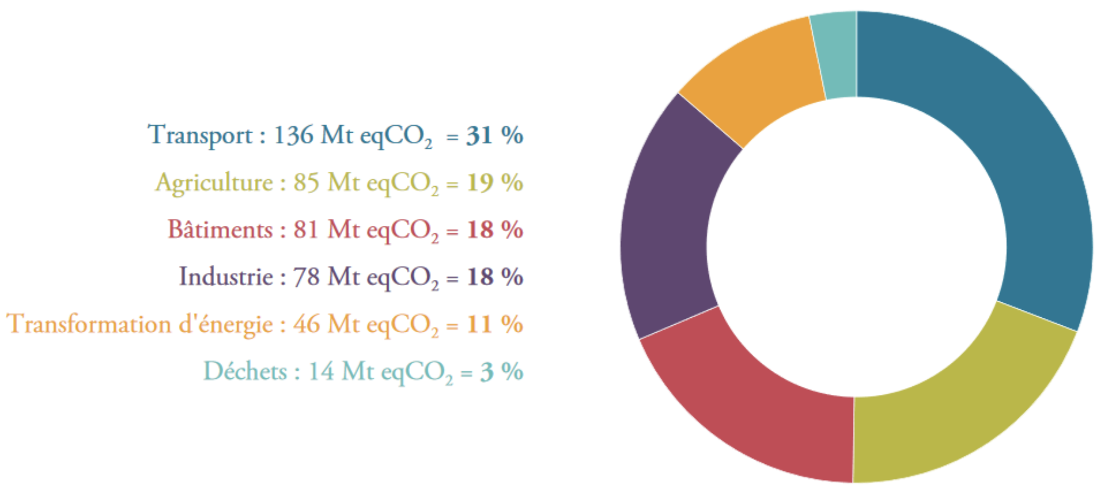
Source : Traitements HCC 2020 d'après Malliet (2020)

Figure 12 – Répartition par bien ou service et par lieu de leur dernière transformation
des émissions de GES de la chaîne amont de l'empreinte carbone en 2011



Source : Traitements HCC 2020 d'après Malliet (2020)

Figure 1 – Émissions nationales de **gaz à effet de serre en 2019**



Source : Citepa, avril 2020 – Format SECTEN

- High mitigation potential in transport <-> Combination of varied measures [31]
    - Low-carbon fuels -> higher flows of metals & lower flow of oil
    - Lowering vehicules energy intensities -> lower flows of oil & metals
    - Encouraging modal shift to lower-carbon passenger & freight systems

      -> lower flows of oil + short-to-medium term higher flows of metals for infrastructure investments
    - Avoid journeys where possible -> lower flows of oils
- This kind of configuration apply generally
    - Specific augmentations in flows of metal are required to lower oil flows
    - Competition between uses requiring metals -> priorities will need to be established

