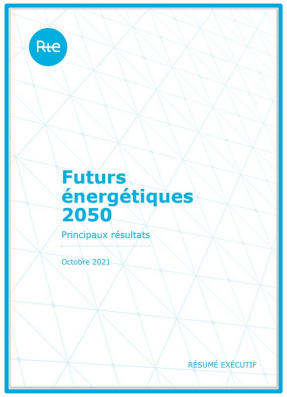
Le réseau de transport d'électricité

# How to steer research and innovation ? Carbon neutrality… and the other half of the parachute

**CEA-Liten Days**
**2022 December 1st**

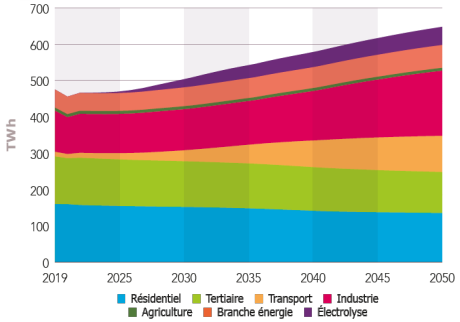
# “Energy pathways to 2050” : how to implement the National Low Carbon Strategy ?

*A double challenge : the increase of electricity consumption and the end-of-life of 2nd gen. nuclear*




*RTE’s study “Futurs Energétiques 2050” was released in October 2021. More than 120 organisations were involved in 40 meetings and 4000 persons contributed to the public consultation.*

## Consumption Scenarios




1. **Baseline trajectory : -40% final energy +35% electricity** — **645 TWh**
2. **Sufficiency scenario** — **555 TWh**
3. **Reindustrialisation scenario** — **755 TWh**

## “M” Generation scenarios

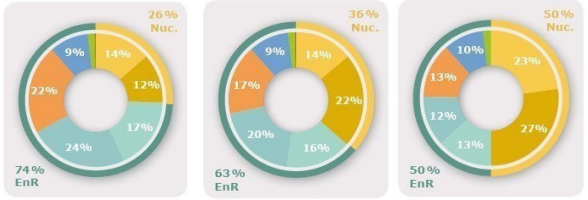
**Without new nuclear, a 100% renewables mix in 2050 or 2060**

| M0 | M1 | M23 |
|---|---|---|
| 100% in 2050 | Distributed | Large plants |

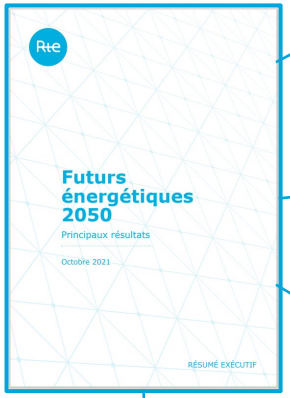

## The “N” Generation Scenarios

**RES and new nuclear**

| N1 | N2 | N03 |
|---|---|---|

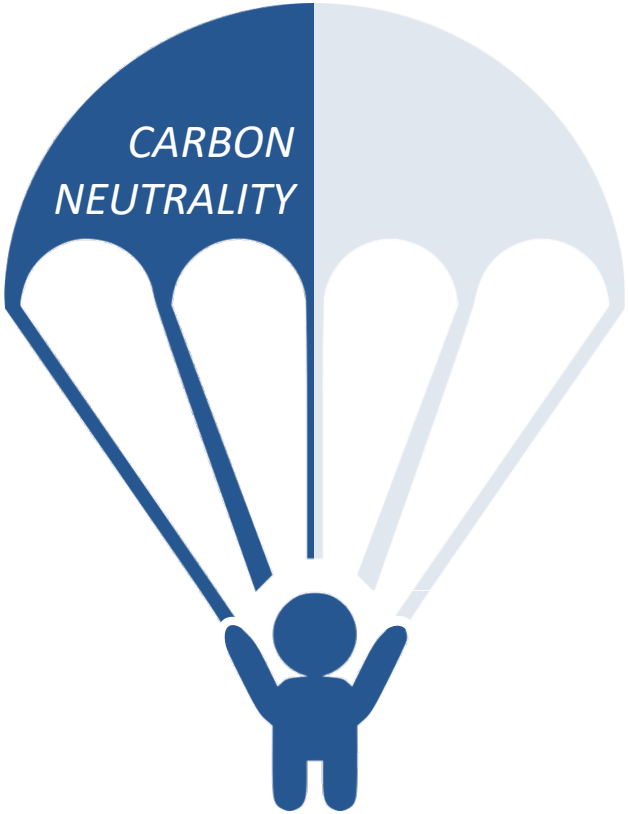


# Directions for research and innovation from « Energy pathways to 2050 »

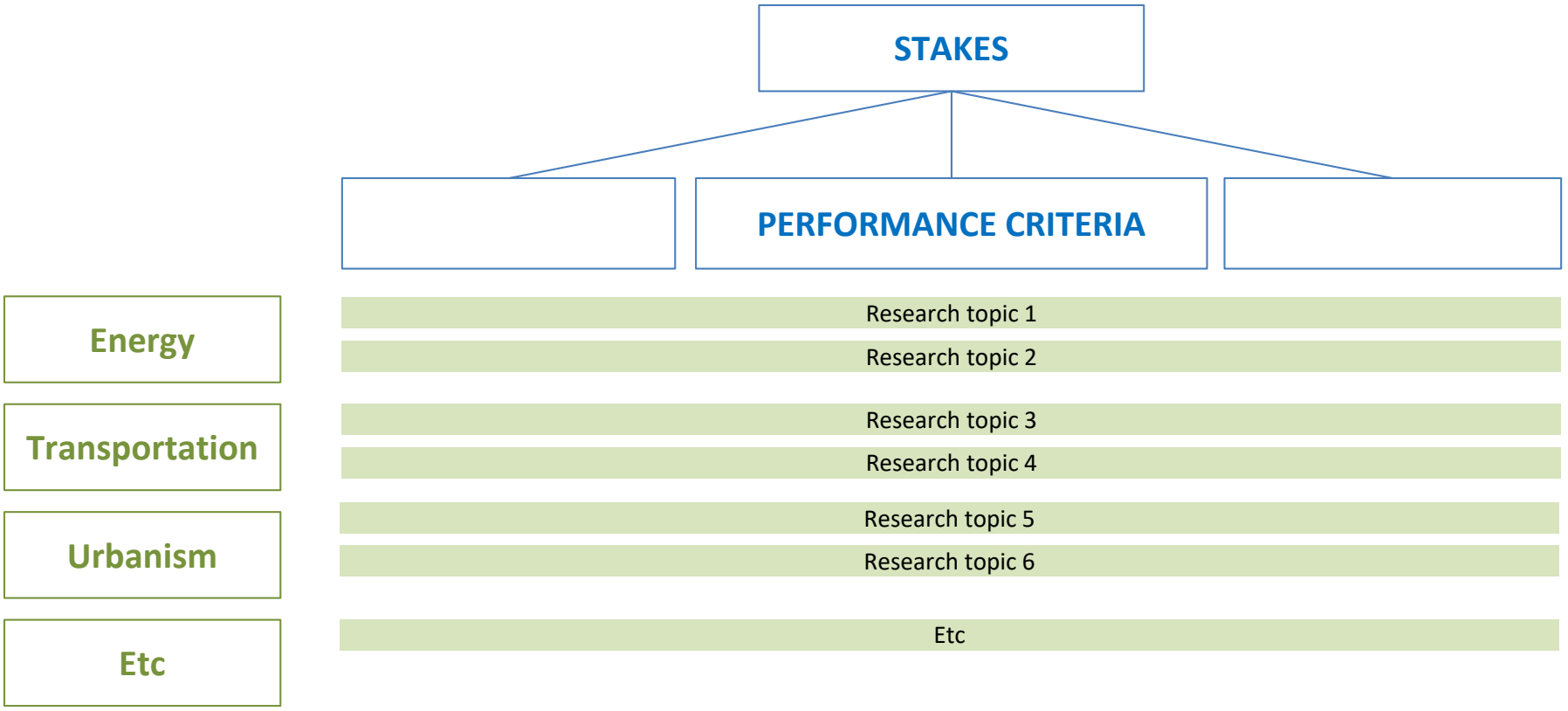



- **Consumption**
  - electrification 2 3 → else low carbon hydrogen 10
  - efficiency 1
  - sufficiency 1
- **Generation**
  - RES 4 7
    - off-shore (esp. M0 and M23) 11
    - accelerate (all scenarios, esp M) 5 11 17
  - Nuclear 5 6
    - accelerate (N. scenarios) 11
    - extend nuclear >60y (N03 scenario) 11
    - develop SMR (N03 scenario) 11
- **System**
  - Flexibility 8 11
    - demande-side
    - batteries
  - Grid
    - interconnexions
    - reconfigure 11
    - accelerate (all scenarios) 9
  - stability 11
- **Transversal**
  - urgent action 18 is needed (all scenarios)
  - possible tensions on mineral resources 15
  - impacts of climate change 12

