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2025 *Activity Report*

RESEARCH CENTRE: **Inria Centre at Université Grenoble Alpes**
IN PARTNERSHIP WITH: **CNRS, Université de Grenoble Alpes**

Project-Team

STEEP

Sustainability transition, environment, economy and local policy

In collaboration with Laboratoire Jean Kuntzmann (LJK)

Project-Team STEEP

Creation of the Project-Team: 2015 December 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A5.2. – Data visualization

A6.1. – Methods in mathematical modeling

A6.1.4. – Multiscale modeling

A8.2.1. – Operations research

A9.6. – Decision support

Other research topics and application domains

B2. – Digital health

B3.1. – Sustainable development

B3.1.1. – Resource management

B3.4. – Risks

B3.5. – Agronomy

B4.1. – Fossile energy production (oil, gas)

B4.3. – Renewable energy production

B4.4. – Energy delivery

B4.5. – Energy consumption

B7. – Transport and logistics

B8.3. – Urbanism and urban planning

B8.5.1. – Participative democracy

B8.5.3. – Collaborative economy

B9.1.2. – Serious games

B9.2. – Art

B9.6.3. – Economy, Finance

B9.6.9. – Political sciences

B9.9. – Ethics

B9.11. – Risk management

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2 Overall objectives

2.1 Context

> "We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide. [. . .] [However] it is not too late to make a difference, but only if we start now at every level from local to global, [and by this we mean] a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values."
>
> *Robert Watson, President of the IPBES, on May 6, 2019*

Environmental issues now pose a threat to human civilization worldwide. They range from falling water tables to eroding soils, expanding deserts, biodiversity loss, rising temperatures, *etc*. For example, half the world's population lives in countries where water tables are falling as aquifers are being depleted; roughly a third of the world's cropland is losing topsoil at an excessive rate; glaciers are melting in all of the world's major mountains. The consequences on present human societies are critical; they comprise for example increasing threats on global food security, increasing pressures resulting in important population movements (such as climate refugees) and explosive geopolitical tensions. See [39] for a global picture of the situation.

The risks associated with delayed reaction and adaptation times make the situation urgent. Delayed reactions significantly increase the magnitude of the overshoot of the planet's carrying capacity and the probability of uncontrolled and irreversible evolutions on a number of fronts, potentially leading to global environmental collapse [59, 47]. This systemic problem is amplified by two facts: the environment is degrading on all fronts at the same time and at the global planetary scale, a first in human history.

Sustainable development is often formulated in terms of a required balance between the environmental, economic and social dimensions, but in practice public policies addressing sustainability issues are dominantly oriented towards environment management in Western countries. This approach is problematic as environmental problems and sustainability issues result from socio-economic phenomena (for example the economic growth model which is strengthened by powerful and polluting technologies). In addition, most efforts towards tackling them bear on developing technological solutions. However, it has been clear for several years if not decades that, albeit necessary and/or useful, this will not be sufficient [44, 45, 53]. We need to rethink our socio-economic and institutional models in order to leave room for a possible paradigm shift. In this perspective, we believe that crucial steps should be taken in research to help elaborating and implementing socio-economic alternatives.

Although environmental challenges are monitored worldwide, the search for appropriate lines of action must nevertheless take place at all institutional levels, in particular at local scales. We indeed believe that local levels are pivotal in this effort. In particular, we think that two local scales are going to be increasingly dominant in the near future: urban areas (more exactly the employment catchment areas of main cities) and "regions" (such as *régions* in France, *Länder* in Germany or *Province* in Italy). It seems essential to us that local policies and actions are made coherent and articulated across different scales, from local to global.

2.2 Objectives and outline of research axes

The research program of the STEEP team takes the above warnings seriously and aims to "help bring about a profound transformation of economies" at all scales, with a particular focus on sub-national scales over which actors have more control. This program is articulated around two axes.

The **GSR** (**Global Systemic Risks**) axis analyzes, on a global scale, the trend dynamics of risks and collapse, with a characteristic time step of the order of a decade or more, as well as the risks of systemic contagion, with a much shorter time step, due to the interconnection of key sectors of the economy (e.g. energy, finance, just-in-time supply chains, etc).

