FRANCE22
FRENCH PRESIDENCY OF THE COUNCIL OF THE EUROPEAN UNION

Low carbon energy, climate change, environmental health and biodiversity

ANCRE
Alliance Nationale de Coordination de la Recherche pour l'Énergie

aviesan
alliance nationale pour les sciences de la vie et de la santé

ALLISTENE
l'alliance des sciences et technologies du numérique

AllEnvi
Alliance nationale de recherche pour l'Environnement

ATHENA
Alliance thématique nationale des sciences humaines et sociales

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Executive summary

Beyond disciplinary research and education questions, is it possible to raise more systemic horizontal concerns, regarding the major transitions: climate, ecology, energy, food and heath? Over the last decade, crises are increasingly frequent and have a tendency to pile up. They affect the way of life, the way of consumption, the way of production. Such periods of tension provide information on the significant damages caused by the different types of climatic disturbances, such as social or health crises, or the loss of biodiversity and also reveal the high level of the interdependencies underlying the current ways of life. Enough observations, data and tools are now available to understand and model the impact of these global changes on the environment, health, biodiversity and society.

In the European context, the Green Deal aims at making Europe the first carbon-neutral continent; this policy aims to preserve biodiversity, reduce pollution, and promote a clean and circular economy, while making this green transition a factor of economic growth, by ensuring a fair transition. The European legislative package «Fit for 55» will establish the mechanisms for fitting to the new European ambitions in the reduction of greenhouse gas emissions (a 55% at the horizon 2030, cut-off compared to 1990 level, to reach carbon neutrality in 2050), thus requiring an acceleration of the energy, environmental, sanitary and digital transitions, the implementation of carbon sinks, and probably major systemic disruptions.

Progresses in disciplinary research and innovation are able to provide many solutions. On the other hand, whereas the problems are largely systemic, the approaches of them are often led in sectoral silos. Innovations must be more and more hybrid, bringing together a broad spectrum of technologies and skills from different disciplines. Working at the interfaces of different scientific fields - life sciences, physical science, digital science, engineering science, human and social science - will contribute to boosting systemic innovations that are necessary to reach a carbon-neutral and resilient society by 2050.

Under the aegis of the French Ministry of Higher Education, Research and Innovation, the five national alliances (gathering the French research organizations and universities under 5 embedding topics: energy, environment, numeric, health, human and social sciences) have produced a positioning document which reflects a common and shared vision of new directions in research, to serve the major transitions, in the emerging academic discipline of sustainability science.

The 5 alliances have identified major interdisciplinary research directions :

Climate change, energy transition, society and health

Climate change and energy conversion methods influence human health through several direct and indirect mechanisms. Developing a map of their health impacts is a complex and multidisciplinary task for which major research efforts are needed. Improving the integration of public health criteria in the development and evaluation of strategies to adapt to and tackle climate change is also a necessary move. The major environmental transitions are opportunities to make progress with complex public health issues that have not yet been resolved. The role and impact of public health policies in order to contribute to a carbon-neutral society also need to be better assessed. Collection of relevant data, interventional studies and multi-generational prospective modelling work to investigate the health impact of climate change and transitions are required.

Negative carbon emission, decarbonization and biodiversity

The longer it takes to introduce measures to decrease CO2 emissions directly linked to human activity, the more difficult it will be to offset them. This implies not only the reduction of emissions but also the immediate introduction of negative emission technologies (NETs). Among the different NETs, it is proposed to emphasize on one of the most promising, the massive soil carbon storage, which consists in optimizing the transfer of biomass from agroecosystems in soil by capitalizing on soil biodiversity. A very significant research effort to accompany the policies for NETs deployment is also needed, as well as a framework and conditions for mass deployment and to be socially appropriate.

Numerics, climate and society

The increase of the environmental impacts of digital technology (technologies, services, data processing and storage, recycling) is alarming, but at the same time, digital tools are essential to foster transitions. This contradiction can be resolved:

- by teaching, training and materializing the environmental impacts of Information and Communication Technologies,

- by stimulating research on the eco-design of digital tools and services and by promoting their massive deployment,

- by stimulating research in modeling, optimization and data science including artificial intelligence, to build multi-objective and multi-criteria decision making tools.

Democratic challenges in the transitions

Citizen support and engagement are essential for driving transitions. This is the responsibility of interdisciplinarity and open research:

to examine social reconfigurations, the economic and environmental implications of policies and technical devices implemented at different spatio-temporal scales,

to understand the perceptions, interpretations and practices of populations,

to investigate, in a comparative approach, individual or collective forms of contribution and citizen commitment,

to develop relationships with stakeholders, managers and citizens to share its objectives, issues and results.

Challenges at different spatial scales

The territory, at each scale - individual, local, regional, national, European and global - is the reference point to enhance the value of research, transfer innovation, explore the viability of solutions and prepare for their deployment. It embodies the changes - namely environmental, social, energy and digital - undertaken in the different transitions. The territories are nodes within a system of flows, which cross through them and link them together. Societies are based on this mesh of contracts with an ever-expanding geographical reach. With more frequent upcoming shocks, the territories are simultaneously places of anticipation, preparation and resilience. Research could help in proposing approaches available to manage the potential renunciations in choices to be made and set new objectives and new types of desired transitions (equality, sobriety, environmental impact, which social model, etc.).

The French alliances have formulated 9 proposals, both on methodological approaches and on the organisation of the research and training system.

Methodological proposals- Implementation within 2 years

Promote systemic approaches based on the multi-dimensional quantification and qualification of impacts and resources: this invites to promote more interdisciplinary programs with explicit criteria for evaluating interdisciplinary projects (to be defined).

Promote systemic modelling, using artificial intelligence (data-driven models), to develop decision-support tools.

Open the world of research to third parties and citizens: integrate a broad spectrum of stakeholders (communities, associations, companies, local authorities, etc.) in more open research groups; involve citizens as active partners in research projects (similar to patient cohorts or patient associations, or consumer/producer groups in food or energy chains); develop living labs on a territorial scale. All this requires the creation of ad hoc programming tools and a funding capacity including third parties (going beyond research and industry).

Proposals of organization of research and education system- Immediate implementation

Innovate by supporting large-scale experiments at the territorial scale : conducting large-scale instrumented experiments when the input is territorial, in relation with local authorities, groups of local players, and by opening the different options up for public debate.