# Carbon neutrality : necessary but not sufficient



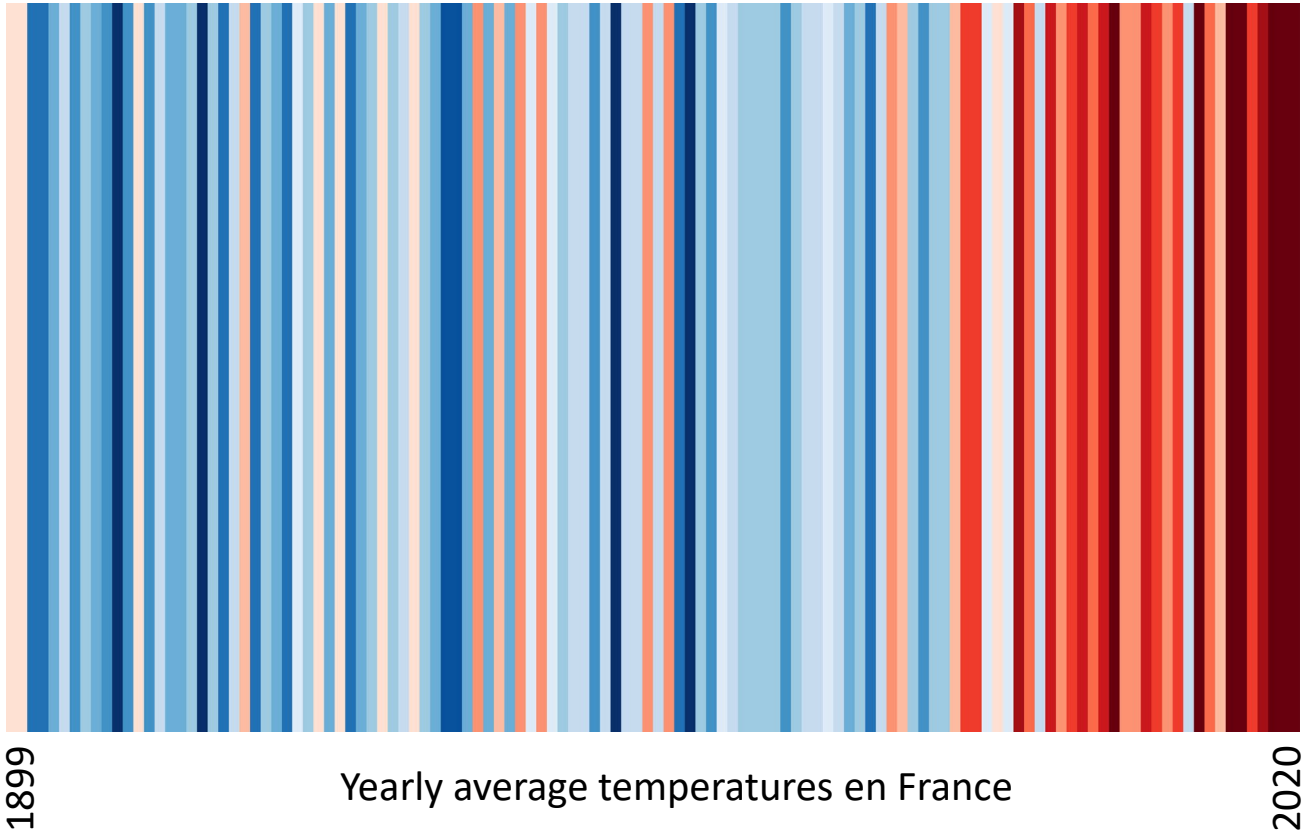
# Let us put aside our current list of research topics and make explicit major stakes and performance criteria



# Foresight based on the identification of « telluric forces »

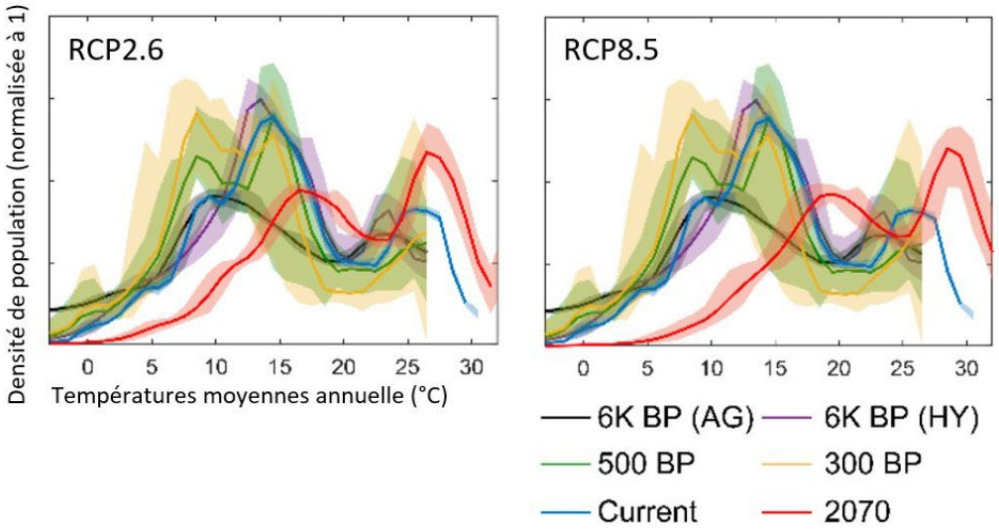
- as opposed to try forecasting the future « landscape »
- and based on scientific observations

# Climate change



# Climate and habitability of Earth

## BY 2070: 1 TO 3 BILLION PEOPLE IN A HOSTILE CLIMATE



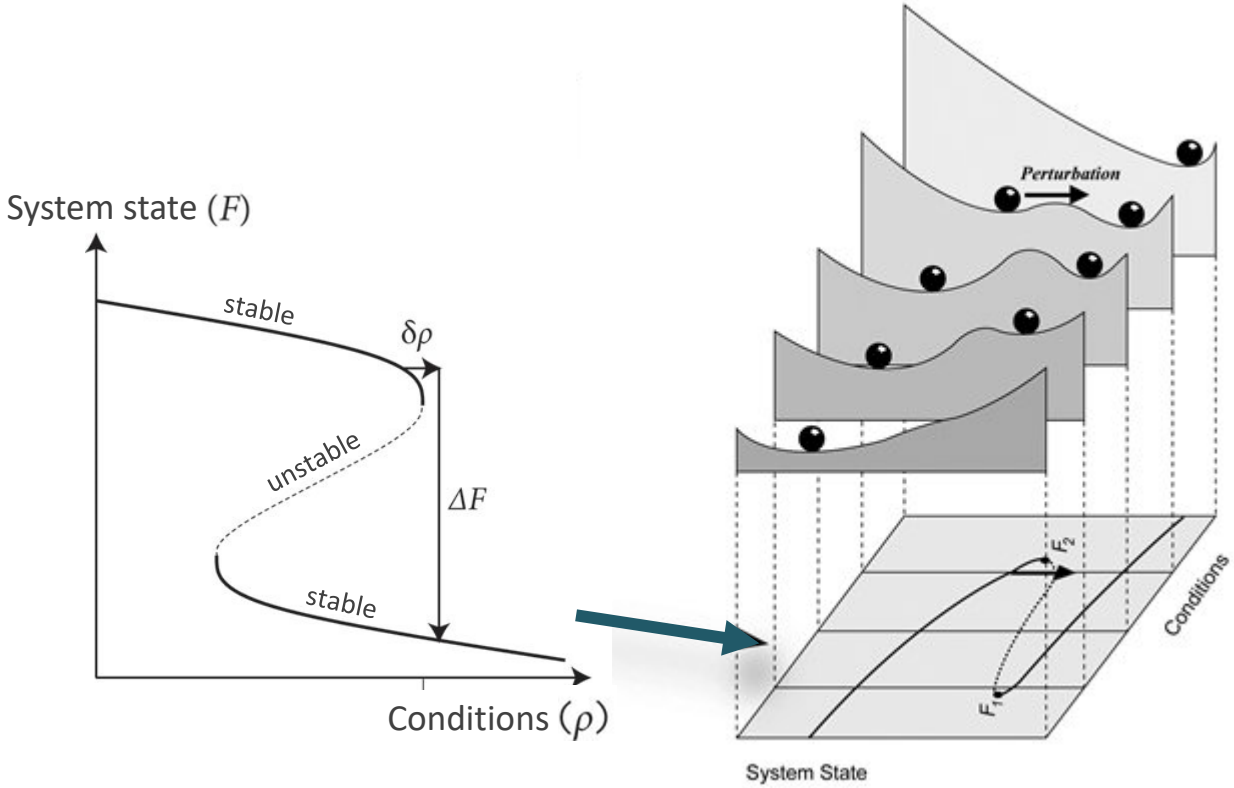

Distribution of the projected human population in 2070 (red) compared to the current and past situation (other colours) as a function of mean annual temperature in the SSP3 demographic scenario. The bands represent the 5th and 95th percentiles of the overall climate and population reconstructions. Source : "Future of the human climate niche" PNAS May 26, 2020 117 (21) 11350-11355, annex, figure S6.

# Climate tipping points

« Exceeding 1.5°C global warming could trigger multiple climate tipping points (CTP) »

" Current global warming of ~1.1°C above pre-industrial already lies within the lower end of five CTP uncertainty ranges. **Six CTPs become likely (with a further four possible) within the Paris Agreement range of 1.5 to <2°C warming**, including collapse of the Greenland and West Antarctic ice sheets, die-off of low-latitude coral reefs, and widespread abrupt permafrost thaw. An additional CTP becomes likely and another three possible at the ~2.6°C of warming expected under current policies. (…) We show that even the Paris Agreement goal of limiting warming to well below 2°C and preferably 1.5°C is not safe as 1.5°C and above risks crossing multiple tipping points."

