Robotics under planetary constraints

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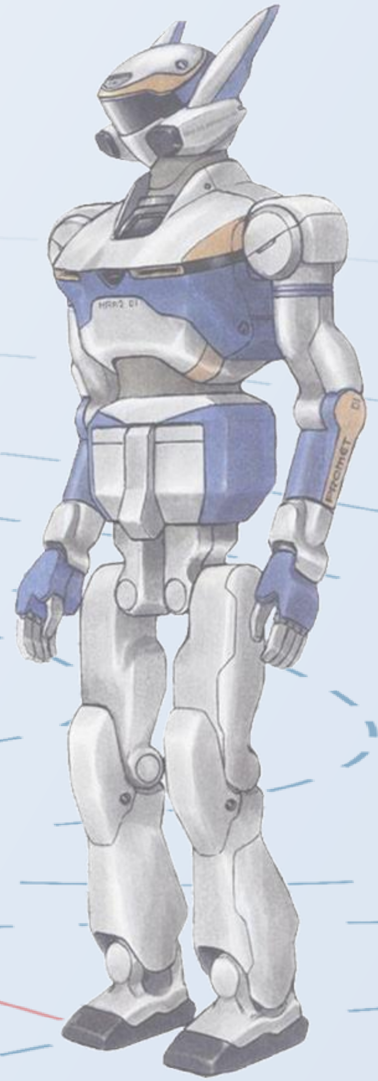


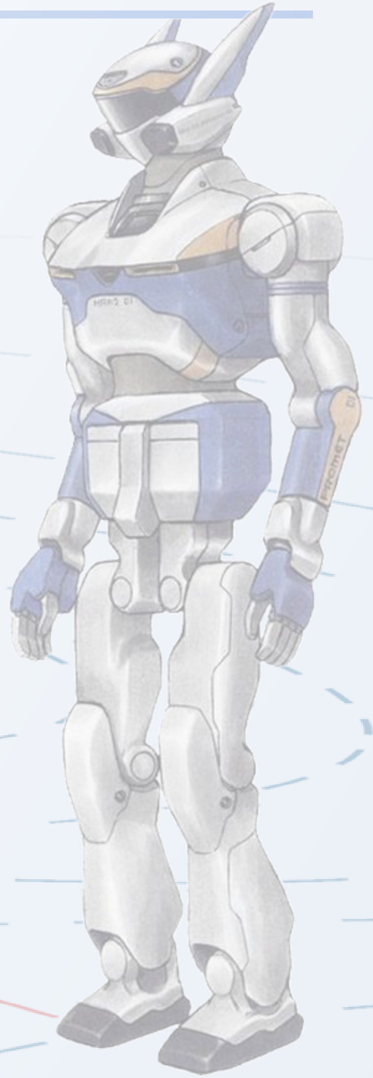
Inria

Aim and outline

- Pushing on many limits of Earth: constraints appearing
  - This should and will change the way we work as roboticists
- Aim:
  - make us think about the way we work
  - push the robotics community to embrace the topic

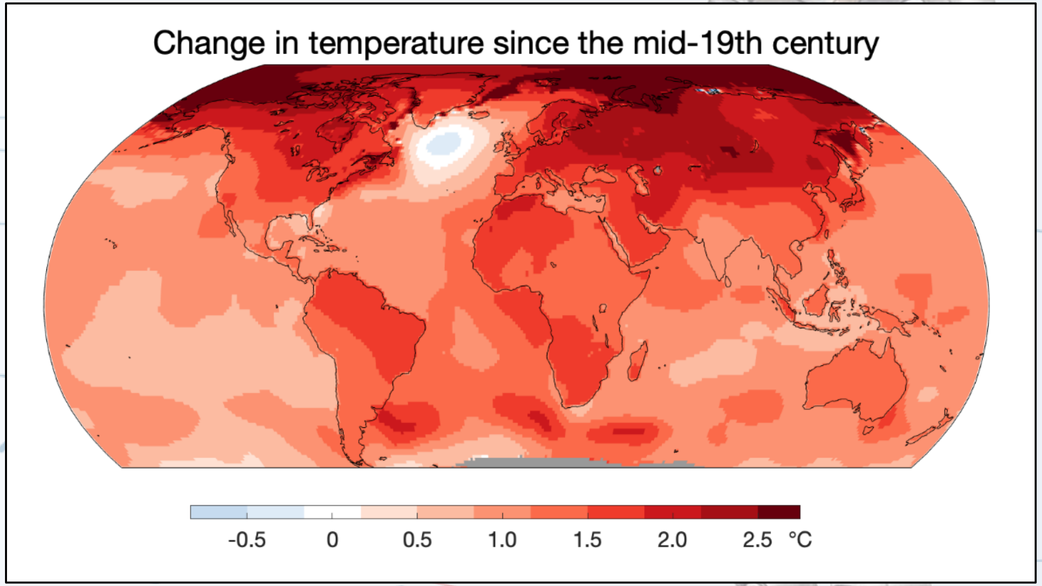
- Outline:
  - Climate change
  - Resources constraints
  - Some implications and questions for robotics

- Warning:
  - More questions than answers, no turnkey solutions
  - Simplifications