Promote medium/long-term, transnational observatories and living-labs, e.g. to assess the impact of NETs over 5-10 years in particular for the carbon storage in soils, to observe the hydrogen-based ecosystem development or to engage on multi-generational, prospective modelling work to investigate the health impact of climate change.

Encourage the development of research initiatives especially caring for the needs of the youngest generation in shaping Europe's future, by conducting ambitious, interdisciplinary research actions

Promote interdisciplinarity in education systems (initial and long-life training, re-skilling): the younger generations are on the front line when it comes to climate change challenges for 2050, and need to have the tools to make informed decisions to take the appropriate actions for these major transformations. In view of this, training and education for citizens and future decision makers must run alongside these transitions by integrating interdisciplinary (e.g. education integrating science, technologies and humanities) and systemic approaches from primary school through to higher education.

Encourage the development of inter-disciplinary training courses based on the concept of "T-shaped people" (vertical part of the T: specialist core skill, horizontal part of the T: more generalist knowledge and the capacity to implement holistic approaches), and training courses based on two skills: sciences + humanities or digital technologies + humanities, …

The design and implementation of innovative teaching practices (cooperative learning, learning by problem-solving, serious games,...) on the challenges associated with the transformations in energy, ecology, health and digital technologies must be encouraged.

Thematic sheet

1 Climate change, energy transition, society and health

Challenges

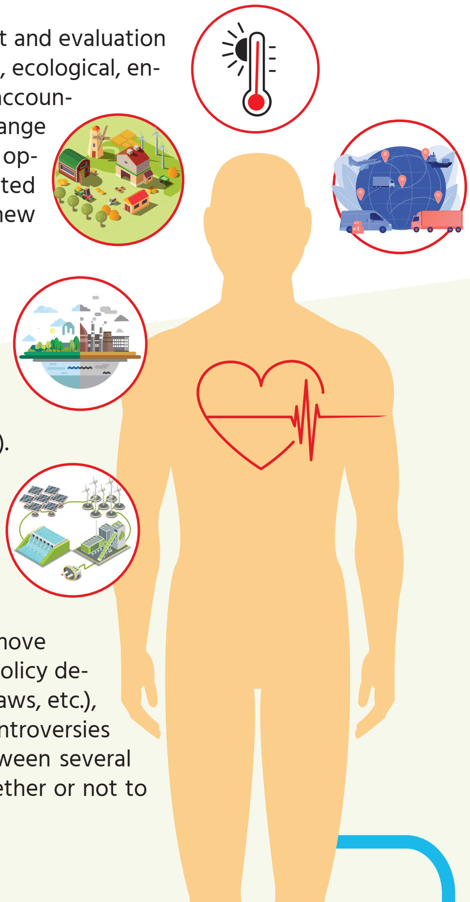
- Climate change and energy conversion methods influence human health through several different direct mechanisms (related to ambient temperature) and indirect mechanisms (related to biodiversity, extreme weather conditions, air pollutants from different sources, etc.). The direct effects of temperature operate through a range of different biological, behavioural and environmental mechanisms. Therefore, developing a map of the health impacts of climate change and energy conversion methods and usage is a complex and highly multidisciplinary task.

- The implications of a carbon-neutral policy and energy transition for public health policies need to be identified. These implications are still not sufficiently theorized and targeted with definite actions, including in relation to the organization of the healthcare system and health promotion. The role of whistle-blower, promoted by Richard Horton, editor-in-chief of The Lancet, of informing patients and healthcare personnel about the health impacts of climate change among others, are emergent practices.

- Improving the integration of public health criteria in the development and evaluation of strategies to adapt to and tackle climate change (agricultural, food, ecological, environmental and energy transitions) is also a necessary move, while accounting for both health effects related to the attenuation of climate change and co-benefits for health. The aforementioned major transitions are opportunities to make progress with complex public health issues (related to transport, food, energy conversion methods, the introduction of new technologies, etc.) that have not yet been resolved.

- The role and impact of public health policies also need to be better assessed in order to contribute to a carbon-neutral society relative to a set of players and initiatives also working towards this objective by adopting new ways of living, health practices and new sustainable production, mobility and consumption methods (citizens' initiatives, local policies, general political choices not related to health policies). Alongside that, it is useful to understand how certain social, economic, political or cultural contexts make it difficult or even impossible to adopt the new ways of living, health practices and production and consumption methods (irrespective of how social players themselves perceive or represent the aim of a carbon-neutral society).

- Finally, it is important to understand the processes that enable us to move from research evidence on the health impacts of climate change to policy development and policy development and implementation (measures, laws, etc.), as the switch from the former to the latter is not automatic; the controversies that may be associated with these processes; and the conflicts between several ultimate objectives that can lead to decisions being made as to whether or not to continue the trajectory towards a carbon-neutral society.



Climate change and energy conversion methods influence human health through several different direct mechanisms and indirect mechanisms

Various institutional and scientific barriers currently hinder the development of necessary research programs on the health impacts of climate change or energy conversion methods:

Barriers

- The public health community in France is not mobilised or organised enough on the issue of the effects of climate change on health. Human and social sciences are mobilised via different thematic entries (from studies on the green economy to those on environmental/climate mobilisations) but doubtless nsufficiently coordinated among the different fields and with the other disciplinary sectors of public health, including environmental epidemiology (One Health, etc.).
- Documentation on the multiple mechanisms by which climate change is likely to have an influence on health is very irregular, with significant variations in the quality of available evidence. At this stage, it appears impossible to draw up a reliable ranking of the health impacts of climate change according to the health burden they represent. Collection of pertinent data, interventional studies and prospective modelling work are required, in particular in French study territories.
- There is a lack of the multi-generational modelling work required to create reliable predictions for the future and to study the impact of scenarios in the context of climate change. The health impacts of such climate change scenarios should be evaluated through comparisons to counterfactual climate change scenarios, which would require active cooperation between climatologists, epidemiologists and public health researchers.
- At a global level or through comparison of territories, and at different spatial scales (from local regions to international scale), studies that would help understand the implications of a policy geared towards carbon-neutrality on public health policies are still lacking.
- Surveys are also required to inventory and analyse the way in which individuals, families, social groups and societies as a whole are situated relative to the aim of a carbon-neutral society. Such studies should help understand which health and living conditions are needed to endorse this aim, the kind of conflicts it is likely to cause, the scale of values it implies, what initiatives have already been taken to this end (by associations, public authorities and, if necessary, at which levels?), and the role national and European environmental law plays or could play.
- Public health issues have not been included enough in discussions on the major transitions to a carbon-neutral society. It would be useful to analyse the place of public health in (urban) policies concerning transport, urbanism, the energy transition, the environment, agriculture and food. It is a question here of finding the right alignment for policies on public health, energy management and the preservation of biodiversity.