Our objective here is to rely on or develop numerical models (such as system dynamics, hybrid models including agents, etc.) that allow us to understand the vulnerabilities of our society and the environmental and socio-economic determinants that will constrain its sustainability. The systemic dimension is a key point here. Given the levels of uncertainty and complexity linked to the factors involved here, the idea is not to make predictions, but to understand the mechanisms and processes at play by providing robust qualitative or semi-quantitative analyses (providing orders of magnitude or comparative elements, for example). This work has for us a double objective: 1) to bring new crucial elements of scientific understanding to the public

debate on these issues and to continue to increase public awareness and to aler key actors; 2) to inform the decision making process regarding the alternatives that can be implemented (in terms of vulnerability and sustainability determinants).

The second research axis is called **STA** (**SocioTechnical Alternatives**). Its objective is to contribute to enrich the debates around possible alternatives: what would an economy within the planetary limits look like and what living standards would it correspond to? What trade-offs would have to be made between socio-economic and environmental criteria, between vulnerabilities, equity and territorial sustainability? The approach adopted does not consist in seeking to optimize the existing system but to imagine and evaluate radically different futures. In this perspective, the first step is to correctly describe *"where we are starting from and where we want to go"*, which might then guide elaborations on the relevant trajectories (*"how do we get there?"*).

Work in this axis relies on several types of approach: modeling the material basis of the economy (in particular through material and energy flow analysis), which requires numerical tools (such as numerical optimization and uncertainty propagation), modeling immaterial and institutional aspects of the territorial metabolism, participatory processes.

Overall, the objective of STEEP is to develop tools for decision aid based on or enabling a systemic vision of the issues – both globally and locally – and to implement sustainable policies at local scales, in particular to transform the productive system and consumption patterns.

- It is very important to integrate the whole **decision process** in the analysis of sustainability issues, for three reasons: 1) to ensure that the designed models address the most relevant issues in terms of **sustainability**; 2) to develop tools that have a real impact; and 3) to amplify the effective use of these tools by the different stakeholders at local scales (decision makers, decision-help agencies, citizens, organized civil society, . . .).

- The focus on **local scales** reflects not only the relevance of these decision levels, but also the relative lack of relevant modeling exercises at such scales.

- Because the numerous and interrelated pressures exerted by human activities on the environment make the identification of sustainable pathways arduous in a context of complex and sometimes conflicting stakeholders and socio-ecological interactions, the **systemic and integrative dimension**, whether **multisectoral** or **multi-scale**, is essential from the scientific point of view, as well as for the decision process. We expect to provide highly integrated tools compatible with practical use taking into account the intrinsic constraints of decision processes. A strong level of integration is desirable to identify feedback phenomena which would be very hard to anticipate otherwise. This is why we also strive to develop **transdisciplinary approaches**.

Figure 1 is an attempt to map the structure of the research axes and the links between them and their components. The figure also includes our previous work on LUCC (Land Use and land Cover Change) modeling.

3 Research program

3.1 Research axis 1: Global Systemic Risks

Strictly speaking, in the scientific literature, the term “risk” designates a hazard compounded by its probability of occurrence (e.g., the risk of a plane crashing). Systemic risks refer to system wide risks (e.g., risk of financial crises of large magnitude). Global systemic risks (cross-sectoral risks) arise because systemic risks are often interconnected, and characterized by many feedbacks at various spatial and temporal scales (e.g., climate change and its impacts on the environment and human life and activities). A number of global systemic risks are subject to an intrinsic form of indeterminacy that invalidates the very possibility of a probabilistic approach. Quite often, the term risk is then used in a more casual way, referring to a vulnerability associated to a hazard, and this second, more informal meaning is the one used in this document, in particular because some risks are indeterminate in the meaning just specified.