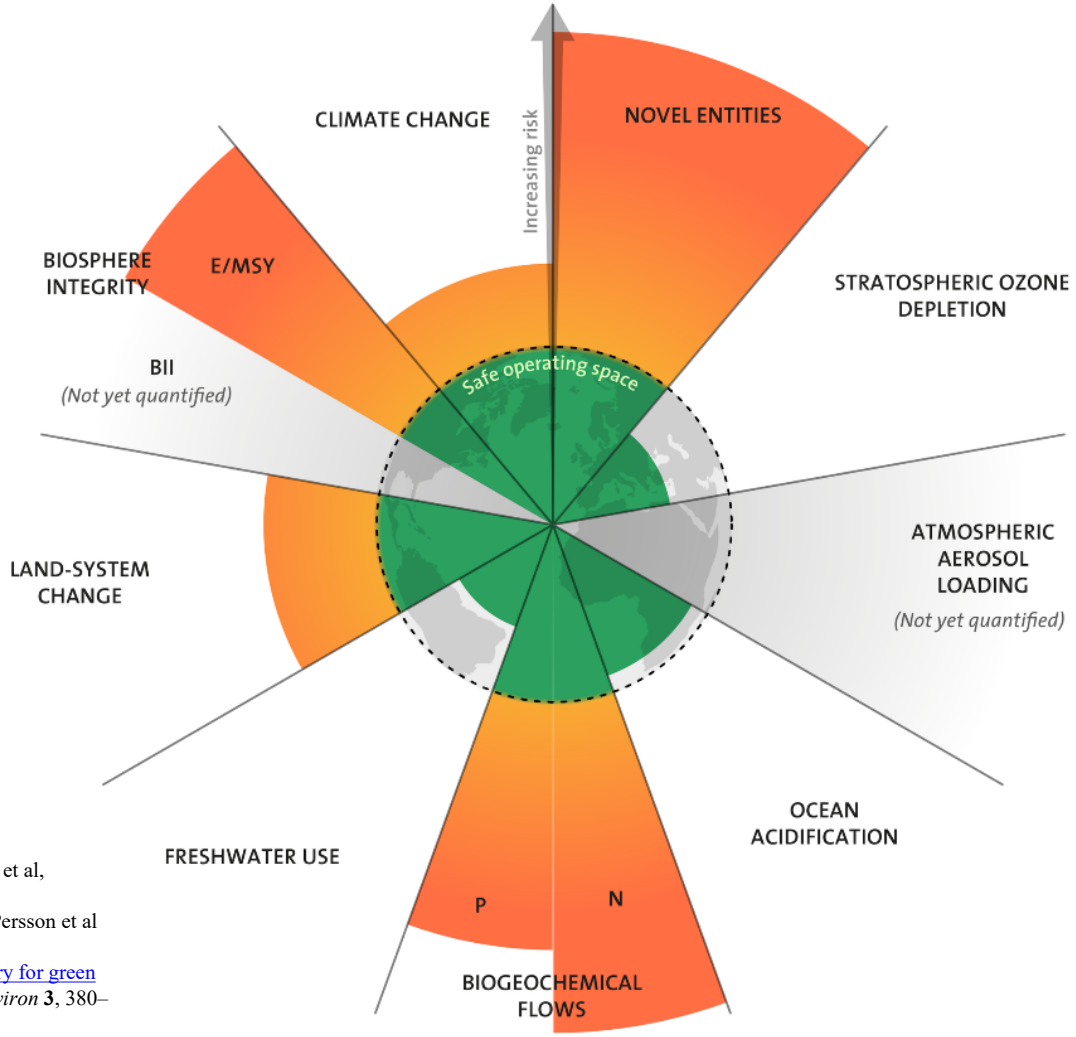
ARMSTRONG et al, SCIENCE,
9 Sep 2022, Vol 377, Issue 6611, DOI:
10.1126/science.abn7950



# Planetary boundaries

Any crossing of the frontier of the 'safe operating space' exposes Earth to the risk of tipping out of the Holocene.

Jusqu'à quand pourrons-nous dépasser les limites planétaires ? Boutaud, Gondran, 30/05/2022 Theconversation.com

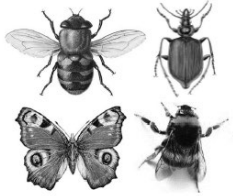




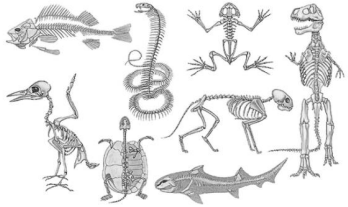
- "Planetary boundaries: Guiding human development on a changing planet" Steffen et al, SCIENCE•13 Feb 2015•Vol 347, Issue 6223 DOI: 10.1126/science.1259855
- "Outside the Safe Operating Space of the Planetary Boundary for Novel Entities" Persson et al 2022, Environ. Sci. Technol., 2022, 56, 3, 1510–1521
- Another overshoot dimension, not yet illustrated in diagram : "A planetary boundary for green water" Wang-Erlandsson, L., Tobian, A., van der Ent, R.J. *et al. Nat Rev Earth Environ* **3**, 380–392 (2022). https://doi.org/10.1038/s43017-022-00287-8

# Biodiversity collapse

« The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever. We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide. », R. Watson, President of IPBES.



In **10 years**, in Europe, the mass of arthropods has **fallen by 40%** in forests and by almost **70%** in grasslands.



In **44 years**, the world's wild vertebrate populations have **fallen by 60%**.

**Anthropogenic causes: 75%** of the terrestrial environment and **66%** of the marine environment are severely altered by human activities, **87%** of wetlands have disappeared.

Sources :
- IPBES press release on the release of the 2019 global assessment report on biodiversity and ecosystem services
- Le Monde, 18/10/2017, “In thirty years, nearly 80% of insects would have disappeared in Europe”, according to a study published by Caspar Hallmann et al, in the journal PLoS One.
- Le Monde, 9/11/2019, “The collapse of life in our latitudes remains largely under the media radar”, according to a study published by Wolfgang Weisser et al, in the journal Nature.
- IPBES, « In 44 years, populations of wild vertebrate animals have fallen by 60% ».

# Future impact of climate on biodiversity : what is at the stake ?
# One example considering forests

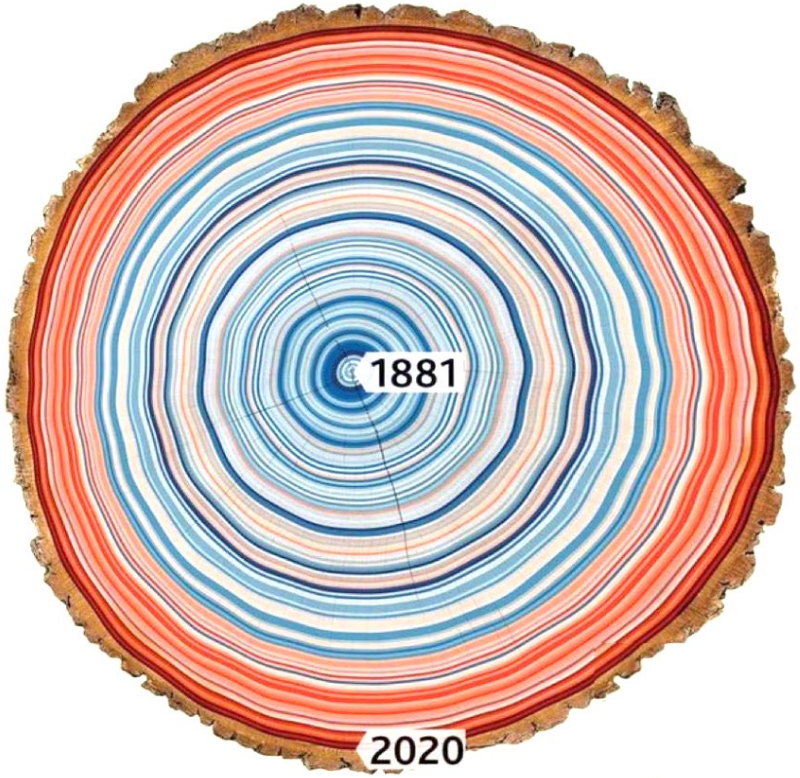
« Hydraulic safety margins are generally low for all forest ecosystems »

Hervé Cochard, INRAE, Université Clermont-Auvergne

Source : Cochard-DRAAF (agriculture.gouv.fr)

« No forest, no rain further than 500 km from the coasts »

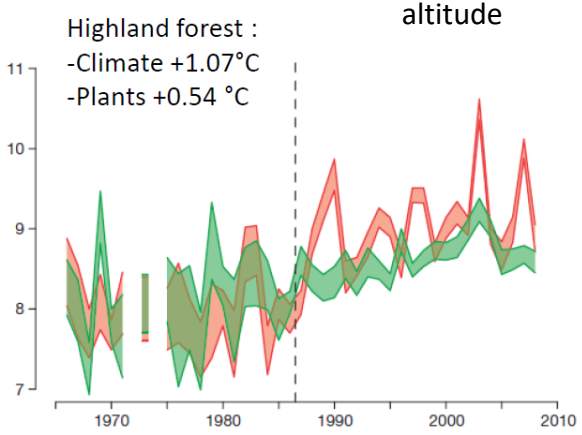
Peter Wohlleben, The secret life of trees



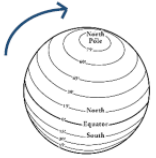
# Is the rate of climate change compatible with the adaptive capacity of species?