The actions described below aim to encourage the emergence of a research community in public health, focused on the health effects of climate change and the health implications of strategies to adapt to and combat climate change (including the associated major transitions).

Actions

The following actions must be envisaged in the short term:

- Map out the strengths and weaknesses of the national public health and human and social science communities on these research topics and mobilise the community on questions pertaining to the health implications of climate change.
- Identify existing observatories on which the (necessarily multidisciplinary) aforementioned studies could draw on, or create such observatories if necessary.
- Set up an initial call for funding "Young Climate-health Stars" to attract young high potential researchers and their research groups.
- Set up a call for interdisciplinary research projects that foster research on the continuum from climate sciences to those of public health, with an emphasis on the related transitions (ecological, energy, food, etc.).

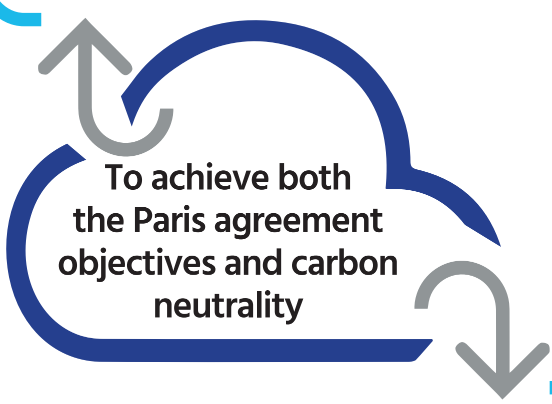
Thematic sheet

2 Negative carbon emissions, (active and passive) decarbonisation and biodiversity

Challenges

On the trajectory of the Paris agreement

Global net CO_2 emissions (combustion of fossil energies, industries and changes in land use) currently stand at nearly 30 Gt CO_2/yr and the projection of the IPCC's RCP 6 scenario, which is not the most pessimistic, forecasts over 50 Gt CO_2/yr in 2050, which translates as an increase in the atmospheric concentration of CO_2 that could reach a figure between 700 and 1,000 ppm of CO_2. The Earth's temperature is also set to increase anywhere between 2.0°C and 3.7°C (AR5 IPCC1). Only a scenario that incorporates in negative emissions (RCP2.6) would give an increase in the Earth's temperature of between 0.9°C and 2.3°C, compatible with the objectives of the Paris agreement (COP21-2015). To achieve both the Paris agreement objectives and carbon neutrality, a mandatory reduction in emissions of around 10 Gt CO_2/yr is required.



Act fast

The longer it takes to introduce measures to decrease CO_2 emissions directly linked to human activity, the more difficult it will be to offset them. This not only means reducing emissions (burning fossil energies and industries, agriculture/livestock farming) but also the immediate introduction of negative emission technologie (NETs)[1].

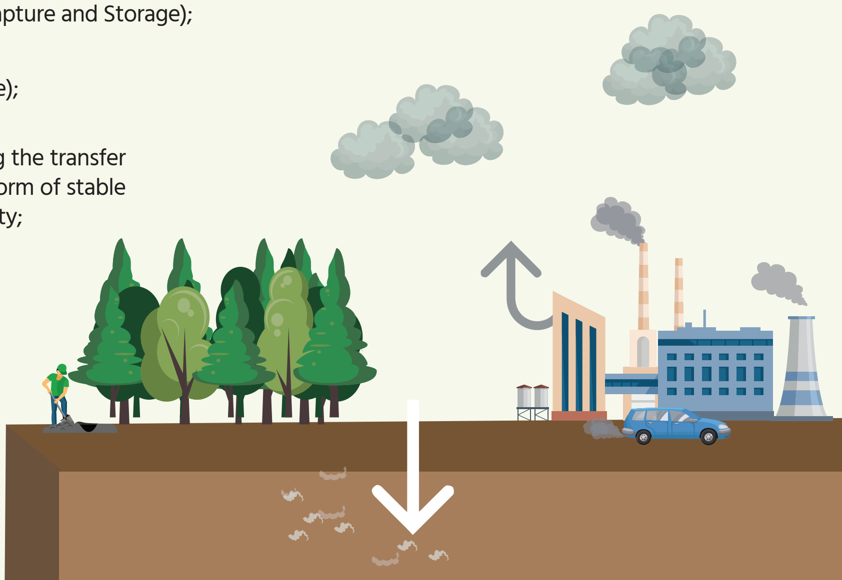
Several Negative Emissions Technologies are now common knowledge (Minx et al., 2018)[2] and in particular:

i The association of Bioenergies such as 3rd generation biofuels (with the aim at optimising the added value of microalgae), biogas obtained by anaerobic digestion, associated with carbon capture and storage (CCS) techniques, referred to as BECCS (BioEnergy with Carbon Capture and Storage);

ii DACCCS (Direct Air Carbon Capture and Storage);

iii Soil carbon storage which consists in optimizing the transfer of biomass from agroecosystems in soil in the form of stable organic matter, by capitalizing on soil biodiversity;

iv Reforestation and afforestation.



1 - Definition of negative C emissions: set of solutions used to capture the surplus carbon dioxide in the atmosphere.

2 - Minx et al 2018 Approx. Res. Lett. 13 063001

Barriers

Several barriers hinder the deployment potential of these technological solutions for negative emissions:

- There is no interdisciplinary analysis of the impacts of NET solutions to shed light on to implement them policies. The processes from proof of concept, with regards to the implementation of NETs, to policy development and implementation need to be understood, as the transition from proof of concept to implementation is not straightforward.
- NETs solutions must prove their capacity to be deployed on a large scale, and current knowledge on this issue has not yet proven to be convincing enough (cf. GSDR4 2019). It is important to note the difference between the challenges for technological NETs (technological maturity) and those for natural NETs (sink saturation and competition for land use).
- In addition to improving processes and their integration in productive systems, the analysis should focus on their compatibility not only with Sustainable Development Goal (SDG) 13 but also with the other SDGs, on the preservation of soil ecosystem services and the adaptation to specific territorial conditions. Finally, the perception that citizens and society have of NETs is still very limited.
- As the theme is interdisciplinary, a common language and semantics need to be developed among researchers working in different sectors and, most importantly, between the research world, citizens and the political sphere.