b) Economics interdependancies

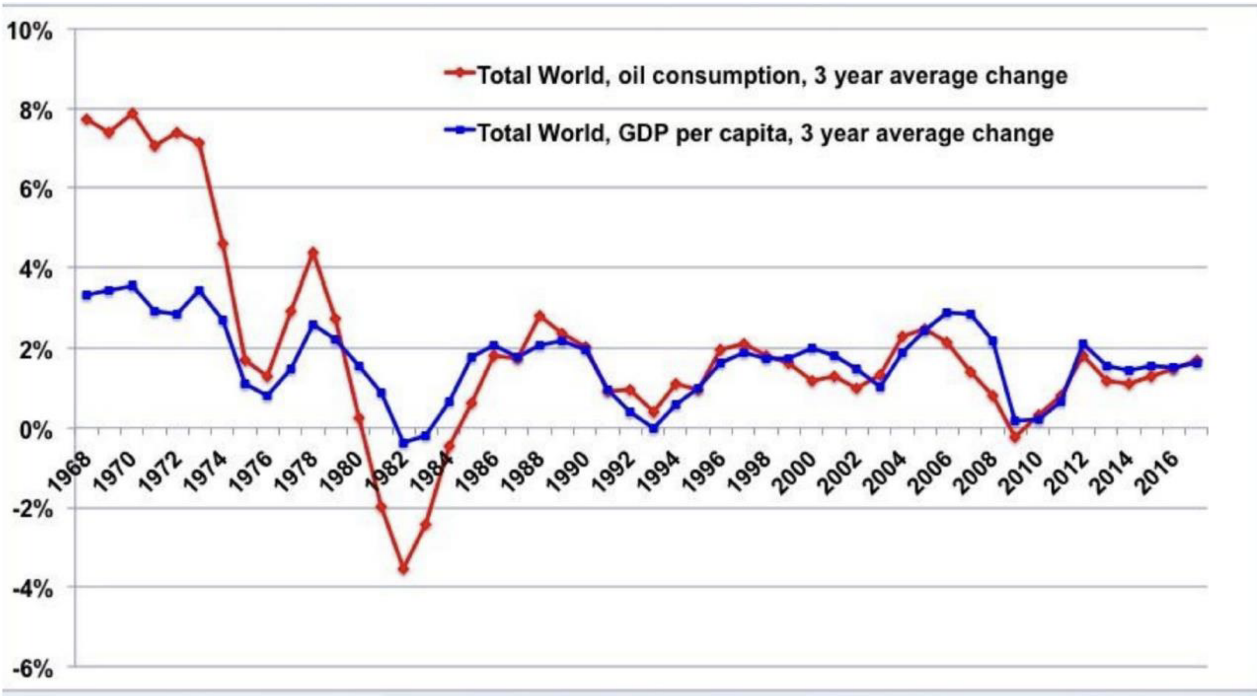
[15] JANCOVICI, Jean-Marc, 2019. Les Energies fossiles. *Ecole des Mines* [online].

[34] HABERL, H., *et al*, 2020. A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II : synthesizing the insights. DOI 10.1088/1748-9326/ab842a[1].

[33] HCC, 2020. Rapport annuel - Redresser le cap, relancer la transition. *Haut Conseil pour le Climat* [online]. 2020.

- At world scale, there is a historical link between primary energy & material consumption, and economic production (as measured by GDP) [15] & [34]
    - There is no consensus on the exact nature of the relationship nowadays [33]
    - But we know that energy & material availability enables GDP growth
    - And GDP growth, by anticipation of economic growth causes energy & material use