Numbers and climate change

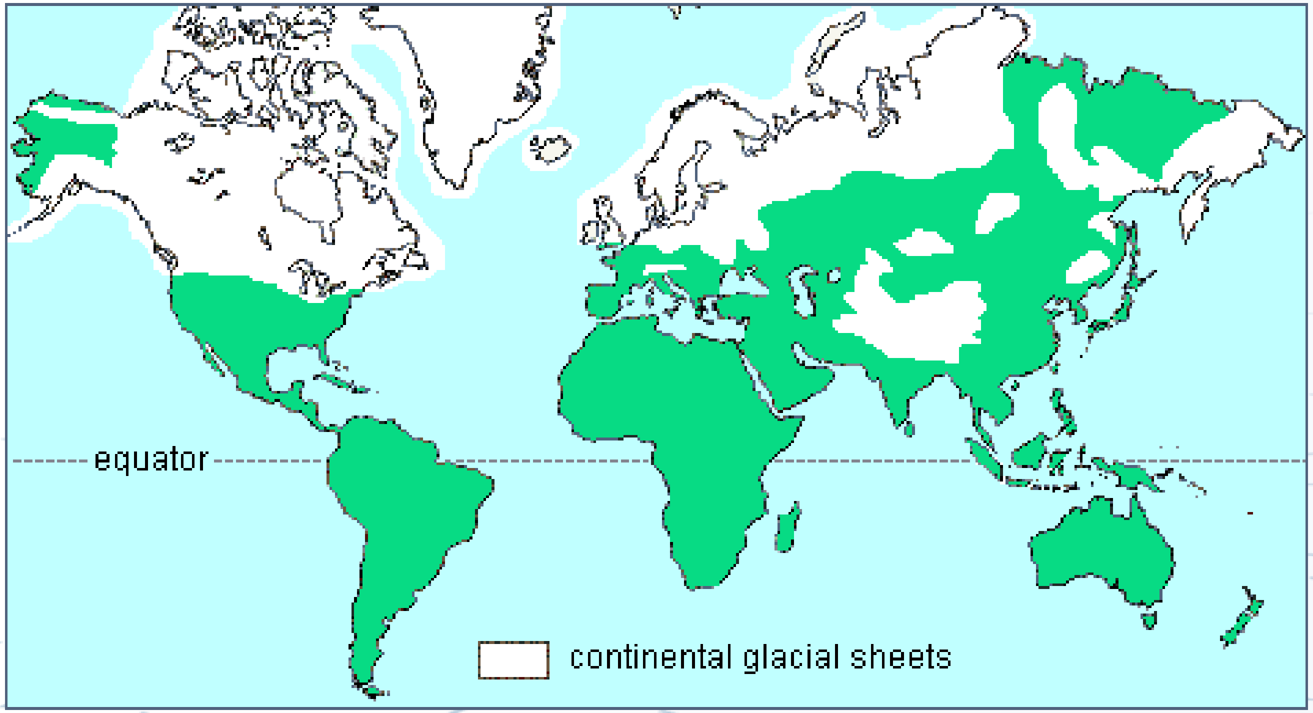
- We see a variety of numbers:
  - Current warming: +1.1°C
  - Paris Agreement: +1.5°C, +2°C
  - French government: adaptation to 4°C
  - In 2100
- GMST: Global Mean Surface Temperature
- Reference temperature: average of 1850-1900
- Local vs global
  - Oceans, continent , poles
  - GMST 1.1 °C -> 1.7 °C in France
  - GMST 2.7 °C -> 4 °C in France

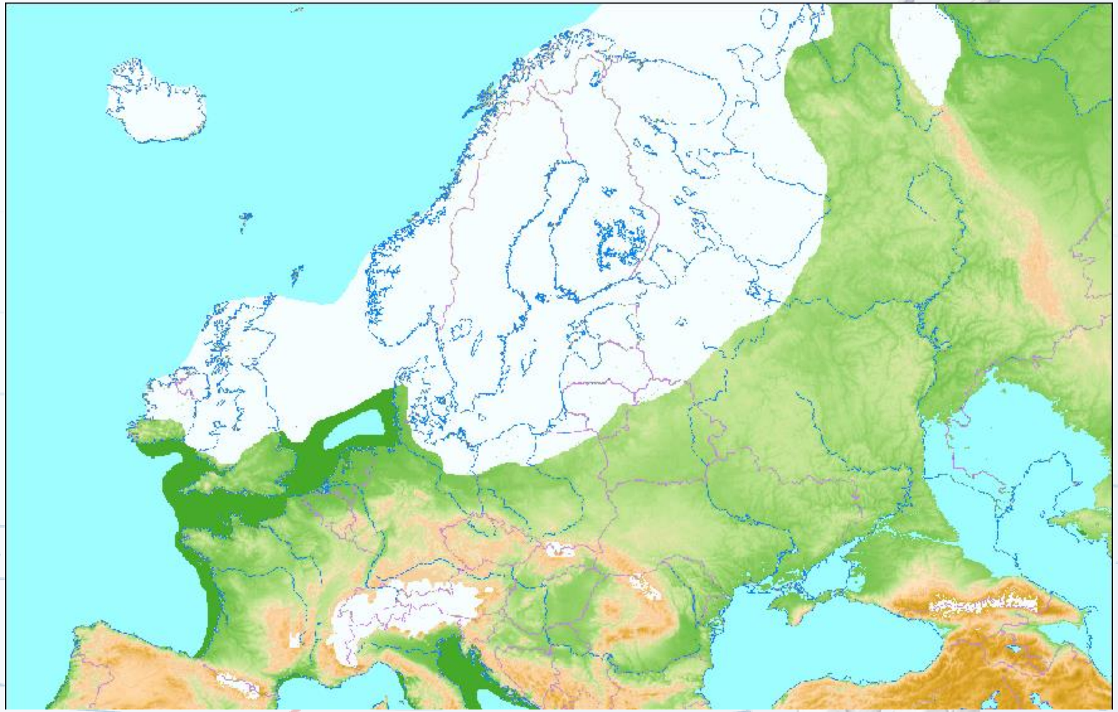


Ed Hawkins, Climate Lab Book, 2021

Impact and magnitude of the corresponding changes?

20 000 years ago: last glacial maximum





Wikimedia Commons user Ulamm

- Ice sheet reaches New York, England
- 3 km of ice above Scandinavia
- Sea level -120m, Channel River
- Artic tundra in France