## Adaptation in highlands

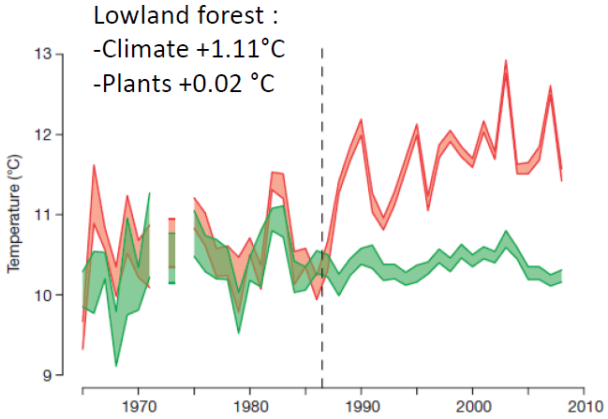
Going up in altitude




## Stalling in lowlands



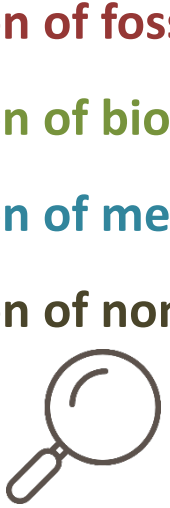
Going up in latitude




In red, the evolution of the temperature in the environment studied,
In green, the evolution of the temperature tolerated by the communities of species observed in this environment.
Bertrand et Al, "Changes in plant community composition lag behind climate warming in lowland forests." Nature 479.7374 (2011): 517-520.

# Accelerating extraction of resources

| | 1970 → 2017 |
|---|---|
| Population | x 2.0 |
| Extraction of fossil fuel | x 2.5 |
| Extraction of biomasse | x 2.7 |
| Extraction of metals | x 2.6 |
| Extraction of non-metallic minerals | x 4.9 |



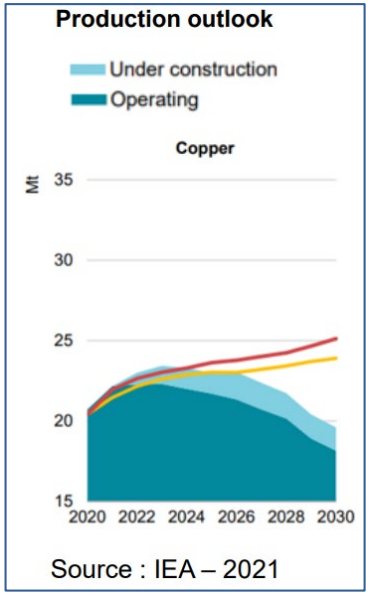
sand :
x3 in 20 years

upcoming substitutions

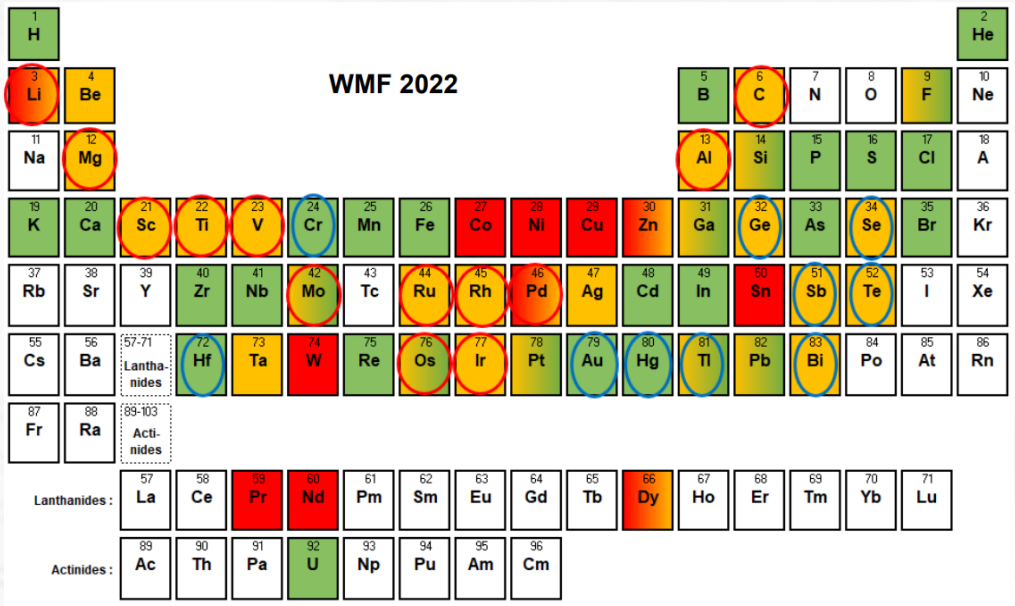
Sources : U.N. World Population Prospects + U.N. Global Resources Outlook

# Forecasted tensions on resources

Christophe Poinssot, BRGM,
Chief Scientific Officer,
[Presentation at World Materials Forum 16-18 juin 2022]




## 2022 Criticality Assessment results by BRGM, CRU & McKinsey




**Red elements combine:**

- Role in electrification & energy transition
- Long term uncertainties
- Short term supply chain bottlenecks
- Limited substitution possibilities

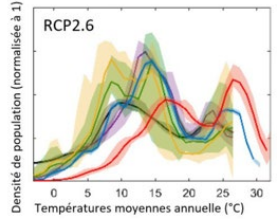
- Very high degree of risks
- High probability of risk occurrence
- Risk occurrence to be closely followed
- Low probability of risk occurrence
- Low degree of risks

Note: Elements in white have not been assessed

# An instable system of « telluric forces »

health impacts
of diffuse pollution

**Degradation of habitability and living conditions**

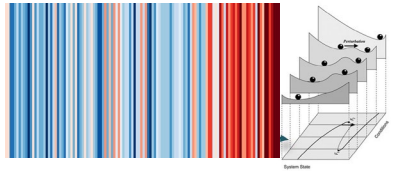


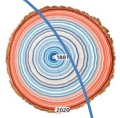

end of the world
vs. end of the month

average and extreme weather,
fires, access to fresh water,
degraded agricultural productivity

substitution of fossil fuels,
prepare to or recover
from climatic catastrophe

**Climate change**





degradation of ecosystem services
(water, air and soil quality,
pollination, etc.)

**Accelerating extraction of resources**

| | 1970 → 2017 |
|---|---|
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| Extraction of fossil fuel | x 2.5 |
| Extraction of biomasse | x 2.7 |
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| Extraction of non-metallic minerals | x 4.9 |

sand :
x3 in 20 years

fossil fuels

degradation
of carbon sinks

**Biodiversity collapse**

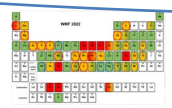
habitat reduction and fragmentation
new entities (plastics, pollutants, etc.)
biochemical flows (N, P)
intensive agriculture, overfishing

end of the world
vs. end of the month

degraded economic activities
inequalities, social conflicts
global exodus
populisms

**Increasing risk of recurrent major social, sanitary, economic and geopolitical crises (*)**

increasing competition for resources
geopolitical tensions, shortages
increasing frequency of zoonoses (intensive livestock farming)



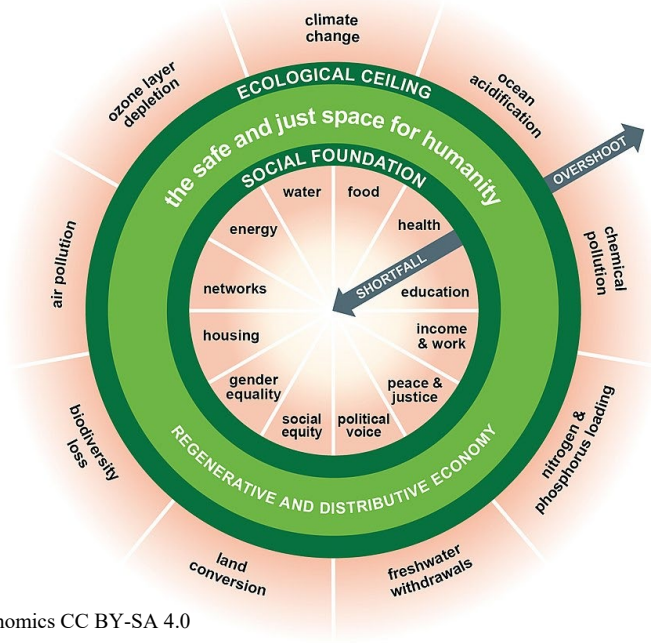
Causal chains with positive
reinforcement loops (vicious circles)

(*) U.N. source : "Our World at Risk : Transforming Governance for a Resilient Future", Global Assessment Report On Disaster Risk Reduction 2022 GAR2022. This report points to the growing risk of systemic collapse in relation to global limits.

# Proposal : 2 major stakes

## SUSTAINABILITY

of lifestyles and of the economy
relatively to social and environmental limits
*(including carbon neutrality)*




Crédits : DoughnutEconomics CC BY-SA 4.0

Raworth, K. A Doughnut for the Anthropocene: humanity's compass in the 21st century. Lancet Planet. Health 1, e48–e49 (2017)

## RESILIENCE

to new living conditions
and to crises resulting
from the overshooting of limits

Climate disasters, food insecurity, disputed resources, pandemics, global exodus, economic, social and geopolitical crises...

Migrants in La Manche © AFP / Sameer Al-Doumy

Reference on the lack of research on resilience : « Climate Endgame: Exploring catastrophic climate change scenarios », Kemp et al, PNAS 2022 Vol. 119 No. 34, https://doi.org/10.1073/pnas.2108146119

# Proposal : 7 performance criteria

## SUSTAINABILITY


## RESILIENCE

(*)

| Environn. efficiency | Sufficiency | Circularity | Regeneration of the living | Solidarity | Robustness | Agility |
|---|---|---|---|---|---|---|
| Reduce footprint for equivalent service (technical efficiency, not just CO2 ) | Reshape the expected service in order to reduce footprint (individual and collective lifestyles) | Repair<br>Reuse<br>Recycle via factories<br>Recycle via ecosystems | Positive biodiversity footprint<br>Relationships with non-humans | Social cohesion | Sizing<br>Diversity | Agility of organisations<br>Agility of technologies |

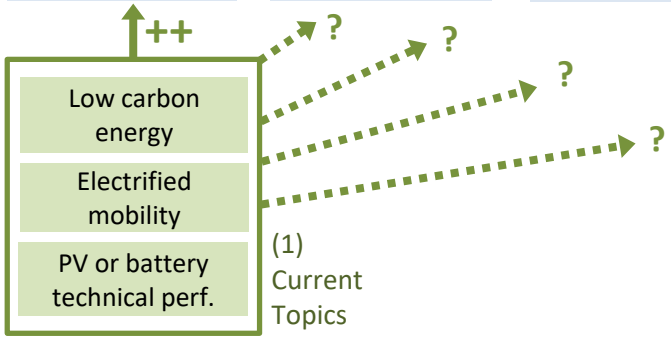
(*) This U.N. report identifies inequality and poverty as an anti-resilience factor: “Our World at Risk : Transforming Governance for a Resilient Future”, Global Assessment Report On Disaster Risk Reduction 2022 GAR2022.