[1] https://doi.org/10.1088/1748-9326/ab842a

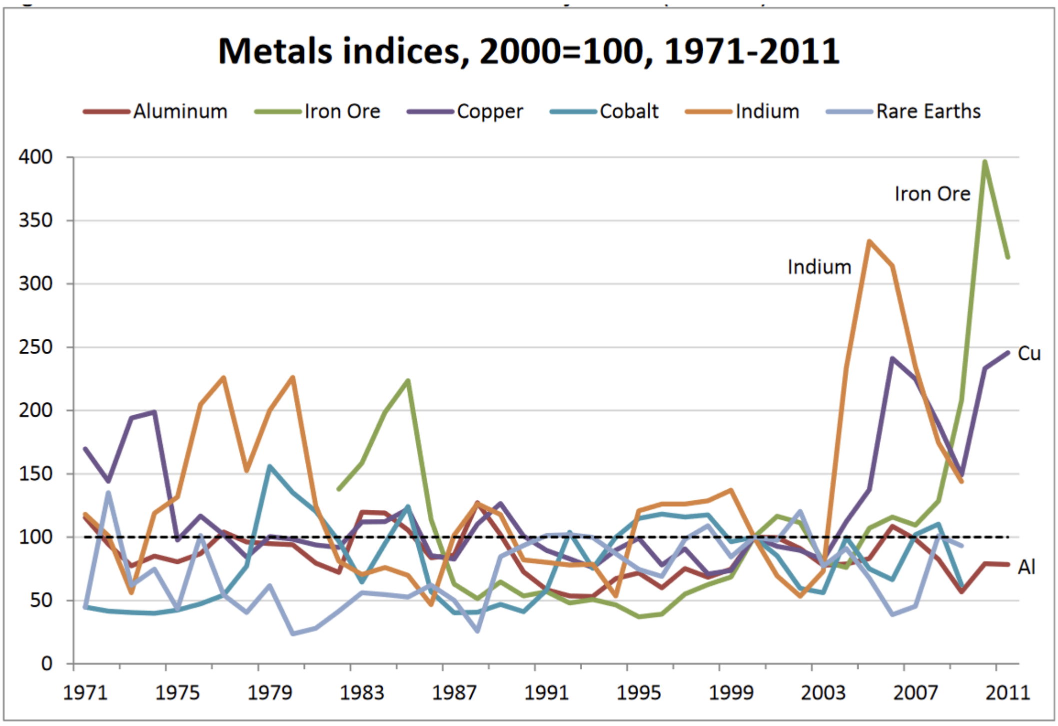


- A lot of ambitious climate target rely on the concept of « decoupling » [34]
  - Promotion of economic growth while reducing material & energy footprint (EMF)
  - When theorized as absolute -> EMF reduction & GDP growth
  - When theorized as relative -> EMF slow growth & GDP high growth
- Recent systematic review clarifies that :
  - Relative decoupling is frequent for material use, GHG emissions, but not exergy
  - Relative decoupling of GDP and primary energy use can be caused by energy efficiency (higher ratio of exergy / primary energy use)
  - Absolute decoupling situations are very rare and are related to small short-term reductions of emissions
  - No evidence that absolute decoupling can be generalized
- Degrowth/Sufficiency currently seems indispensible to meet climate target and sustainable use of abiotic resources:
  - Require a contraction of current economics functionning
  - And even fundamental changes in its functionning too
  - A byproduct of this scientific inquiries is that GDP is more & more considered as an irrelevant indicator for these problematics

c) Volatility of prices

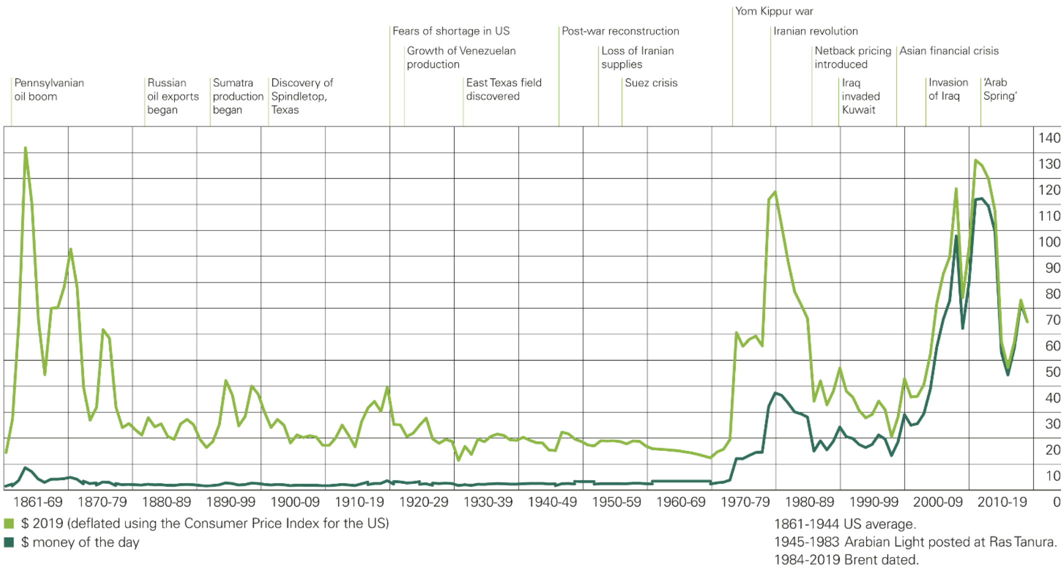
[35] ECORYS, 2012. *Mapping resource prices: the past & the future* [online]. Final report to European Comission.

- Base metals' prices are historically quite constant relatively to each others but individual resource's price is highly volatile [35]



[6] BP, 2020. BP Statistical Review of World Energy. [online].

- Oil's price is highly volatile too[6]



- Resources's prices underlying determinations
  - Percieved availability through control of producers
  - Degree of substitutability
- Resources's prices mecanisms of formations
  - Over-the-counter (OTC) markets: traditionnal mecanism
  - Annual or multi-year supply contracts: mainly, Fe and Fe allows
  - Pricing on forward markets
  - Special case of precious metals: considered as quasi-money or OTC.
- Historically, numerous resources exchanges were operated by intermediates

- Contemporary period: developpment of financialization
- Alignment of Raw materials on securities -> far less intermediaries
- Developpment of financial product derivatives + capitalistic concentrations of producers

  -> overvalued prices and speculations

[36] MITTEAU, Gilles, 2018. Economie et finance du pétrole - Heu?reka. [online].