-4/-5° C difference
Change took 10 000 years

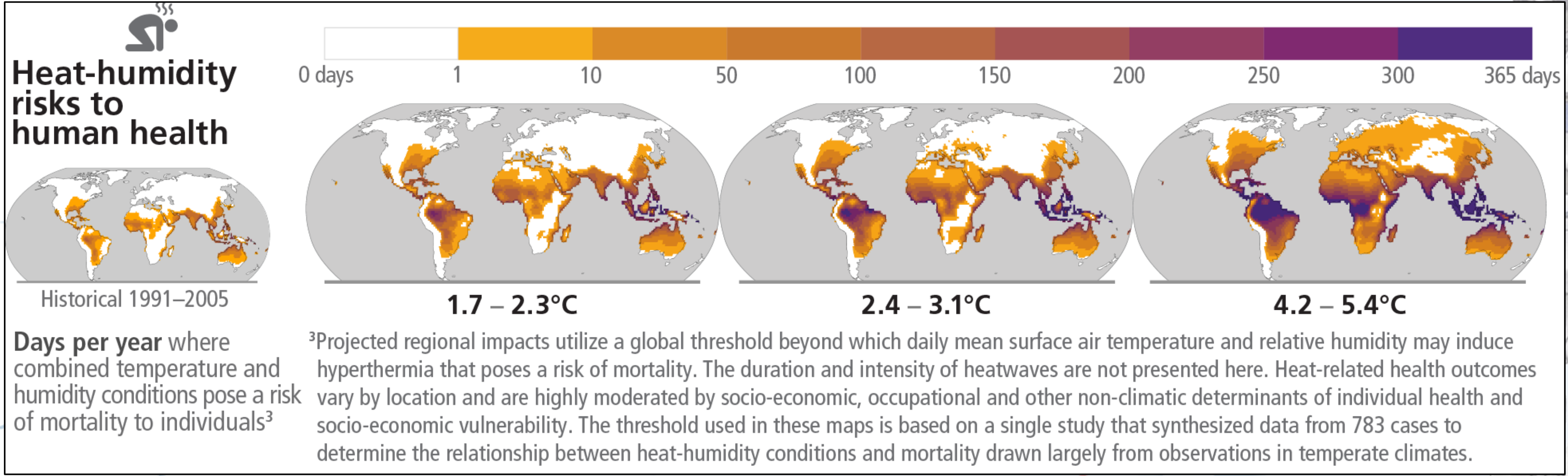
Novel experiment: 2-3[2.7]° C in 200 years

Some consequences of global warming (1)

- 1.5°C: likely tipping point for glaciers and glacial sheets (Greenland, West Antarctica)
- 2°C: possible tipping point for permafrost
- Sea level rising:
  - Lot of inertia
  - Committed for hundreds of years and several meters-tens of meters
- Risks to humans and ecosystems
  - Water scarcity
  - Loss of humidity in soils
  - Crop yield decline
  - Extreme events increased frequencies
  - …
  - At +3 °C: generalized food supply instabilities

Some consequences of global warming (2)

- Temperature>35°C, humidity saturation



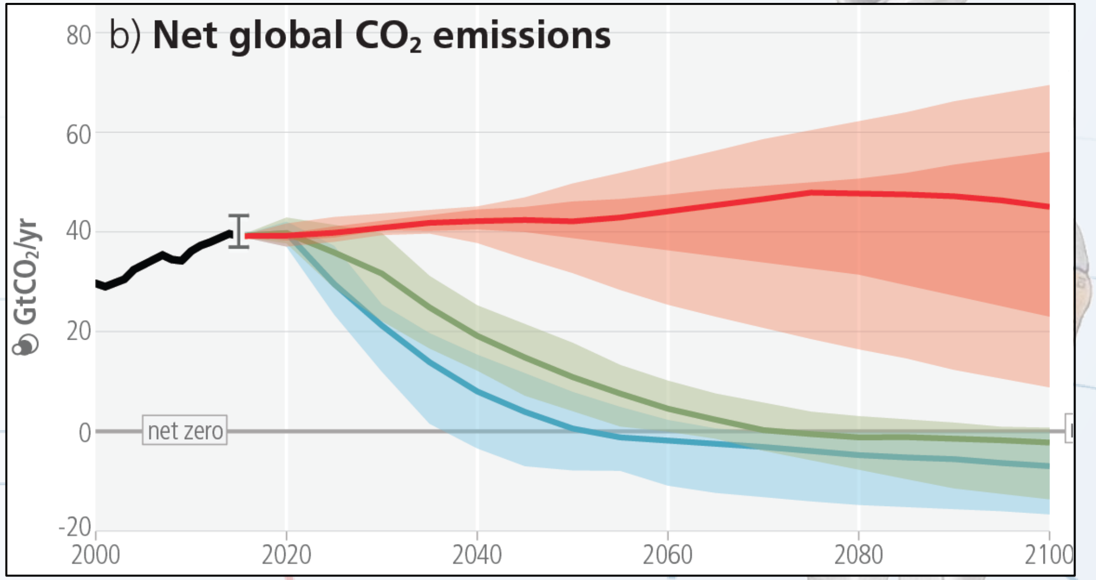
IPCC AR6 Synthesis report, Summary for policy makers, fig SPM3 b)

- +2°C pathway in 2050: areas with unlivable days half of the year are home today to 1-2 billion people
- Current trajectory in 2100: half of the world population

- Significant risks of migrations, geopolitical tension, political instabilities and wars

Carbon budget

- Link between temperature and Greenhouse Gases (GHG) concentration
  - CO_2 main driver, long stay in atmosphere
  - CH_4, NO_2, … very potent



IPCC AR6 WGI, table 5.8

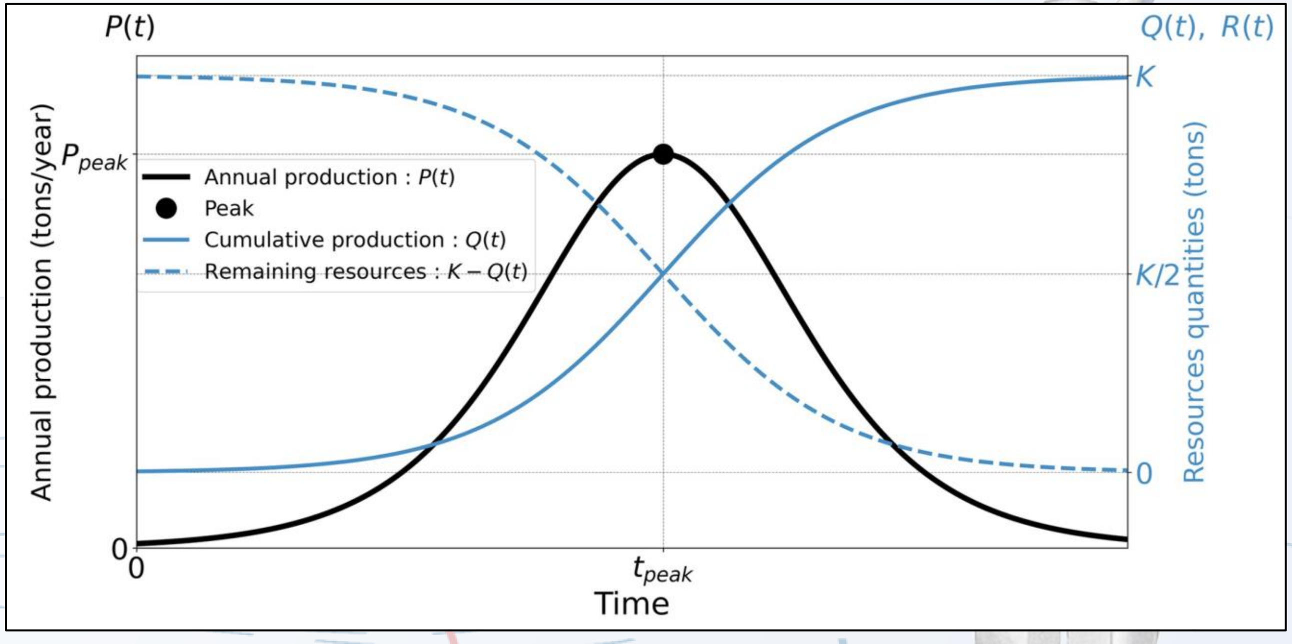
- Remaining emission budget of CO_2:

Target	As of 01/01/20	As of 01/07/23	At current rate	Required decrease
1.5°C (50%)	500 Gt	360Gt	9 years	11-12%/year
2°C (83%)	900 Gt	760Gt	19 years	5-6%/year

- Current rate: ~40GtCO_2/year

Limit on resources

- Finite planet -> finite stock of non-renewable resources
  - Finite subset of accessible resources
- Necessarily:
  - Production/extraction peak -> tensions if demand does not decrease
  - Asymptotic production/extraction is 0



Riondet et al (2023) Applicability of Hubbert model to global mining industry: Interpretations and insights. PLOS Sustain Transform 2(4): e0000047

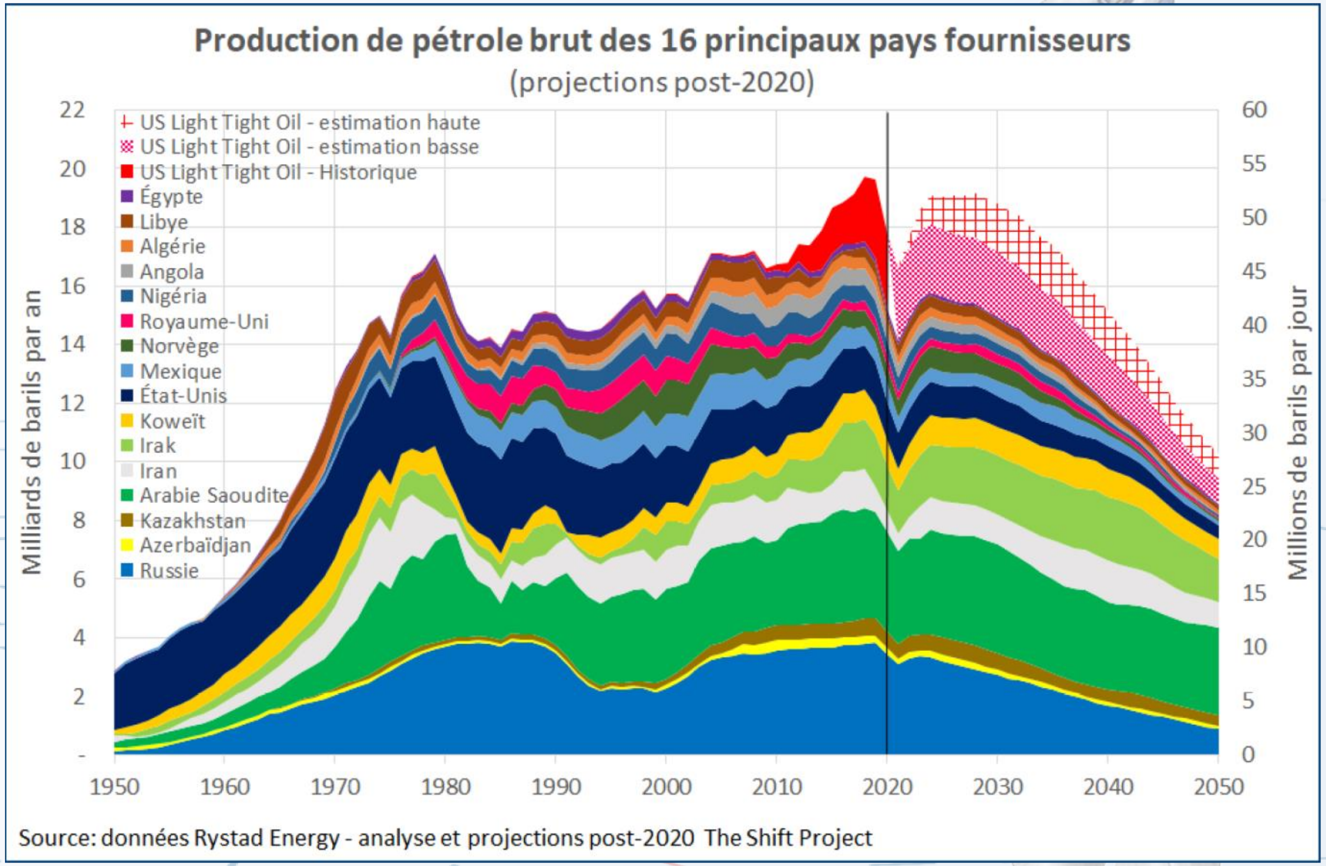
- Some resources have passed their peak or will in the coming decades