All these actions are geared towards:

1. Having tools that clarify the deployment policies for Negative Carbon Emissions Technologies;
2. Specifying the framework and conditions for mass deployment;
3. Creating the conditions for NETs to be appropriated by society.

Actions

- Developing ambitious research programs that aims to create a framework for the interdisciplinary assessment of the different negative emissions solutions, their co-benefits with other services (food security, public health, ecosystem restoration, preserving biodiversity). It is a question here in particular of factoring in the storage potential, costs, energy consumption, long-term efficiency, competition for water, nutrients, competition for land, damage to or preservation of biodiversity, the consequences as regards global health, food, the organisation of technical and economic sectors and social evolution.
- Conducting large-scale experiments when the input is territorial, in liaison with local authorities, groups of local players, and by opening the different options up for public debate (see the IPCC7 Special Report on Climate Change and Land.
- Developing specific instruments designed for and steered by academic sites, on topics such as “Observatories” or “Living labs”.

Thematic sheet

3 Benefits and impacts of digital technologies on energy, the climate and society

Challenges

Digital technologies play a central role in the major transitions taking place.

But the environmental impacts of digital tools (manufacturing, use, recyclability) are a major source of concern. The many aspects of the digital transition (health, employment, consumption, leisure) must not be in conflict with preservation of the environment.

As scientific publications progress, models and numerical simulations provide increasingly accurate and reliable quantitative information on the consequences of climate change, biodiversity loss and the consequences of human activities. The scenarios and levers for action are known.

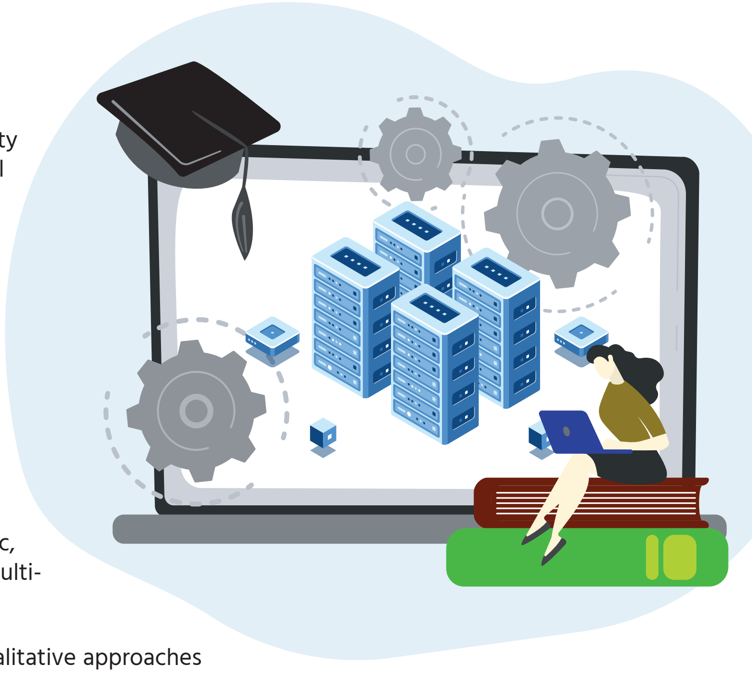
At a time when ambitious commitments are being made (by states and companies, within the framework of international treaties), when environmental concerns are growing and the scientific challenges are immense, research actors must get involved and quickly make concrete commitments.

Observations and diagnoses are often shared

- Environmental preservation is a new paradigm to ensure essential functions in the long term (food, housing, travel, clothing, etc.). The energy and digital sectors (ICT require more and more energy and also offer the potential for better energy management) must be part of this framework and contribute to it by proposing long-term development scenarios.
- In parallel, digital sciences must help us understand and quantify the impacts of our choices and activities and reduce their own energy and environmental impact.
- In this context, innovation, efficiency and sobriety must be combined in a fair balance. Digital technologies have a catalytic role and their direct and indirect impacts must be qualified and quantified, as well as the rebound effects.
- Given the complexity of the investigated systems, interdisciplinary research programs should be developed, combining specialized skills with global and systemic visions.
- The public debate and the public policies supported must be informed by the profound and lasting changes underway, notably due to the high penetration of digital technologies such as AI (Artificial Intelligence), by enabling dialogue between science, technology and society.

The awareness of the importance of environmental issues in the digital sector is now obvious, but its transposition into practices and uses is still in its infancy, because there are several obstacles to overcome:

Barriers



- Eco-design of digital tools and services integrating sobriety objectives, even constraints (in terms of energy, environmental impact and resources).
- Establishment of ecosystems allowing synergies between academic research, innovation, society and territorial actors, in particular for the development of the various uses of digital technologies.
- Attractiveness for young scientists willing to invest in research on modeling on/for the environment and digital sobriety.
- The development of models integrating available data and techniques using artificial intelligence and contributing to decision-making processes. Approaches must be holistic, generating agile and reliable models with a strong stochastic, multi-actor and multi-scale dimension.
- The implementation of participatory processes confronting qualitative approaches and quantitative modeling, allowing to put into perspective the advantages and impacts of digital technologies.

Actions

Several research themes are proposed at different levels:

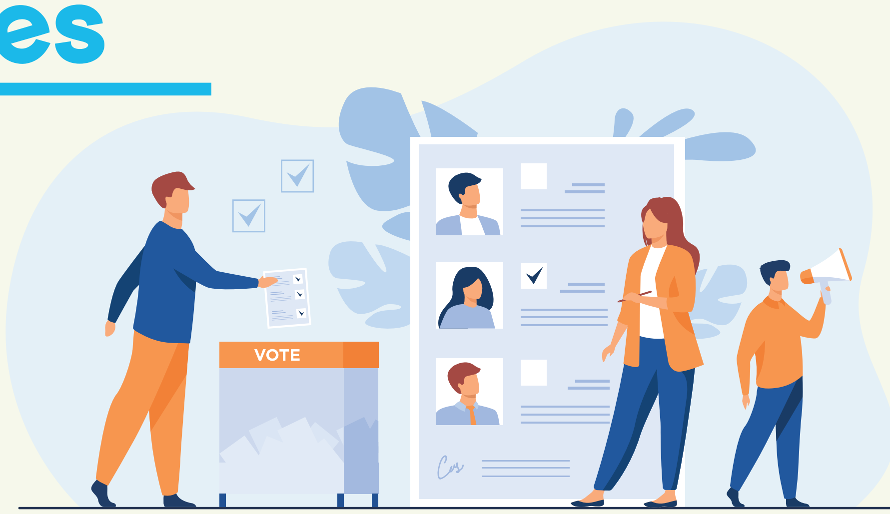
- Develop a project dynamic at the interface between ICT, energy, humanities and social sciences, focused on quantifying and materializing the environmental impacts of digital technologies to prioritize constraints and question the usages.
- Scientific research should not be limited to knowledge or analysis, but should strive to respond to the challenges posed (problem-solving approach).
- Reinforce the objectives of preserving the environment and biodiversity, particularly in the design of digital tools and services (labelling / certification).
- The environmental impacts of digital technologies are often indirect, appear over the long term and are therefore not immediately visible. Education (initial and continuing) in digital technologies and their multiple implications is crucial and must be developed.
- Develop training modules combining digital sciences and humanities. Involve the humanities and social sciences to review the role of models and model assemblies in the policy-making process and their acceptability.
- Encourage open science and increase emphasis on repeatability of scientific work.
- Combine the actions of researchers and citizens, especially when it comes to identifying the benefits and impacts of digital technologies. Promote an ethic of responsibility and encourage scientists to participate in public debate by basing their involvement on the legitimacy of their expertise.
- The health crisis will prompt many people to redirect their research activities towards environmental issues. Activities focused on this theme must be encouraged. This is a major lever for launching new interdisciplinary research initiatives, particularly on the interfaces between digital technologies, energy and society.

Thematic sheet

4 Democratic and sovereignty challenges in the transitions, for a systemic and deliberative vision

The adaptation of human societies to climate change, their commitment to carbon neutrality and the protection of biodiversity, imply a change in direction, multi-faceted changes in production and consumption methods (goods, services, use of digital technologies, food, energy), social practices and ways of life. This relies partly on citizens' agreement, involvement and frequently their initiatives.

Challenges



The first challenge is to create the conditions for a **systemic understanding of climate change, energy, health and environmental challenges**, relevant responses and the subsequent constraints to clarify collective and public decision-making processes.

The second challenge is to **make the major transitions** (related to climate change, health, ecology, energy management for the use of digital technologies, sustainable energy production and consumption dynamics) **an exercise in democracy and sovereignty** within the framework of institutions and public debate, with the support of research systems, promoting citizens' commitment.

The two classical modes of knowledge dissemination, science push and problem-solving model are questioned by the nature of systemic, multi-scale and far-reaching challenges, which imply frameworks and forums for discussion among researchers, decision-makers and citizens as to the status of knowledge, the relevance of actions to be taken, their impacts and their final aims.

Barriers

Several barriers still limit these modes of action:

- Producing analyses that help generate a systemic vision of ecological, climate and energy transitions by developing multi-disciplinary and multi-theme approaches to describe and evaluate the impacts induced by the measures adopted at different space and time scales.
- Depending on the subject of research, establishing the relevant territorial scale or articulation of scales to materialise the interdependency of the different challenges, create conditions for informed deliberation among stakeholders, fostering initiatives and examining opportunities for subsidiarity and sovereignty (in the sense of relative autonomy) in the decision-making process.
- Understanding and anticipating the fundamental social, economic and environmental changes that accompany actions dedicated to the ecological, climate and energy transitions, in particular by examining the transfer of risks, constraints and benefits and how these are transposed as regards social relations, justice and equity.
- Encouraging and analysing the involvement of citizens and communities in the processes contributing to the ecological, climate and energy transitions.

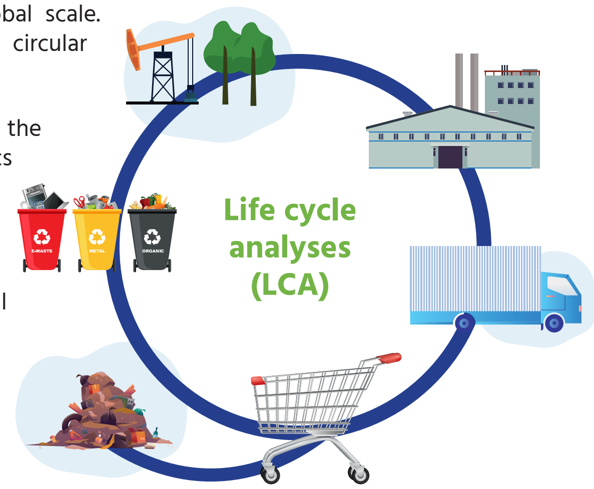
The proposed actions endeavour to:

1. Highlight the systemic and multifaceted nature of the challenges;
2. Understand the deep-rooted changes facing society;
3. Anticipate the ways in which citizens can become proactively involved as a prerequisite to participative research.

Actions

Actions are put forward as proposals for programming research:

- Developing life cycle analyses (LCA) to highlight, evaluate and compare the impacts of a system or product on a regional, national or global scale. Moreover, LCA helps enhance analyses as regards sovereignty, circular economy, consumption of resources and extractive activities.
- Favouring multidisciplinary territorial approaches to review the subsidiarity methods for public policies and the cooperation dynamics between actors, and the conduct of the debate with stakeholders.
- Developing comparative research combining approaches from earth science, life science or social science and humanities, to observe and analyse the social, economic and environmental implications of the policies and technical systems implemented to support the ecological and energy transitions and to protect biodiversity in Europe and worldwide.



They can focus on the analysis and impact of public policies or economic players in order to:

- Understand the perception and reaction of citizens/consumers when they are called upon individually or collectively to take a responsible and proactive role in ecological, climate and energy transitions and build a resilient society.
- Study the misinformation campaigns designed to weaken the significance of scientific findings, reduce agreement factors and capture their critical scope towards the research community[1].
- Create the conditions for a cumulative investigation of different forms of citizens' commitment, whether they correspond to individual practices or collective forms to respond to the effects of climate change, to contribute to the preservation of resources (creating short circuits for food or energy needs, repurposing objects, creating shared workshops) or adapt to the degradation of the environment, to implement alternative solutions or create new activities.