- Financial markets's specific effects
  - Efficiency of market -> Trends of prices themselves tend to diseapear
  - Short-term interest of traders -> Short-term volatility
  - Complexity of the product and implications of prices variations on the economy

    -> Long-term volatility + impossibility to know for sure the causes of prices variations

  -> There is no « natural price-signalling » mecanism that makes a non- renewable resource progressively more expensive overtime

  -> The « natural » functionning of Financial markets seems to impply that the reduction of energy & material flows lead to higher volatility, or maybe higher « volatility of volatility »

For detailed reasonning, strong recommendation of Youtuber Heu?reka on Economy & Finance of oil

2.2. Contracting flows

a) Limits of efficiency

- Like recycling, energy efficiency is necessary
  - Allow to reduce flows for a given performance
  - 25% energy yield -> 30% energy yield -> 1/6 of oil flows spared per year
  - 25% energy yield -> 50% energy yield -> 1/2 of oil flows spared per year
  - Same goes for « material efficiency » (diminshing the quantity of material needed to achieve a given functionnality)
- But it is not sufficient, and could even be harmful on the global scale
  - Energy efficiency, when only measure applied, have mainly cost reduction effects
  - Cost reduction could then lead to democratize preexisting uses or create new ones
  - This then would lead to an overall increase in energy consumption

[37] SORRELL, Steve, 2007. *The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency*. [online]. UKERC

- This would be called a « ***rebound effect*** » [37]
  - The « economy-wide » rebound effect is of combination of direct and indirect rebound effects that can interact with each other
- Some basic examples of direct rebound effect :
  - If fuel-efficient vehicules make travel cheaper -> Consumers may choose to drive further / more often -> Offsets the energy savings
  - If a factory uses energy more efficiently -> Becomes more profitable -> May generate further investments -> More production
- Some basic examples of indirect rebound effect :
  - Drivers of fuel-efficient cars may spend the money saved bying petrol on other energy intensive goods or services (ex: overseas flight)

[38] JEVONS, William Stanley, 1865. The Coal Question. . 1865. P. 213.

- Rebound effect concept coms back to the XIXth century
  - Firstly known as « Jevons paradox » from W. J. Jevons [38]
  - Steam-engines' efficiency had been increased by 10-fold at least in a century
  - Consumption of coal had greatly increased anyway (x 6 in 50 years)
- The same considerations could be made about today :
  - Energy efficiency of cars' engines have never been better
  - Our oil cosumption dedicated to it have never been higher

  -> Could be explained by:
  - The growth of car use driven by low cost of oil
  - And spared cost of cars invested in high-tech supplementary functions which increase car's weight and maintain oil consumption
  - The increase in heavy vehicules like SUVs

[39] STERN, David I., 2017. How accurate are energy intensity projections?. DOI 10.1007/s10584-017-2003-3[1].

- Quantified contemporary estimations are complicated :
  - There is indeed a correlation between various measures of energy efficiency and continuing growth of overall energy consumption
  - But the causal links between these trends are not clear
  - Difficulty to assess other things than direct rebound effects
- That being said, evidence suggest that : [37]
  - It has the potential to widely vary between technologies, sectors, income groups
  - In OECD countries, automotive transport, household heating & cooling can relatively robustly be considered subjects to a direct rebound effect of 10-30% (microscale)
  - Current energy or material efficiency policies are not up to the task (macroscale)
- Predictions of energy footprint decline itself are generally too optimistic [39]

b) Physics inevitability

[40] HALL, Charles A. S., et al., 2014. EROI of different fuels and the implications for society. DOI 10.1016/j.enpol.2013.05.049[2].