Limit on fossil fuels

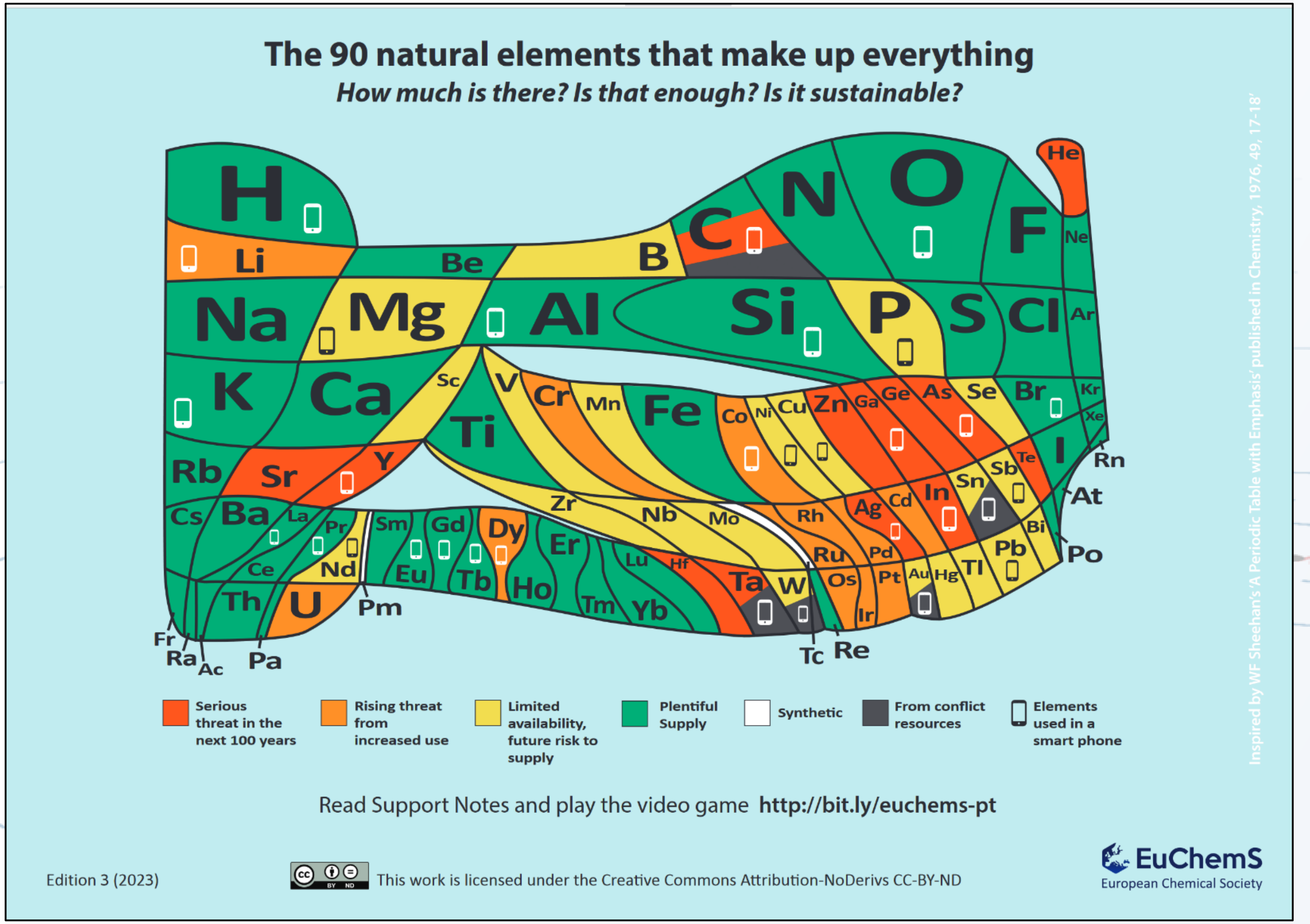
- Projection for Europe oil suppliers:
  - -50% production by 2050
  - -> supply for Europe divided by 2-20
- Europe in constrained decline since 2008

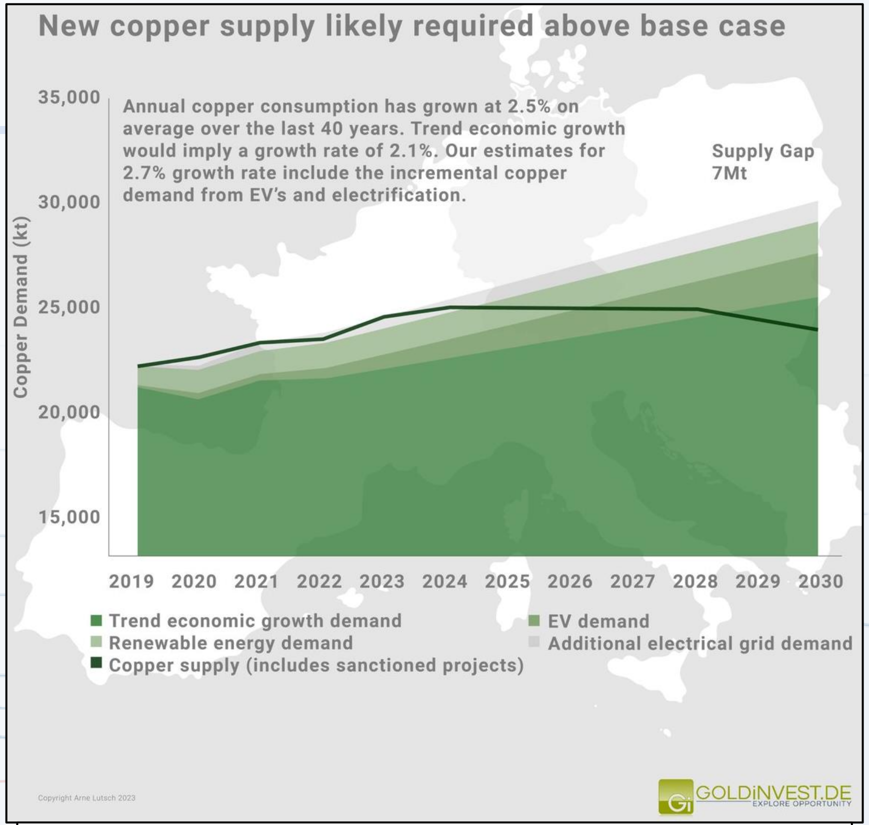
- IEA: worldwide peak oil by 2028
- Gas peak to follow in 203X
- Coal does not travel well

- Fossil fuels: still 80% of primary energy
  - Huge dependency of our industrial civilization (incl. worldwide supply chain)