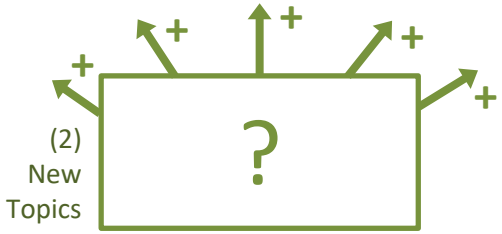
# Based on major stakes and performance criteria, (1) let us revisit our current research topics and (2) think of new topics

## SUSTAINABILITY

## RESILIENCE

| Environn. efficiency | Sufficiency | Circularity | Regeneration of the living | Solidarity | Robustness | Agility |
|---|---|---|---|---|---|---|
| Reduce footprint for equivalent service | Reshape the expected service in order to reduce footprint | Repair / Reuse | Positive biodiversity footprint | Social cohesion | Sizing | Agility of organisations |
| | | Recycle via factories | Relationships wth non-humans | | Diversity | Agility of technologies |
| | | Recycle via ecosystems | | | | |

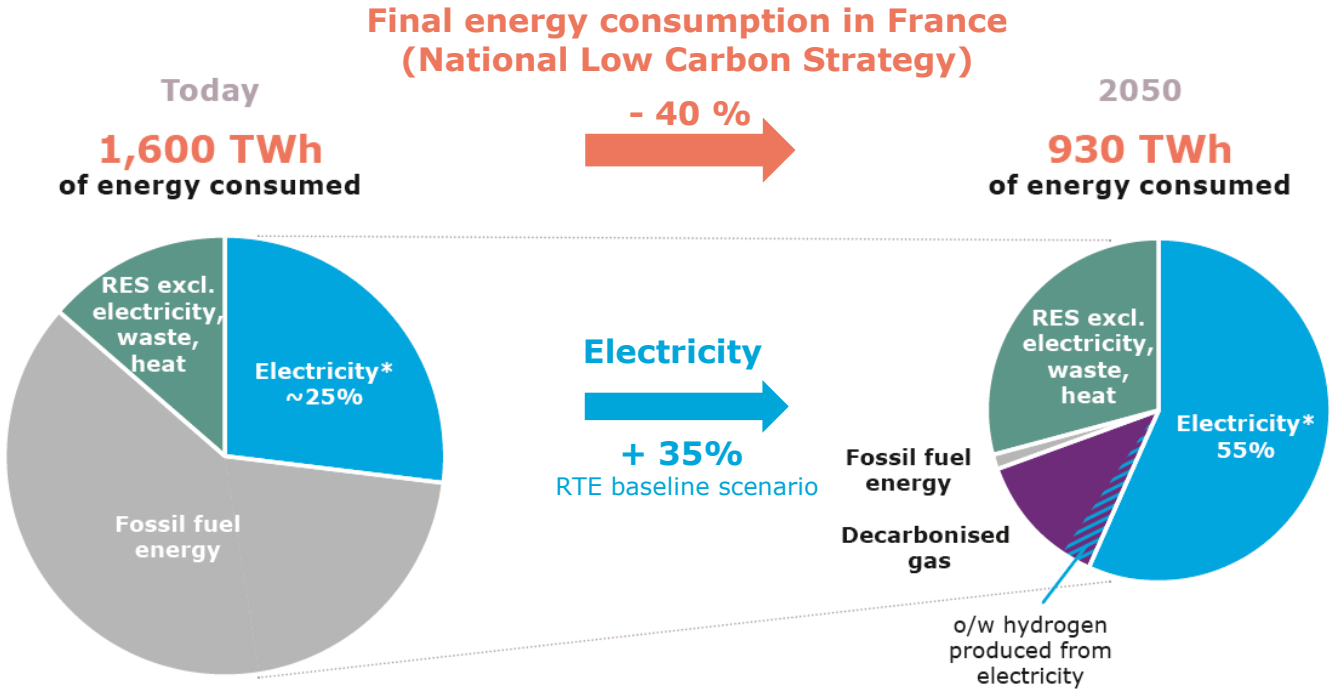


# Appendix : key findings from “Energy Pathways to 2050”

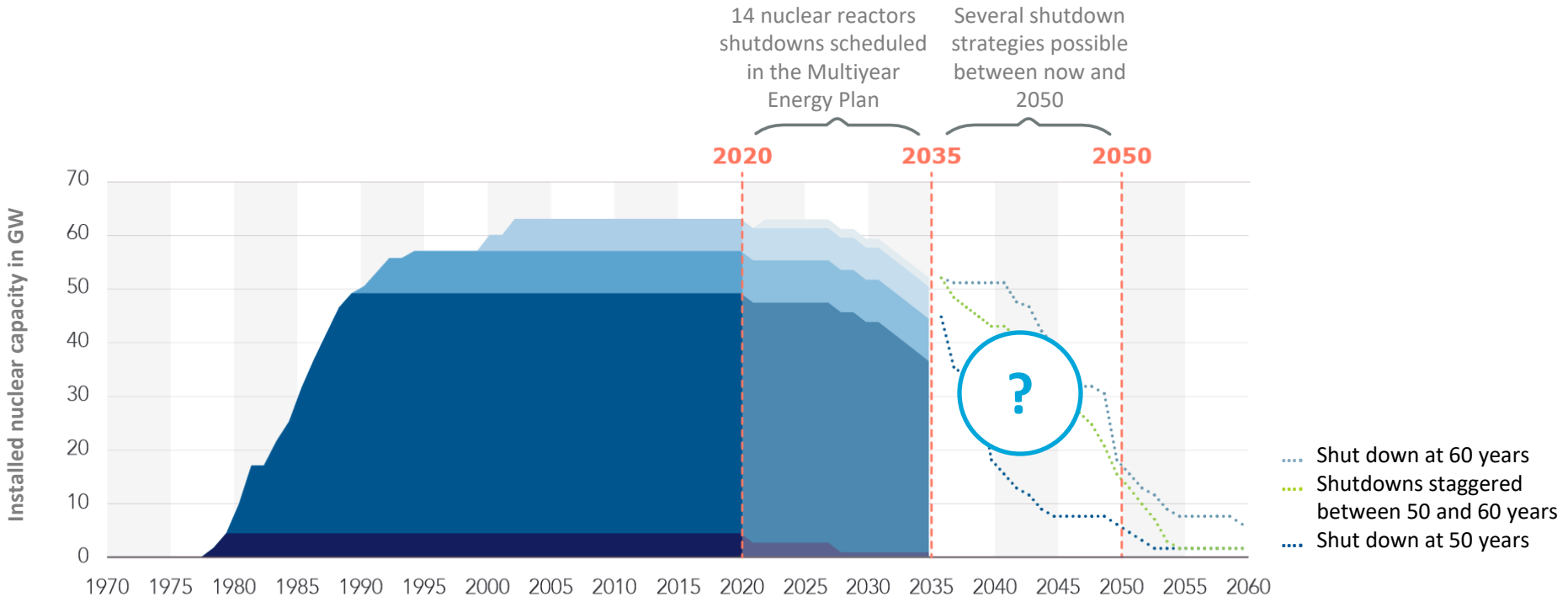
*RTE’s study “Futurs Energétiques 2050” was released in October 2021. More than 120 organisations were involved in 40 meetings and 4000 persons contributed to the public consultation.*

# Challenge 1 : electrification



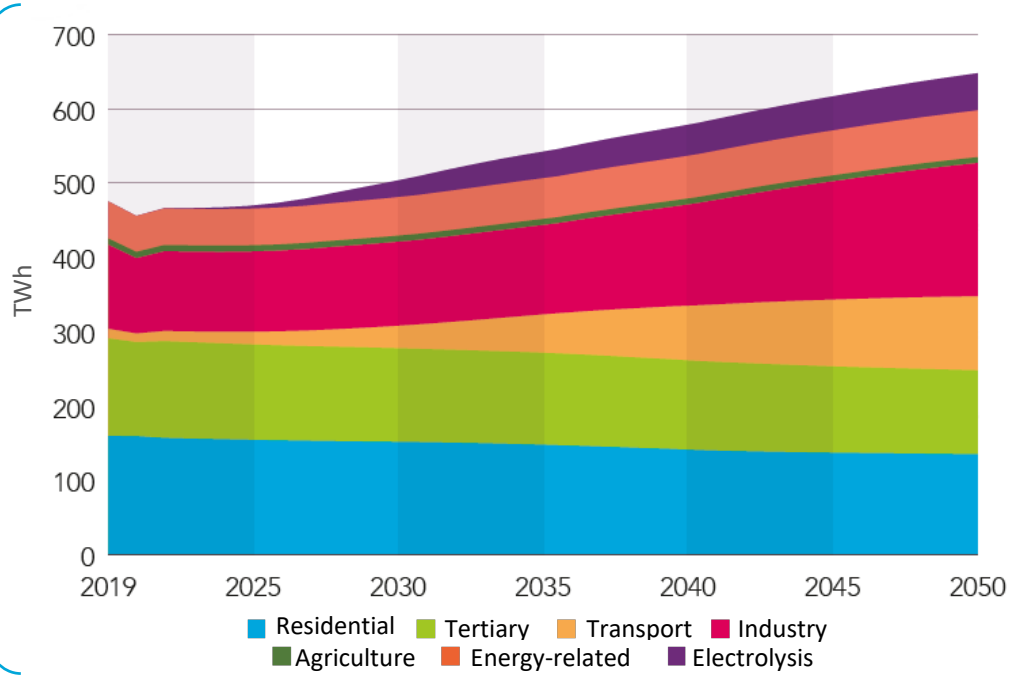

*Final electricity consumption (excluding losses, consumption related to the energy sector, consumption for hydrogen production). Total electricity consumption in RTE's baseline trajectory = 645 TWh