- Material & Energy flows will decline anyway due to the physics underlying the production peak
  - We've seen that the decline in ores's grade do lead to an exponential demand in energy for base metals extraction, and that a mineralogical barrier can happen for rarer metals
  - But oil itself needs energy to be extracted!
- Last notion of this course : ***EROI – Energy return on investment***
  - Ratio of energy delivered by a specific energy vector and the energy invested in the capture & delivery of this energy
  - Measures the relative quality of energy vectors
- Varied possible choices of boundaries in systemic assessments, so as much EROI calculations: standard ; point of use ; extended ; societal
  - Estimates re complicated due to oil compagnies low level of transparency

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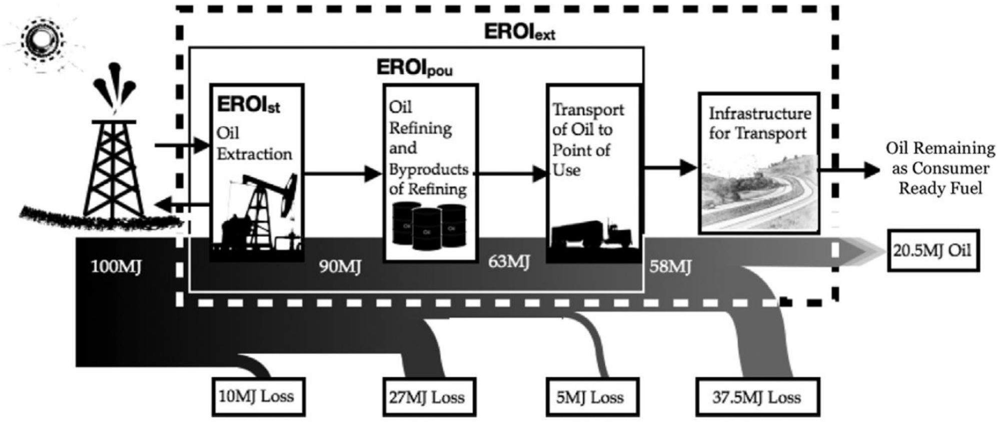
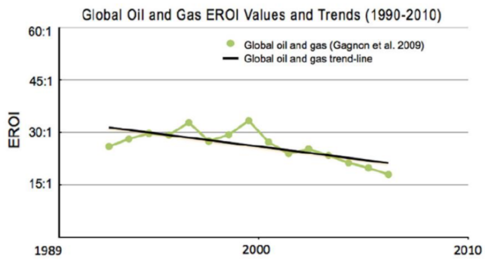
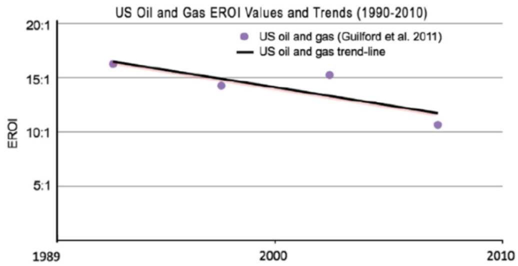
[1] https://doi.org/10.1007/s10584-017-2003-3
[2] https://www.sciencedirect.com/science/article/pii/S0301421513003856?via%3Dihub

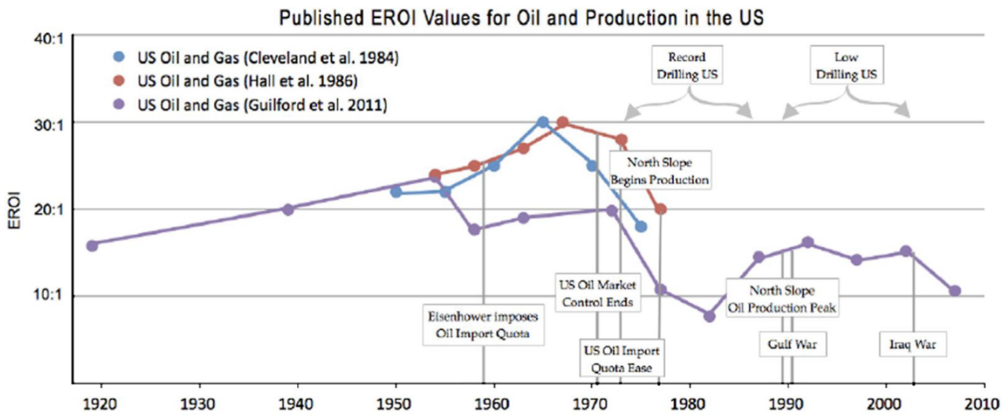


- As oil is often extracted together with natural gas, calculations can be tricky
  - But all estimates tend to show a progressive decrease in EROI for every place where data is available : ***here in USA***