Limit on metals

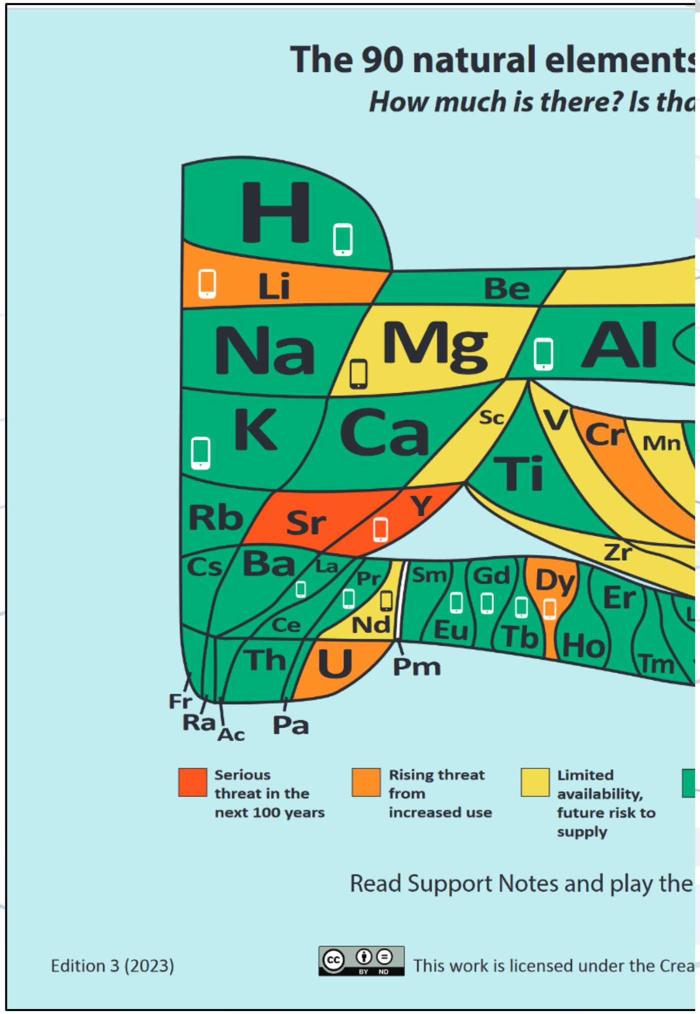


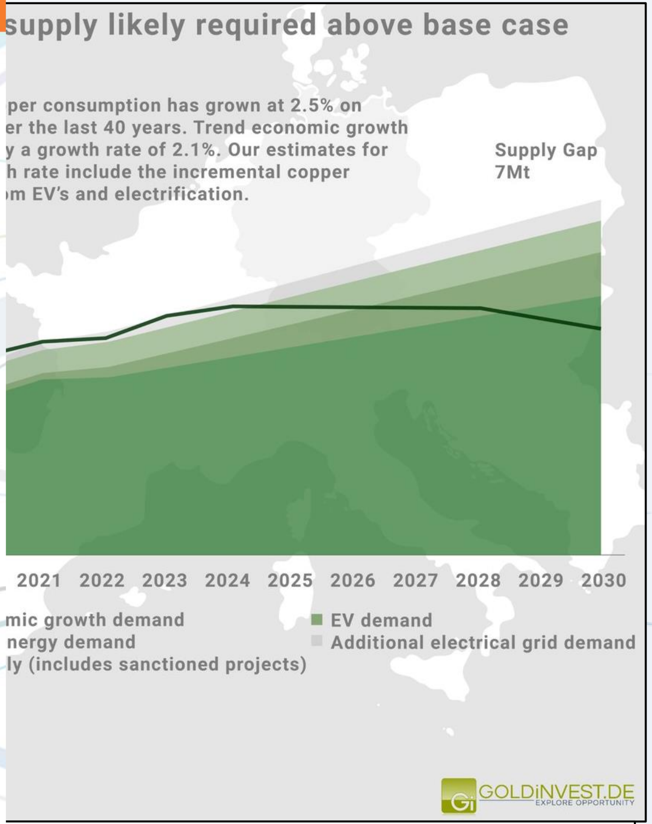


The New York Times

The U.S. Needs Minerals for Electric Cars. Everyone Else Wants Them Too.

The United States is entering an array of agreements to secure the critical minerals necessary for the energy transition, but it's not clear which of the arrangements can succeed.






The New York Times

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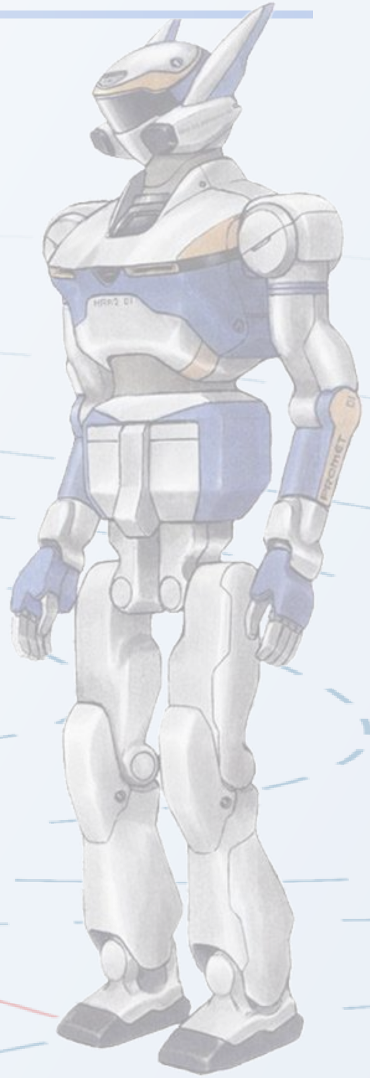
Physical constraints