# Challenge 2 : end-of-life of nuclear reactors



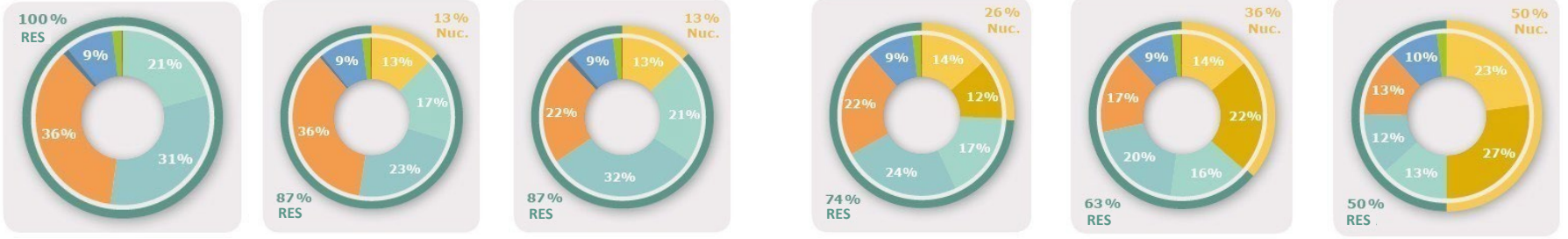
# 3 consumption scenarios depending on reindustrialisation and sufficiency

1. **Baseline trajectory : electrification and efficiency** — **645 TWh**
2. **Sufficiency scenario** — **555 TWh**
3. **Reindustrialisation scenario** — **755 TWh**



# 3 generation scenarios with new nuclear (N)
# 3 generation scenarios without new nuclear (M)

| M0 | M1 | M23 | N1 | N2 | N03 |
|---|---|---|---|---|---|
| 100% RES in 2050 | Distributed RES | Large RES plants | RES + new nuclear 1 | RES + new nuclear 2 | RES + new nuclear 3 |




**The "M" scenarios**
**Without new nuclear,**
**a 100% renewables mix in 2050 or 2060**

**The "N" scenarios**
**With new nuclear**

Hydro | Solar | Onshore wind | Offshore wind | Historical nuclear | New nuclear

# Hourly simulations of supply-demand at European scale

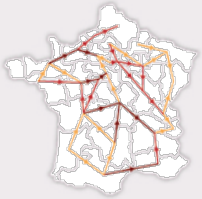
## Modelling of the power system in the study

**Assumptions for France and Europe**

- Reference meteorological database
- Different patterns of availability of power plants
- Different hourly patterns of renewable energy production
- Different hourly patterns of power consumption
- Flexibility and sector coupling

Simulations of the supply-demand balance on an hourly basis + economic investment

Study of network needs



- Network volumes
- Energy balances & flexibility volumes
- **Full system costs** investment needs…
- $CO_2$ emissions, materials consumption, soil artificialisation, nuclear waste…

# Findings related to consumption

1. **Reducing consumption through energy efficiency, and possibly energy sufficiency, is key to reaching climate targets**

2. **Energy consumption will decrease but demand for electricity will increase as it replaces fossil fuels**

3. **Accelerating France's reindustrialisation by electrifying processes will increase its electricity consumption but reduce its carbon footprint**

# Findings related to generation

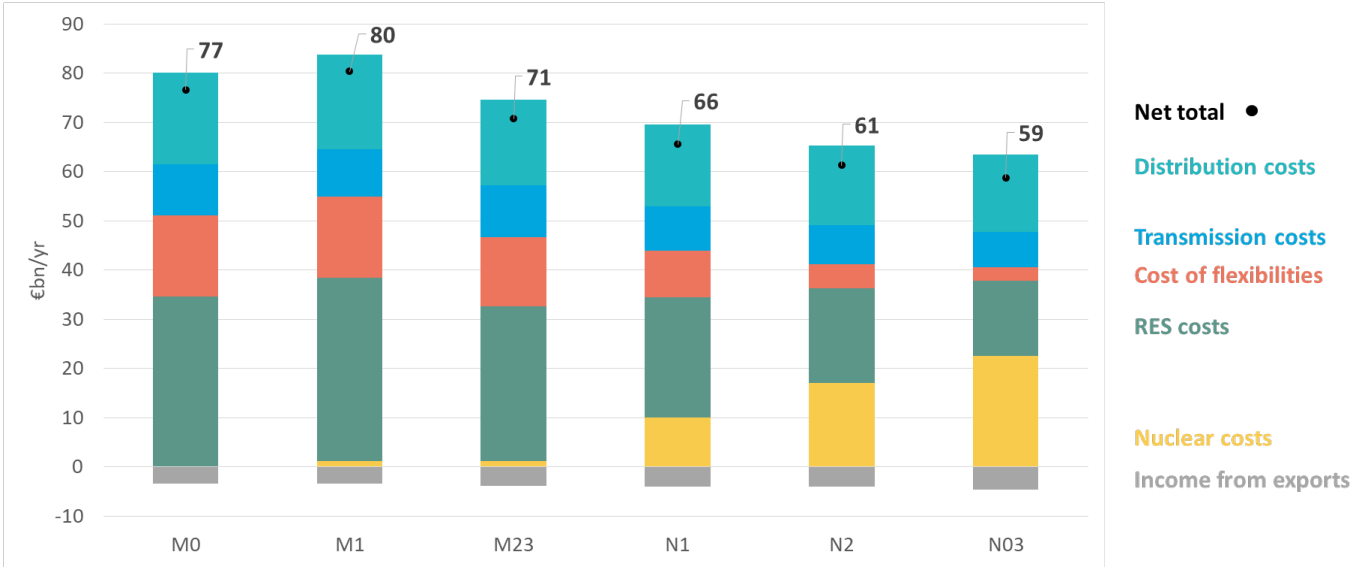
**4** **Carbon neutrality cannot be achieved by 2050 without significant renewable energy development**

**5** **Without new nuclear reactors, renewable energy will need to be developed at a pace exceeding that seen in the most dynamic European countries**

# Findings from the economic analysis

**6** **Building new nuclear reactors makes sense**, particularly if it allows a 40 GW fleet to be in place in 2050 (existing plus new nuclear plants)

**7** **Renewable electricity has become a competitive solution.** This is particularly true in the case of large solar plants and onshore and offshore wind farms



# Findings from the flexibility analysis

**8** **The system will require very different types of flexibilities to ensure security of supply in the different scenarios.** There is an economic case for

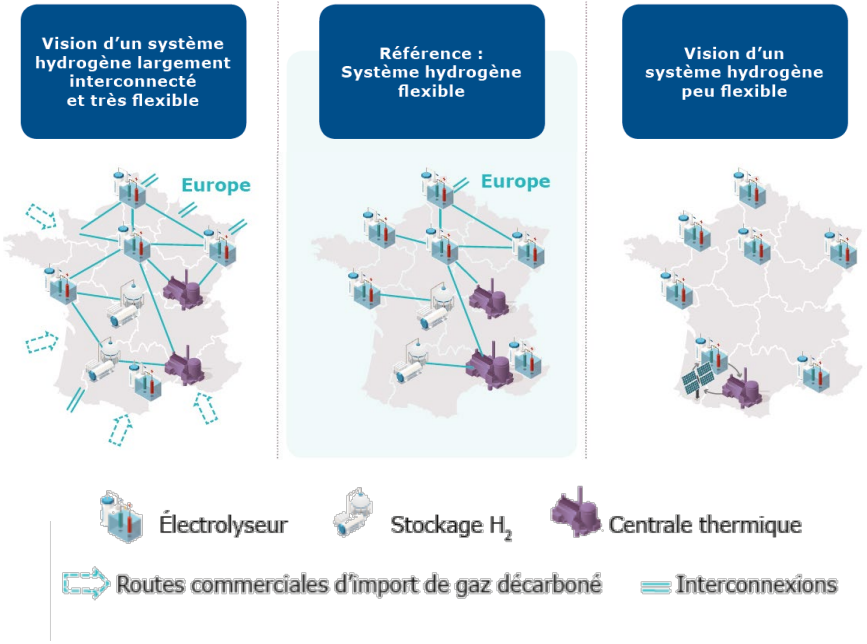
- increasing demand-side management,
- expanding interconnections and hydropower storage,
- and installing batteries to support solar power.
- Additionally, new thermal power plants fuelled by decarbonised gas (including hydrogen) will be necessary if the nuclear revival is minimal. And this need will be massive – and thus very costly – if the system moves toward 100% reliance on renewables

**9** **In all scenarios, the size of the power grid will need to be adapted rapidly to make the energy transition possible**