1 - This action is part of a practice of open science support and promote the involvement of citizens, civil society, and end-users (Strategic Plan 2021-2024 Horizon Europe, p 26)

Thematic sheet

5 Energy of the territories

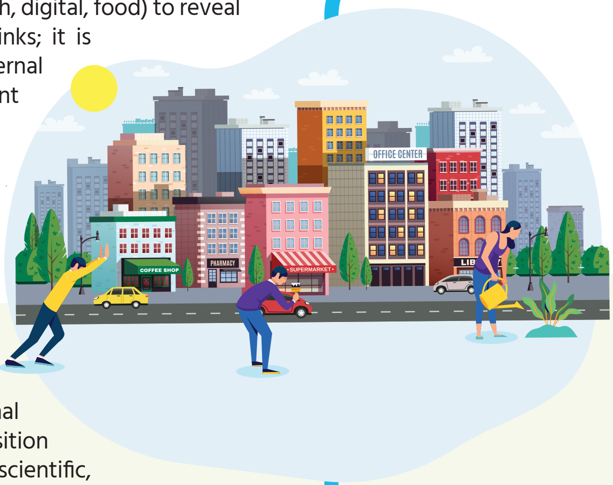
Energy, society, digital technologies and health

Challenges

The region, at each scale - individual, local, regional, national, European and global - is the reference point to enhance the value of research, transfer innovation, explore the viability of solutions and prepare their deployment. The region embodies the changes - particularly environmental, social, energy and digital - undertaken in the different transitions. The regions are nodes within a system of flows, which cross through them and link them together. Societies are based on this mesh of contracts with an ever-expanding geographical reach. Citizens & organizations, regions and systems are the triangle around which links are created and unfolded.

The challenges are therefore to:

- **Adopt the different regional scales,** as a key to analysing the complexity of systems (energy, ecology-environment, health, digital, food) to reveal the combinations, flexibilities and symbiotic links; it is about reviewing the ideas of internal and external resources, given that systems develop at different levels (local, national, global). Any territorial approach implies factoring in the necessary inter-scalar synergies.



- **Analyse the regional cohesion factors** and look beyond the notion of social acceptability to move towards more participative and democratic approaches in the construction of projects, and the concerted management of benefits, risks and responsibilities. It is also necessary to consider local initiatives, at regional level, since the local actors are in a better position to identify resources (environmental, human, scientific, technical, physical or biological), to reveal industrial, agricultural and energetic legacies, and develop suitable scenarios for general principles and equilibria.

- **Preserve social justice, equality (intra- and between territories), autonomy and sovereignty** by rethinking sovereignty as a fair interrelation between local capacities and global connections, and drawing parallels between democracy and actual capacities to concrete achievement.

- **Bear in mind the lessons learned** from the COVID-19 pandemic with regards to consumption (energy, digital, health, environment, food) behaviours at regional scale, and the potential changes in direction, analyse the rebound effects and strategic dependences.

Barriers

- System complexity in particular due to interactions;
- Perception of relations and interdependencies between the different levels;
- Large number of players and stakeholder relations;
- Multiple objectives and indicators and the partial incompatibility among them;
- New data acquisition, collection and use

Actions

Investigate regional contributions:

- Investigating local flexibility proposals for global resilience; analysing the dependency of local and global flows;
- Exploring possible compromises between economic costs, autonomy and sovereignty, resilience and regional cohesion, according to inter-level approach;
- Increasing the strategic capacity of regions in terms of knowledge, data availability and the deployment of multi-scale initiatives and dialogue with professional sectors.

Examine and revise regional interdependencies:

For example via life cycle analyses (LCA), the inventory of good stocks and flows to clarify discussions and rank sometimes contradictory orders; investigating the regional metabolism by highlighting its material and organisational weak points; adopting the territorial scale as a key to analyse the complexity of systems (energy, ecology-environment, health, digital, food) to reveal the combinations, flexibilities, virtuous symbioses and tensions; linking the quantified analysis of stocks, materials flow and energy with qualitative analyses of their modes of appropriation, management and sharing, as well as any environmental impacts or injustices they engender.

Move from the technological demonstrator to the social and territorial demonstrator (living lab) to better integrate the impact of change and build the foundations for exporting to other regions:

By experimenting procedures for incorporating all the players in a region in the development of transitions, the management of local resources and the changes under way. This will imply the analysis of common denominators among local regions, and comparing them with global common denominators in connection with private, individual and collective players. The implementation of the demonstrators will require longer time-frames than that for testing a given technology, to support collective local learning curves and the possibilities for structuring national sectors. This helps review the hierarchy of needs, benefits and renunciations in the event of a crisis that may be decided democratically. The "living-lab" projects need to be monitored using a systemic approach, moving away from silo approaches where problems are structured into sector-specific layers.

Thematic sheet

6 Territories in a state of shock, resilience:
climate, energy, health and society

Challenges

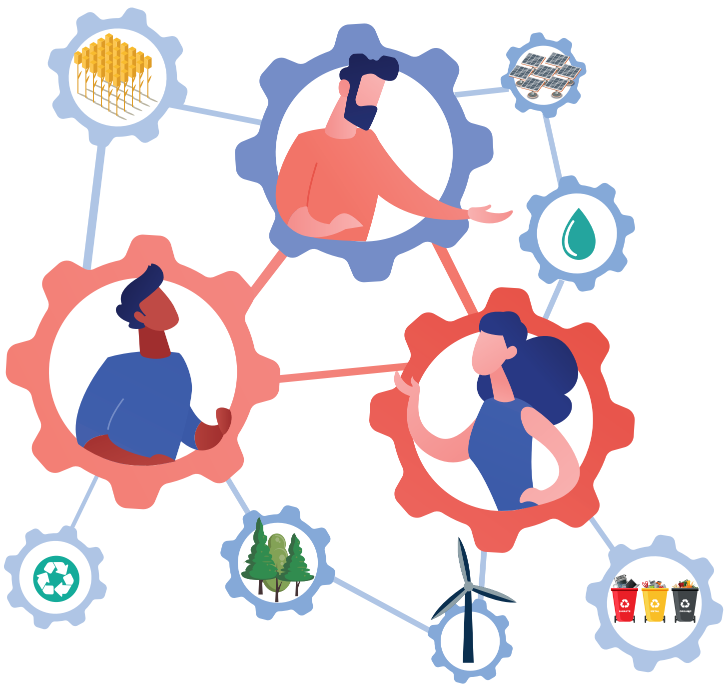
By virtue of their different taking into account the dimensions and local organizations, regions suffer, accentuate or reduce the impact of shocks and crises. They are simultaneously places of anticipation, preparation and resilience, as well as opposition and objection. The challenges therefore lie in:

- **Tensions between short-term efficiency** and preparation of **multi-and inter-level** resilience owing to the integration of a system of geographical, social and technological constraints: exploring possibilities, synergies, and the local flexibility of systems and players to work toward local and global solutions and resilience;
- **Adopting measures designed to protect from shocks that can be accurately predicted or are expected,** and to prepare general conditions to help react appropriately in the case of more uncertain and ill-defined shocks;
- **Questions as to what extent the local flexibility of systems and players contribute to global resilience** to think about the challenges at all local and national levels, and their interactions;
- **The analysis of shocks in terms of both, negative and potential favorable** effects allowing many possibilities of recompositions. This encourages to integrate the reasons of the shocks into the analysis, to bring out opportunities for solutions.