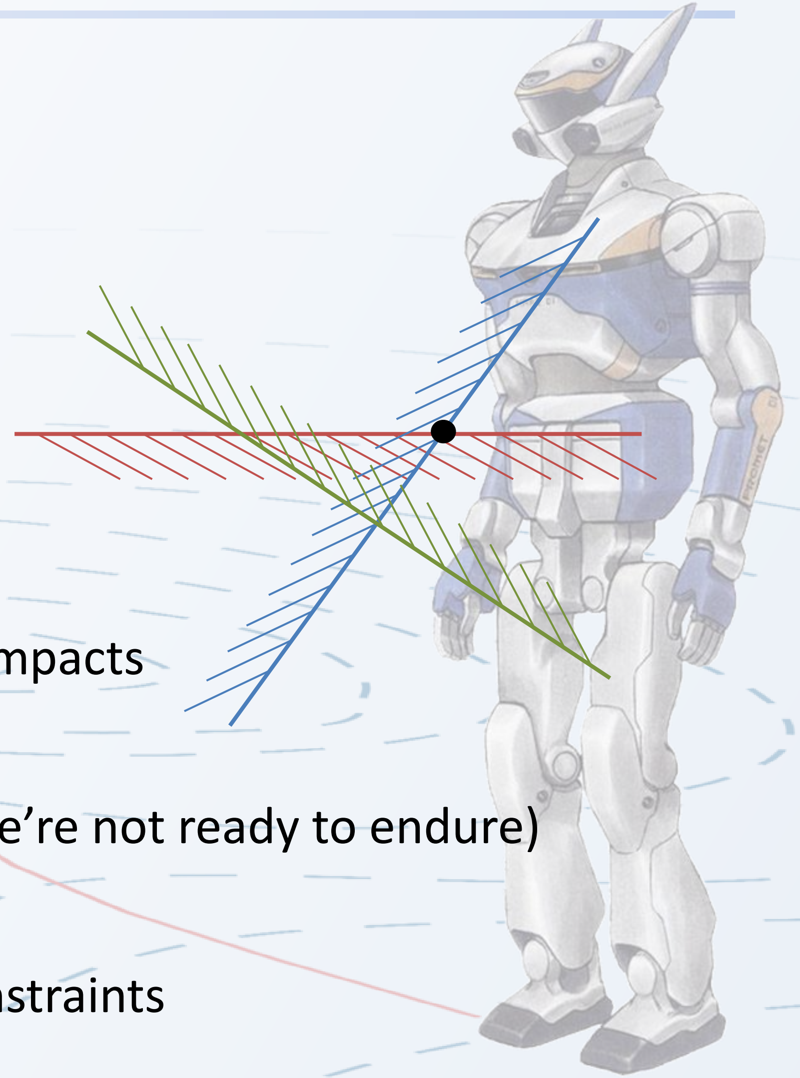
- Facing more problems with less resources
  - Whether we want to address the problems or not
- Constraints -> competition for usages
  - Need for choices
- Some domains have no foreseeable solutions
  - E.g. intercontinental mass transportation (people and goods)
- Zombie technologies (José Halloy)
  - Unsustainable -> will not last
- Future technologies
  - Can’t be depended on (time and resources)



What about robotics?

What actions can we take, professionally?

- (Importance of individual and government actions)
- For roboticists:
  - General actions as a researcher, in the research system
  - Why do we do robotics?
  - How do we do robotics?
- What we should do
  - Limitation of climate change, of resources exhaustion and their impacts
- *vs* What we’re ready to do
  - Deviation from our habits/expectations (cost of inaction: what we’re not ready to endure)
- *vs* What we’ll have to do
  - Physical limits & adaptation to adverse conditions, legislative constraints



At the lab level

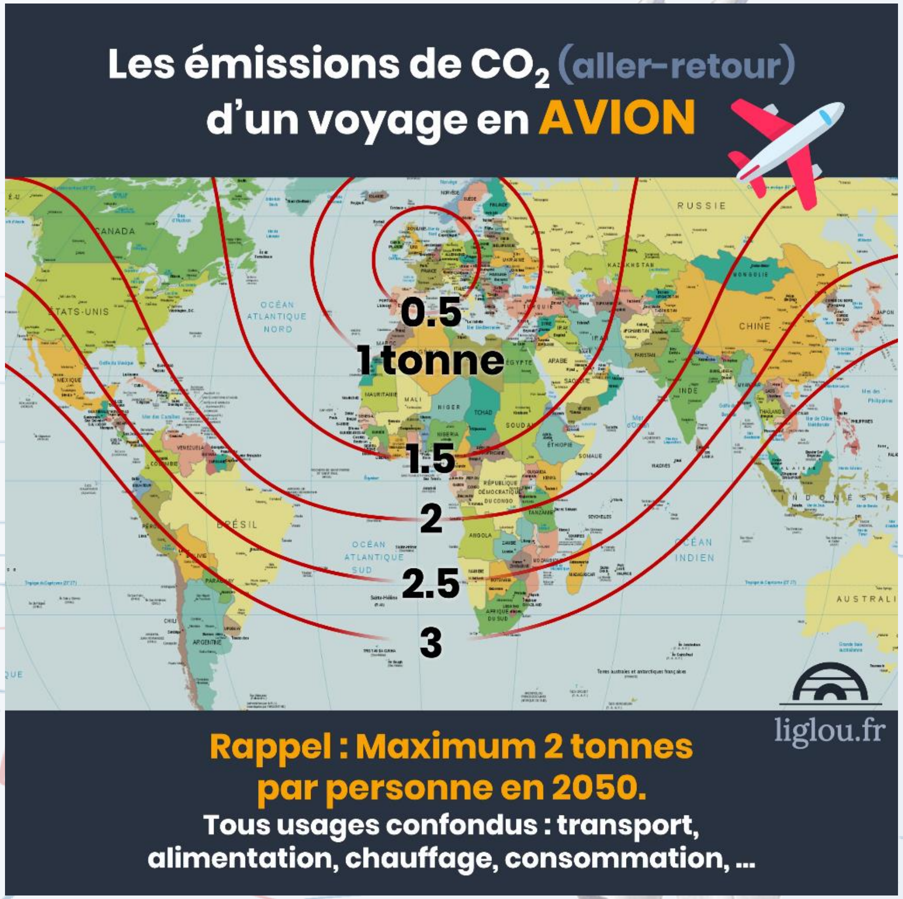
- Carbon footprint
  - Daily commute
  - Missions
  - Purchases
  - Energy (heating, computations, …)
- Target of -5% yearly: where to gain?
  - Daily commute: smaller or shared vehicles, low-carbon alternatives, telework (/!\ rebound effect)
  - Missions
  - Purchases: keep equipment longer, no budget-finishing purchases, …
  - Energy: building insulation, efficient heating/cooling systems, …

  } Need for institutional support (Missions, Purchases, Energy)
- Sharing experiences with other laboratories

Missions and conferences

- Less flying
  - Especially long haul (Paris – East US Coast: ~2tCo_2e)
  - Less people
  - Less frequent
  - Shorter distances
- Difficult choices

- How do we organize scientific exchanges?
  - Less conferences? Multi-localized? Only at convenient hubs?
- How to improve hybrid/online gatherings?