# Findings related to hydrogen

**10**

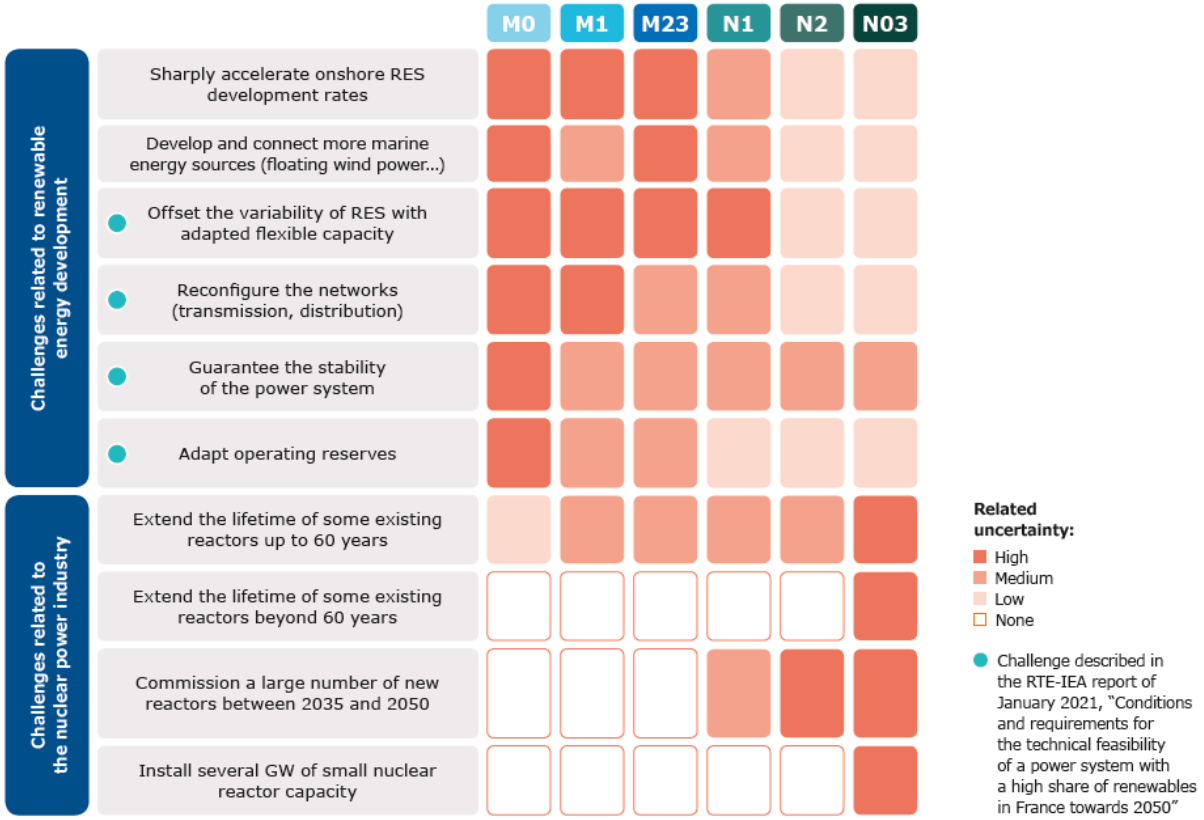
**Creating a high-performance "low-carbon hydrogen system" is an asset for decarbonising certain sectors that are difficult to electrify, and a necessity in scenarios with a very high development of renewables to store energy**



# Findings related to technological challenges

**11**

**Scenarios with a very high share of renewables in the mix, or the one calling for the lifetime of existing nuclear reactors to be extended beyond 60 years, <u>imply overcoming major technological challenges</u> for carbon neutrality to be reached in 2050**

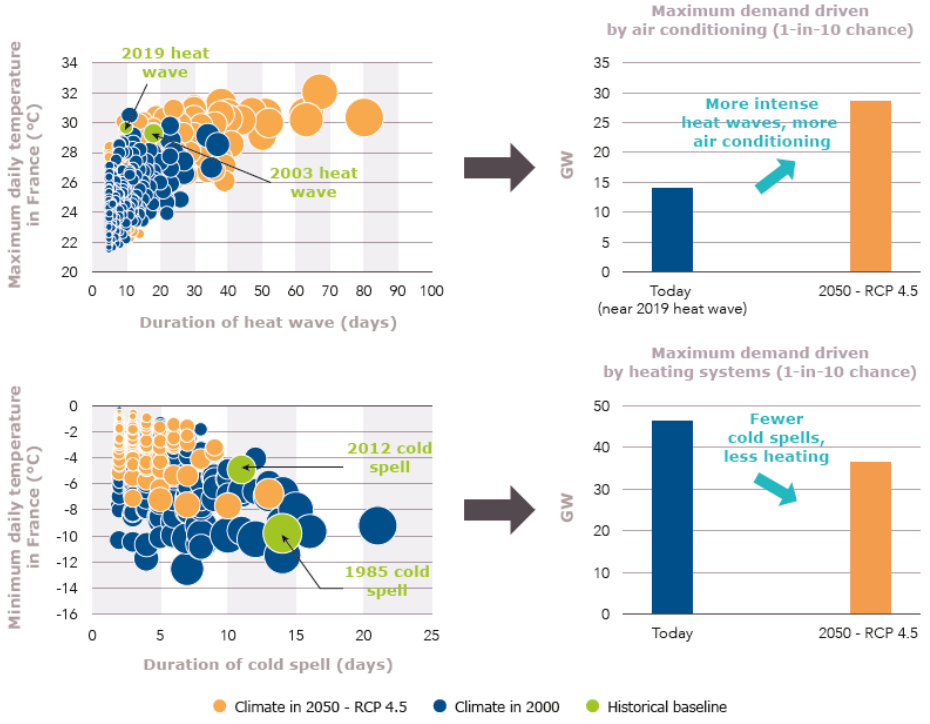


# Findings related to the impact of climate change on supply and demand

**12**

**Starting now, the transformation of the power system must take into account the likely consequences of climate change, particularly its effects on water resources, heat waves and wind patterns**

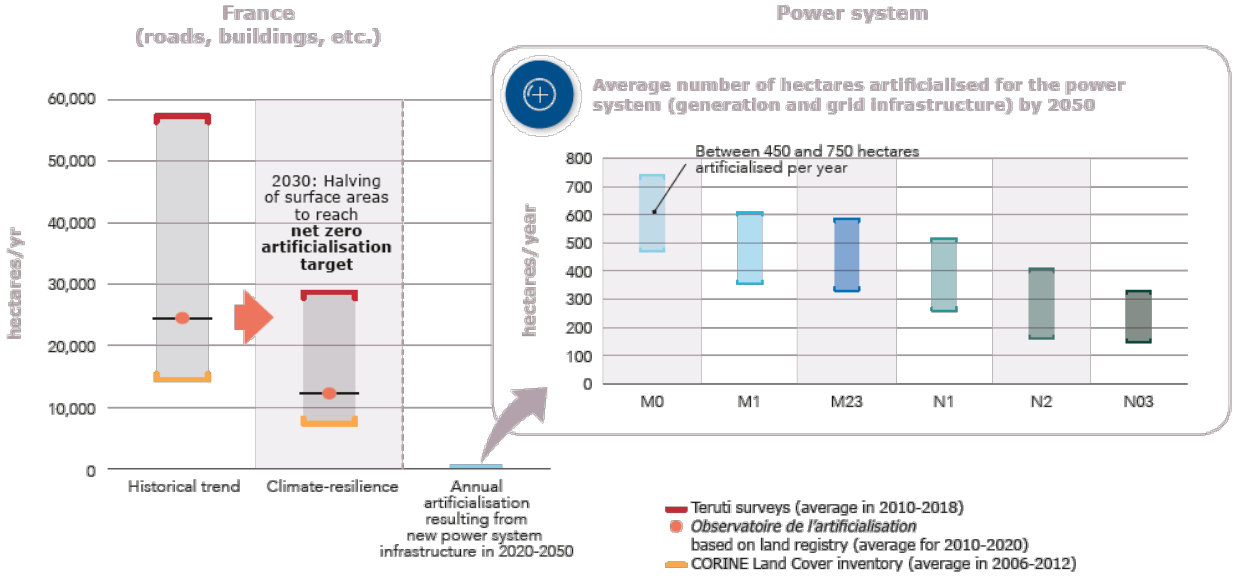
*Trend in the frequency of heat waves and cold spells and impact on power demand related to air conditioning and heating*