Barriers

- Need to think the transitions through (their status, possible objectives, shared intentions, contradictions, etc.) and develop the capacity to observe, identify and then mobilise the faculty of resilience (resources and new impacts) in liaison with the concepts of health, food, digital or energy democracy:
    - Are there any invariants?
    - Is it possible to restore the pre-crisis situation?
    - Can forms of transitions be defined which are not a source of standardisation or dependency on one-off solutions?
- The aim is to have a range of different and complementary actions available at all times:
    - Need for theory- and method-based approaches for rare and exceptional events that fall outside the statistical approaches on large numbers.
    - Need to overcome the difficulty of projecting oneself into future and severe crises (different unpredictable aspects: - psychological, cognitive, ideological, etc.)
    - Need for new participatory and deliberative approaches to manage transitions and crises, look for organisation and management methods coming from players' initiatives to overcome the critical phases, learn lessons from experiences to develop resilience capacities and in particular overcome any possible structural or institutional barriers.

Actions



- **Link between systems under tension and shocks:**
    - Analyse the impact of unpredictable elements in the models;
    - Take into account ideas of stability and junctions;
    - Analyse the conditions for triggering virtuous momentum;
    - Develop approaches by "stress-test" simulation scenarios (e.g. using serious games) to identify risks, weaknesses, barriers, strengths;
    - Facilitate the construction and appropriation of a transition culture which implies familiarisation with new possibilities and constraints depending on the regions, their unpredictable facets and their challenges.
- **Resilience at different regional levels:**
    - Analyse stakeholders with intermediate organisations;
    - Define and consider regional boundaries;
    - Understand how redistributions work.
- **Crisis and redefinition in flows:**
    - Review flow identification and analysis methods after a crisis;
    - Observe post-crisis situations, identify the immediate needs and build structural solutions to increase system resilience;
    - Have democratic approaches to manage the potential renunciations in choices to be made and set new objectives and new types of desired transitions (equality, sobriety, environmental impact, which social model, etc.).
    - Contribute to the elaboration of doctrines in terms of spatial planning, to go beyond the «zonal» approaches too often linked to facilities only. In this sector, develop a culture of adapting to climate change which includes for example the importance of living soils and their biodiversity, the water cycle, renewable energy cycles, seasons and weather extremes (slow down soil degradation, manage heat-waves, etc.). Provide information on the rebound effects of human-centred solutions in relation to the actions taken to adapt to crises.

Methodological approach sheet

7 Challenging and fine-tuning models: working towards new application frameworks for evaluation and decision-making

To support the major transitions (climatic, ecological, environmental, energetic) while preserving an economic, social and health equilibrium, political authorities and citizens must have modelling tools available to formally define the knowledge of a given area of analysis, take the measure of the uncertainties, benefit from prospective analyses, make quantified forecasts and thereby succeed in opting for appropriate decisions.

Challenges

The first challenge

is to increase the capacity of models to render the systemic, multi-dimensional in time and space and multi-agent nature of the major transitions under way, and to handle expected ruptures and crises. This also improves their reliability, agility and predictability.

The second challenge

is to reinforce the credibility and explicability of models at different spatial levels by specifying in which conditions they are valid and by diversifying the context of application. Thinking about the limits of models also implies constructing alternative scenarios and identifying the scientific resources required to respond to breaking events and systemic crises.

Barriers

The first barrier

is the integration in more in-depth and renewed models, the scientific basics to attenuate the detrimental effects of global changes. They could strengthen capacities to mitigate and adapt to the multiple consequences of these changes.

The second barrier

is due to the evolution of the models themselves to deal with complex phenomena, multi-factor and interdependent phenomena. The challenge is to boost the robustness of their capacity to predict in an uncertain situation and to hybridise different methods (often the capacity to describe either discrete or continuous processes), or by integrating the results of big data analyses.

The third barrier

concerns the integration of different qualitative and quantitative approaches to create, through participative approaches or community work, the conditions for a shared and collective anticipation of predictable events.

The fourth barrier

is about the need to have data from territories and stakeholders, for modeling and to form hypotheses, while obtaining elements to compare and validate models

Actions

A first set of possible actions:

- Improve models by drawing on progress made in research and dialogue with public authorities to highlight the needs specific to the different challenges. These improvements, combined with a 'think tank' and debate approach, foster a **shared vision of methods and analyses** and pave the way for decision-making.
- Encourage systemic, integrated and multi-disciplinary approaches to understand the interactions between the physical elements of climate change, the biological or ecological components (in the sense of living systems and ecosystems in particular) and societal components.
- Develop more agile and reliable models with a strong stochastic dimension, with multi-player and multi-scale (space and time) levels, and a privileged consideration of the sobriety (in terms of energy, digital technologies or resources) objectives.
- Design models that integrate the diversity of individual and collective practices and which are able to build scenarios while quantifying uncertainties.

A second set of multi-disciplinary work focuses on model basics and design, in particular on:

- The ways in which artificial intelligence is used to construct models and their potential contribution to holistic methods, while examining their conditions of use.
- The experimentation of methods adapted to extreme crises (taking into account radical uncertainties, rare and extreme events).
- The influence of models and their assembly in the process of developing medium and long-term policies (e.g. carbon-neutrality and environmental policies), by mobilising human and social sciences.

A third set focuses on extending the use of models through experiments that contribute to:

- Using modelling as a support for participative processes in consultations or information processes.
- Comparing and initiating a critical dialogue between qualitative approaches and quantitative modeling methods to prepare the decisions to take imposed by major transitions.