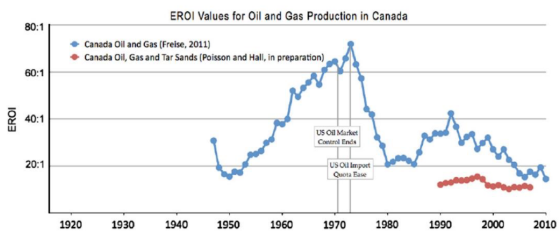


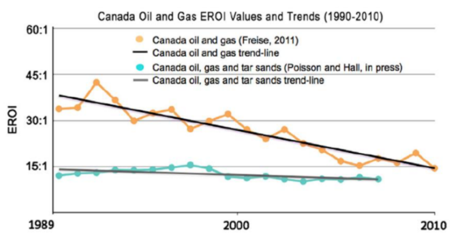


- Is there a trend for oil already?
  - It seems so
  - All estimates tend to show a progressive decrease in EROI for every place where data is available : ***here in USA***

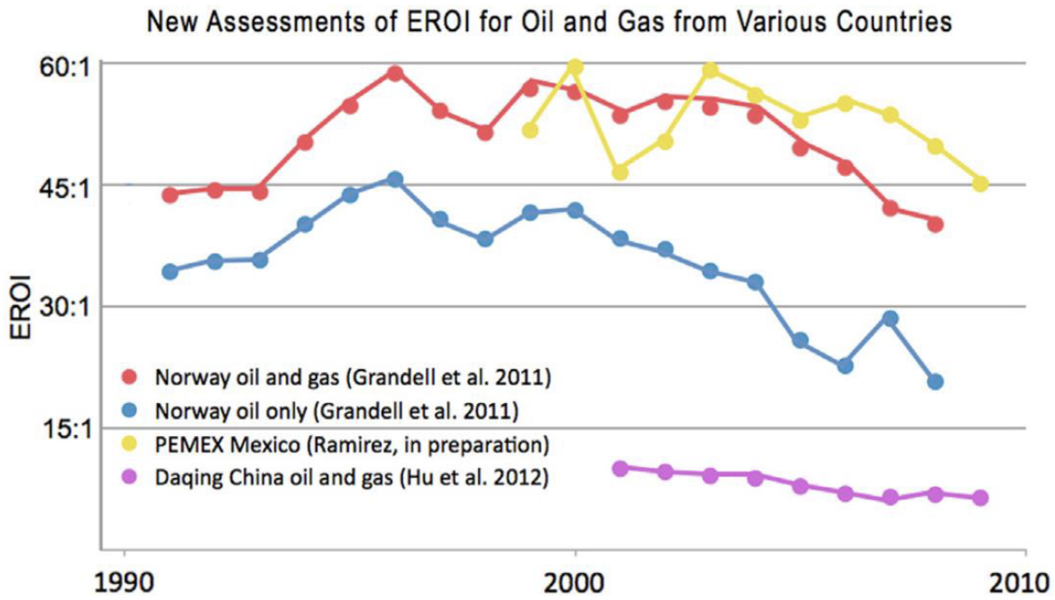


- Is there a trend for oil already?
  - Pretty much so!
  - All estimates tend to show a progressive decrease in EROI for every place where data is available : ***here in Canada***

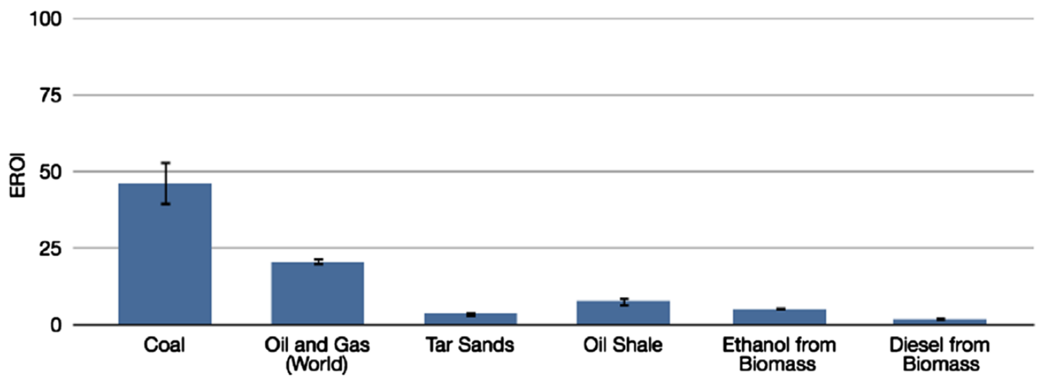




- Is there a trend for oil already?
  - Undeniably so!
  - All estimates tend to show a progressive decrease in EROI for every place where data is available : ***here in various other countries***