# Findings from the environmental analysis

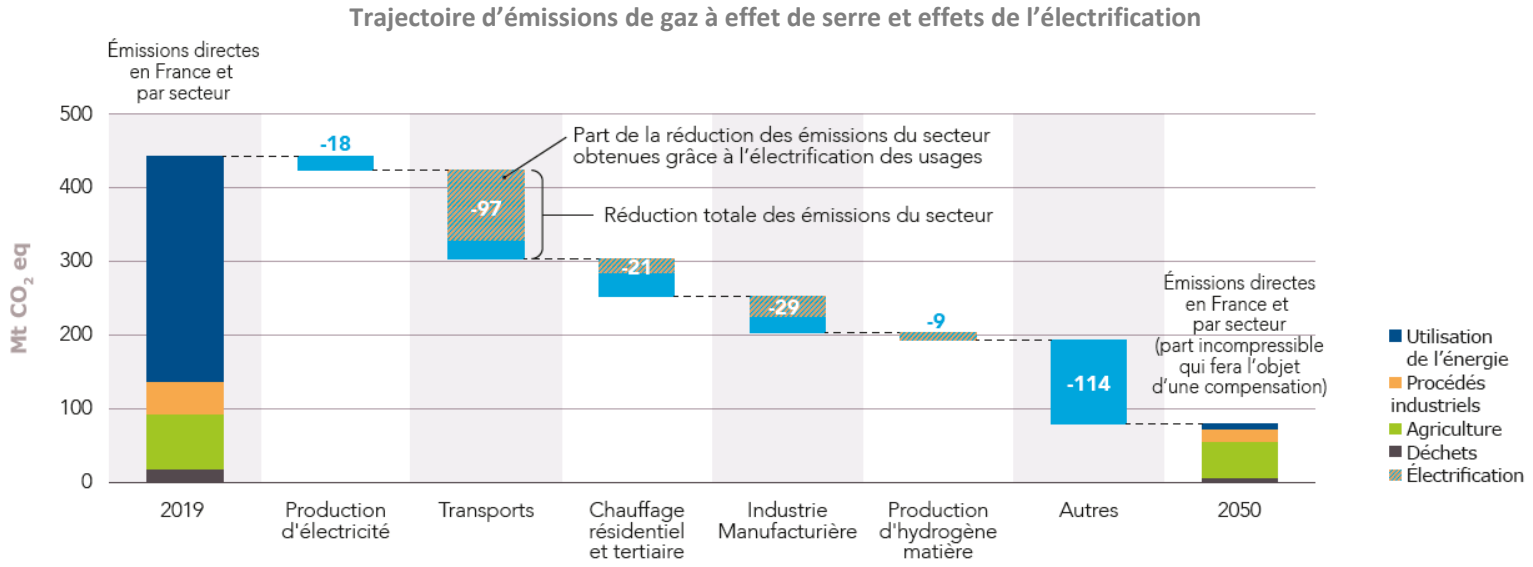
**13**

**Renewable energy development raises concerns about the use of land and the limitation of other uses. Its growth should be able to accelerate without putting excessive pressure on soil artificialisation, though care must be taken to preserve living environments in each region**



**14**

## Even if we integrate the full carbon footprint of infrastructures over their entire life cycle, electricity in France will remain largely decarbonised and will make a major contribution to achieving carbon neutrality by replacing fossil fuels



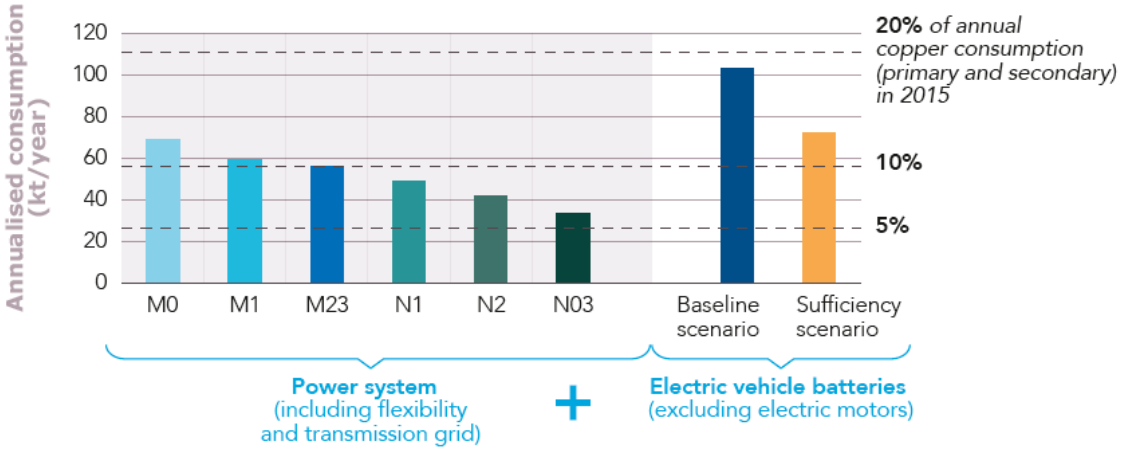
**15**

## There may be tension around mineral resource supply in the energy transition economy, particularly for certain metals, and it will be necessary to plan accordingly

| |
|---|
| Aluminium |
| **Copper** |
| Steel |
| Concrete |
| Rare earth |
| Silver |
| Silicon |
| Uranium |
| Zirconium |
| Graphite |
| Lithium |
| Cobalt |
| Manganese |
| Nickel |
| Chrome |
| Zinc |

Example for copper, supply of which is today considered critical due to surging demand and reserves that could become insufficient

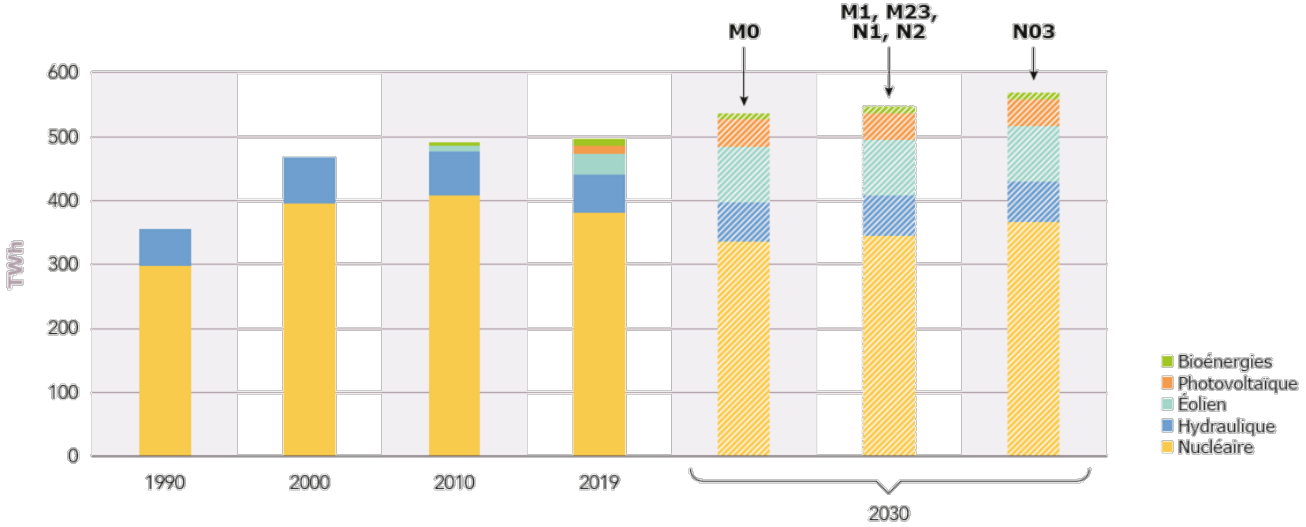
Projected annual consumption of copper in 2050 under different scenarios and for vehicle batteries



# General findings for the short term

**17**

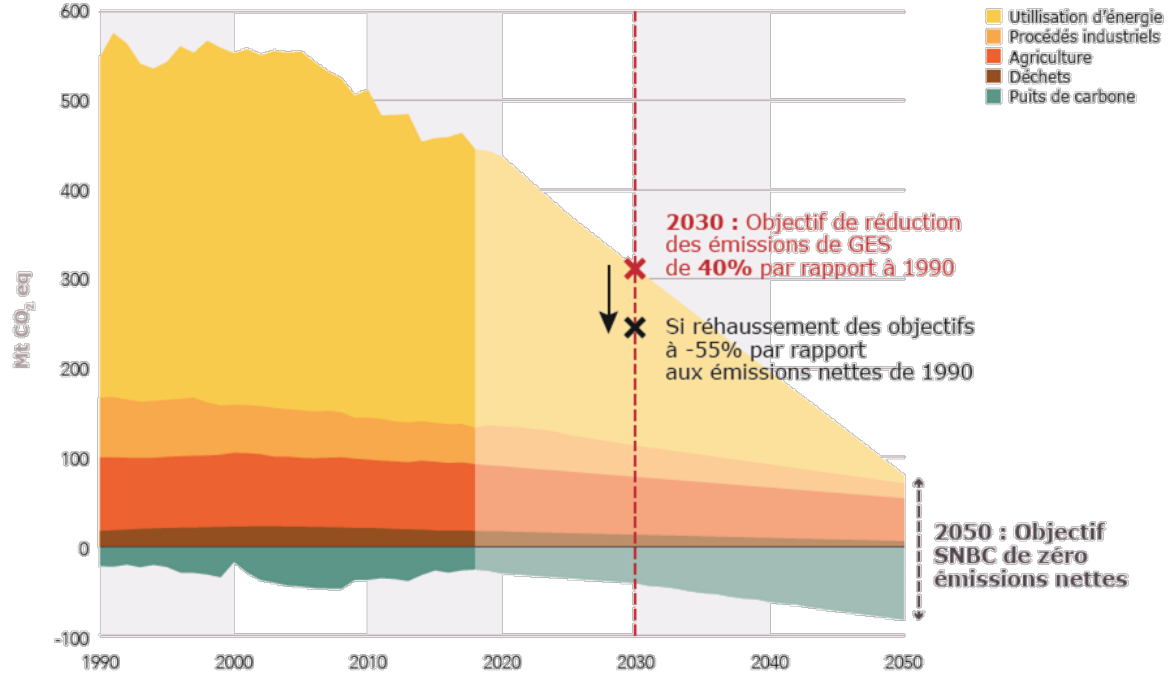
## For 2030: developing renewable energies as quickly as possible and extending existing nuclear reactors in a logic of maximising low-carbon production increases the chances of reaching the target of the new European "-55% net" package




Low-carbon electricity generation in France (historical and 2030 projections)

# General findings for the short term

**18** **Whatever the scenario, urgent action is needed.**




*(Source : SNBC)*