8 Encourage the building-up of teams of researchers and key players, promote the analyses of innovation and development processes

The implementation of climate, ecological, and energy transitions implies disruptive innovations and changes in direction. Their systemic effects and the progressive inductions modify human activities, the way in which space is occupied, access to natural resources, etc. It is important to consider this systemic dimension, which is revealed in the shorter or longer term, to evaluate the potential of an innovation in terms of technologies, products and services or public action. This approach is just as relevant to prepare for large-scale developments. However, it does require the perimeter of competencies mobilised to be extended and diversified.

Challenges

The first challenge

is to adapt technological innovation systems to **incorporate societal and environmental constraints as far upstream as possible.**

The second challenge

is to reinforce the capacity of innovators and leaders to plan ahead as soon as a method, technology or public policy is introduced, for a change of scale or for a renewal in the usage context, while remaining attentive to positive and negative external influences.

Barriers

The first barrier

is the very high prevalence of knowledge mobilised in the technology design phase. This specialisation can be easily explained by the priority given to the contributing sciences, but the consequence is that it eliminates the dimensions other disciplines can bring, for example in terms of health, protecting the living world, social or environmental impact and sometimes in terms of the implementation and durability of the system.

The second barrier

is the difficulty in running long-term observations on an entire process. This is linked to the constraints of organising research and its evaluation, to the difficulties researchers have in accessing this information in the different design, demonstration and development phases. Added to this are the limits encountered in establishing, collecting and gathering data and the difficulties in bringing together the competencies required to produce adaptations and corrections. Overcoming this barrier increases the value of the experiment and fosters an upstream reflection to future processes.

Actions

The first proposals for actions tackle the first barrier by endeavouring to develop the interdisciplinarity of the teams involved as from the design phase of technological and socio-technical systems, and to construct diversified groups to support the development phases.

- Encouraging the diversification of teams who design sociotechnical systems by involving first and foremost, researchers in human and social sciences as from the upstream phases of technological research.
- Creating stable groups, recognised by funding, and which associate researchers and stakeholders (public, industrial actors, elected representatives and citizens) during the demonstration or deployment phases of a new technology or system innovation; mobilising these groups for monitoring and evaluating over time, to provide material for a debate on their social, economic, energy and environmental reach; evaluating the global impacts on climate change.
- Fine-tuning and anticipating the conditions for appropriating socio-technical systems by involving researchers in physical sciences, social and life sciences, in the demonstration, deployment and living phases of these systems.

The last set of proposals endeavours to promote conditions for a systemic and renewed observation, over time:

- Creating observation instruments over five years renewable, designed for research on the major energy, environment, health and climate change challenges. These instruments would contribute to gathering data over time (by collection, sensor networks, surveys, panel monitoring), the production and availability of monitoring and evaluation indicators published according to an "Open Science" principle.
- Initiating inter-disciplinary, wide-range observations. Depending on what they are designed for, these devices can focus on measuring positive and negative external factors (on greenhouse gas emissions, consumption of water resources, biodiversity, local economy, risks of social or energy insecurity or social cohesion). Alongside that, they can also encourage the renewal of teams, approaches and issues.

Methodological approach sheet

9 Recognizing citizens as partners in research on the major transitions

To take part in the required ecological, climate change and energy transitions, more than ever now, the research world has the responsibility of considering citizens as contacts and partners.

Challenges

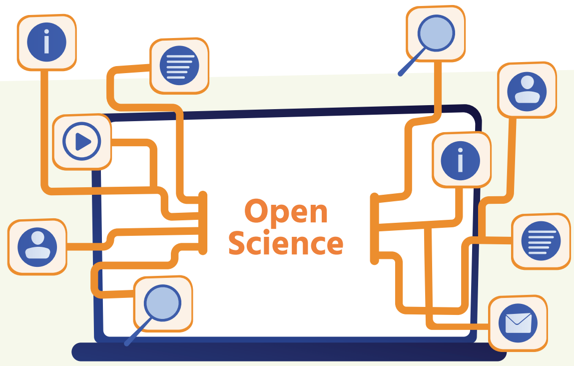
The first challenge

for scientists is to share the established facts, their hypotheses, debates and research questions. Their means of action are based on a reinforced bond between research and training, on the full use of scientific and technical information capacities and on participation in public debates concerning health, ecology and environment policies, or energy challenges and digital practices.

The second challenge

is to make researchers' work more visible, arouse interest in it and increase understanding by arranging the conditions for an exchange and by developing shared or convergent actions.

The Scientific and Technical Information systems with a policy and experience of supporting dissemination, innovation and "Open Science" are a key asset in meeting these challenges in universities and research organisations.



Barriers

Two barriers represent innovation areas suitable for research on the transitions:

- Encouraging stakeholders, leaders and citizens to **rely on the results, and questions raised by research in the analysis and steering of public policies** in terms of climate, health, environment and energy.
- **Supporting the development of research professions** to promote a responsible science, committed to dialogue with citizens and stakeholders. Such initiatives can be based on a participative science approach.

The proposals for action are designed to:

1 Create the conditions for direct dialogue on climate change, energy and ecological challenges by training, teamwork and debate;

2 Foster and recognise responsible scientific practices that are open to discussion.

Actions

Train, discuss and share

- Giving a holistic vision of transitions in higher education curricula, developing training courses combining sciences and humanities, consolidating the consideration of sustainable development goals in further education courses.
- Creating the conditions for a common language between public and economic leaders, citizens and scientists through the experience of dialogue, supervising shared projects, hosting stakeholders in research institutes and public or private organisations.
- Developing, sharing and renewing scientific and technical communication systems to focus on citizens, regional players (elected representatives, companies, leaders,...), develop venues for debates and controversy on the scientific challenges of the major transitions.

Researchers in society

- Supporting scientific actions that display ethics and responsibility and strive to implement sobriety measures in their practices and supporting the training courses they give.
- Facilitating the action of scientists who are determined to create a common language with citizens and decision makers. Presenting the results of their work to stakeholders or developing participative research. Finally, acknowledge the value of these activities in the carrier development of these researchers.
- Encouraging researchers to take part in informing users and citizens on the quality of products and services in terms of reducing greenhouse gas emissions (eco-labelling), and safeguarding health and biodiversity.

ANCRE

Alliance Nationale de Coordination de la Recherche pour l'Énergie

www.allianceenergie.fr/

AllEnvi

Alliance nationale de recherche pour l'Environnement

www.allenvi.fr

ATHENA

Alliance thématique nationale des sciences humaines et sociales

www.alliance-athena.fr

ALLISTENE

l'alliance des sciences et technologies du numérique

www.allistene.fr

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alliance nationale pour les sciences de la vie et de la santé

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