At community and institutional level

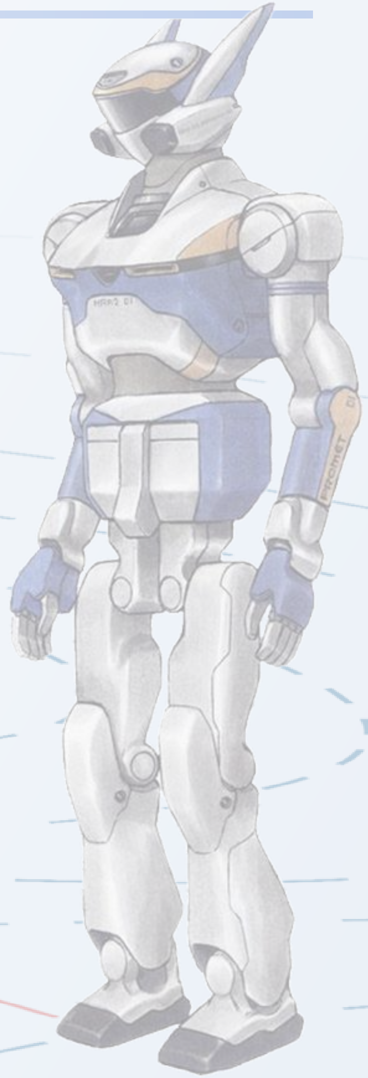
- Ministère de l’Enseignement Supérieur et de la Recherche climate plan:
  - -2%/year of GHG (“5% might be unattainable and demotivating”)
  - -5%/year of energy
- CNRS
  - COMETS (5/12/22): “La prise en compte des impacts environnementaux de la recherche doit être considérée comme relevant de l’éthique de la recherche, au même titre que le respect de la personne humaine ou de l’animal d’expérimentation.” [It is ethically important to take the environmental impacts of research into account]
  - Workshop “Intégrer les enjeux environnementaux à la conduite de la recherche”
  - WIP and slow evolution of the administration
- Communities:
  - GDR Labos1.5, GDR Défis théoriques pour les sciences du climat, workshops of GDR robotics, 2rm,…
- Internationally?

Direct and indirect impacts of robotics

- Not only about how we do research, also about its impact

- Cars vs robots
  - 500 000 new robots per year
  - 80 000 000 new cars per year
- CO_2 cost of robots << cars
- But no robots -> way less cars

- Large scale use of robots: key enabler of environmental damages
- Can we still aim at increasing the industrial production?



Direct and indirect impacts of robotics (2)

- Ethics committee of CNRS (COMETS):

> Le monde de la recherche doit ainsi se demander dans quelle mesure le fait d'utiliser ou de développer tel grand équipement (...) ou de travailler sur telle thématique (...) est susceptible d'engendrer des impacts néfastes pour la biosphère, de conforter à moyen ou long terme des modes de production ou de consommation non durables, etc. Inversement, la recherche doit maximiser son rôle moteur pour produire et mettre en valeur des savoirs permettant d'élaborer des solutions face aux bouleversements environnementaux en cours.

> Researchers must consider how the use or development of a large equipment (…) or researching a given topic (…) may generate negative impacts for the biosphere, favor medium- or long-term production methods or unsustainable consumption, etc. Conversely, research must maximize its driving role to produce and promote the knowledge necessary to deploy mitigating solutions for the environmental disruptions in progress.

Justifying our research

- We can’t ignore the possible impacts of our research
- Our research should actively promote solutions

- How do we justify (carbon budget, resources and other environmental costs)
  – Increase in mechanical complexity, in computational power?
  – Large scale/high impact robot deployment?
  – Low scale/no impact research?
- Usage conflicts: are we ready to defend our research?
- How do we (not over-)sell and evaluate our research?
  – Place of the environmental issues?
  – Carbon budget?
  – Tools and rules?

Robots as solutions?

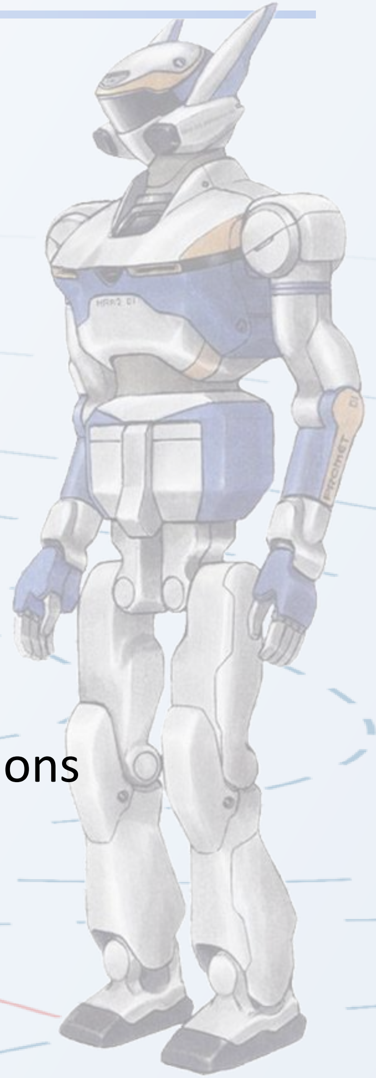
- Climate-wise, machines are the problem
- Resource-wise, constraints are coming
- -> How can developing more robots be a solution?
- Less robots and new robots only when positive impacts?

- Some possibly positive-impact ways:
  - Direct contribution to an environmental problem mitigation (/!\ moving the problem elsewhere)
  - Direct and measurable acceleration of a solution deployment (e.g. renewable energy collectors)
  - Making viable localized, non-specialized production (vs global hyper-specialized supply chain)
- This would require much more capable robots:
  - Can we develop them in time? How to make them sustainable?

Conclusion

- Humanity is heading toward troubled times
- We shouldn’t and can’t ignore the problems
  - cost of inaction, hard physical constraints

- We must make efforts to dampen the problems at every level
- Including in the robotic field:
  - Change the way we do research to quickly and drastically reduce our direct impact
  - Pay attention to the impact of robots and not oversell potentially damaging applications
  - Gather as a community to really think about the applications
- This is the price to justify our work



THANK YOU FOR YOUR ATTENTION