- It is logical from what we've seen about the concentration of resources in general. But why does it especially matter here?
  - The decrease of the EROI of conventionnal oil means we'll need to set aside a growing share of the oil flows just to continue to have a flow
  - This share of oil « lost » will no longer be used to supply other sectors [36]
  - Non conventionnal oils have a base EROI quite lower than conventionnal (and will also decrease with their further exploitation) [40]



c) Managing consequences, tackling causes

[36] MITTEAU, Gilles, 2018. Economie et finance du pétrole -Heu?reka. [online].

[40] HALL, Charles A. S., *et al.*, 2014. EROI of different fuels and the implications for society. DOI 10.1016/j.enpol.2013.05.049[1].

[33] HCC, 2020. Rapport annuel -Redresser le cap, relancer la transition. *Haut Conseil pour le Climat* [online]. 2020.

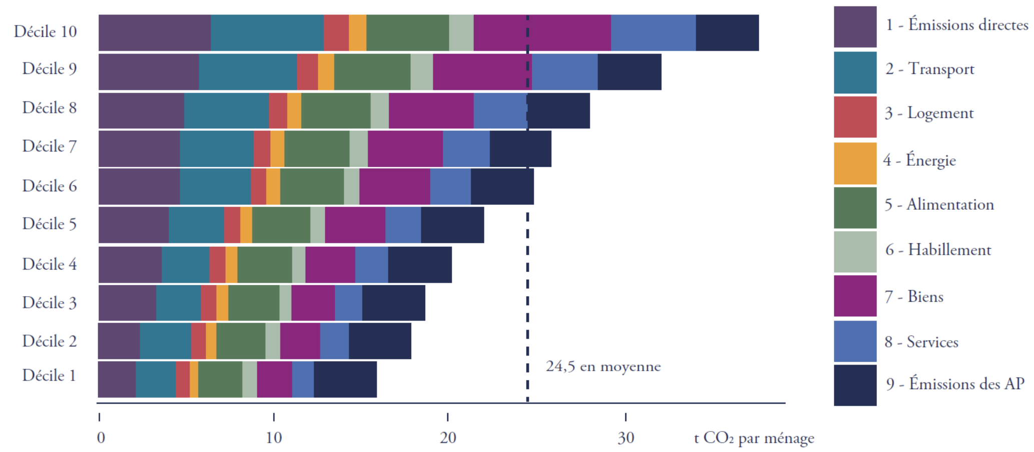
- As there is no absolute decoupling, a contraction & instability of economy and as we know it seems unavoidable in the medium-term, regardless of climate change [36] & [40]

[1] https://www.sciencedirect.com/science/article/pii/S0301421513003856?via%3Dihub

- By « economy », here, we mean that all socioeconomical & geopolitical relationships will be impacted
- Social acceptability of dynamics created by contracting flows will be a key component of the success ofmitigating policies [33]

-> Ecological transition is also a social one

Figure 23 – Empreinte carbone par ménage,
décomposée par source et produit selon les déciles de niveau de vie



Source : Malliet *et al.* (2020) d'après EXIOBASE 3, INSEE BdF 2011 et SDES-CGDD - http://carbonconsumptionsurvey.eu/

- This is were we, as engineers & citizens, have apart to play
- We would gain a lot to take inspiration from the 7 principles of low-techs [30]
    1. Challenging needs
    2. Design and produce truly sustainable
    3. Orienting knowledge to resources' savings
    4. Striking a technical balance between performance & conviviality
    5. Relocalize without losing the right scale effects
    6. De-machinizing services
    7. Knowing to remain modest

[30] BIHOUIX, Philippe, 2014. *L'Age des low techs : vers une civilisation techniquement soutenable.* Seuil.

2.3. Medias

https://pod.utt.fr/video/3950-ev14-abiotic-resources-71-stakes-of-flows/

https://pod.utt.fr/video/3951-ev14-abiotic-resources-72-contracting-flows/