The literature devoted to systemic risks is extended and varied, with roots in exact and environmental sciences [56, 52] or in social sciences [40]. Two areas of systemic risks have been the object of a particular

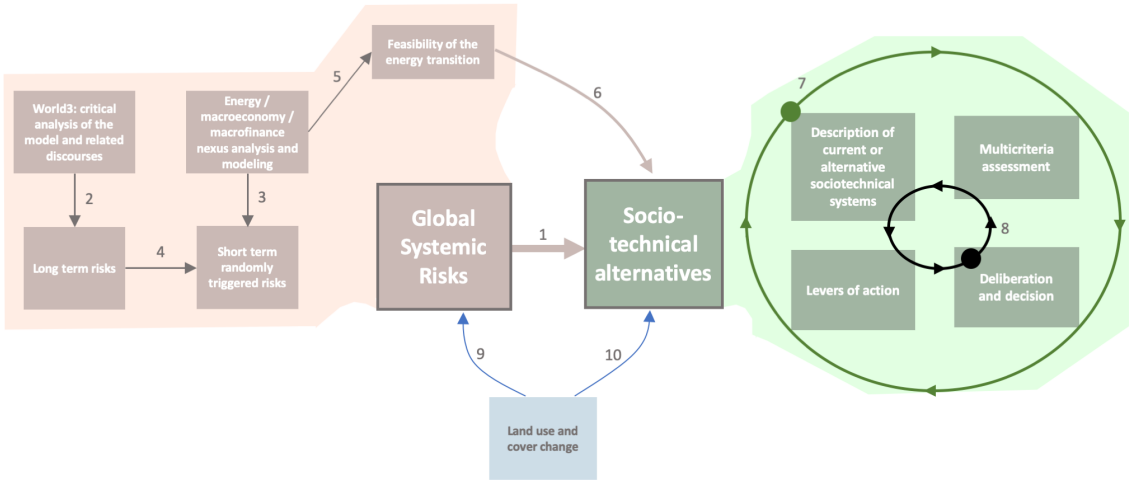

Figure 1: Sketch of the team structure: building blocks of the two research axes and logical connections. The orange and the green areas respectively depict the contents of the Global Systemic Risks axis (GSR) and of the Sociotechnical Alternatives axis (STA). Participatory processes can (and should) intervene in each part of STA (participatory modeling, participatory simulation, participatory decision-aiding).
The meaning of the arrows is as follows: (1) GSR's inform on the vulnerabilities of current or imagined sociotechnical systems and potentially change actors' representations, priorities and decisions; (2) Long term risks are currently analyzed through our work on the World3 model; (3) Short term risks are currently analyzed through our work on the energy/macroeconomy/macrofinance nexus; (4) Long term degradation trends increase the probability of occurrence of (short term) domino-effect crises; (5) The nexus model is an input to assess the feasibility of an energy transition, and is in effect also a potential short-term risk; (6) The latter limits the option space for STA's; (7) The most common way to navigate between the 4 STA blocks is to start by describing, assessing and evaluating the current system and then to identify levers of action. Note that this cycle is performed for several alternatives depending on the chosen levers. STA's are seen as biophysically consistent narratives that feed (and derive from) people's imaginaries. After deliberation, a decision is made on the desired alternative and actions are taken; (8) It is also possible to go the other way round, that is, to deliberate on the desired goals (here, desired indicator values) and then examine the option space corresponding to these goals, in terms of STA's and levers of action. Sociotechnical lock-ins can be an obstacle to the decision on, and implementation of, levers of action; (9) LUCC (Land Use and land Cover Change) is a planetary boundary which is triggering GSR's; (10) Finally, LUCC models contribute to the description of the system and the spatialization it provides enables the translation of environmental pressures into impacts on ecosystems.

focus in the past decades: environmental risks (e.g., climate change), and financial risks, but many more types of interconnected risks can be identified. They are often grouped into five categories: economic, geopolitical, environmental, social and technological. In the economic sector, the main risks are related to market instabilities, particularly in the energy sector, and financial risks. Geopolitical risks are largely related to potential sources of conflict, whether or not linked to the threat of terrorism. On the environmental front, climate change, loss of biodiversity and their consequences appear to be dominant, but natural disasters can also play a role; issues related to changes in land use (deforestation, erosion and desertification, artificialization) are also very important. At the societal or socio-political level, issues of inequality, food security, access to water, health risks (particularly pandemics) and migration are prominent. As for technological risks, they largely concern the fragility of modern computerized communication systems and network infrastructures (e.g. electricity distribution networks). These categories of risk and their interactions are represented in Figure 2.

From a process point of view, global systemic risks can be grouped into two categories:

- **Long term trends related risks:** These are produced by the decade or century long evolutions of our modern global societies. They arise from the growing tension between resource use, production of

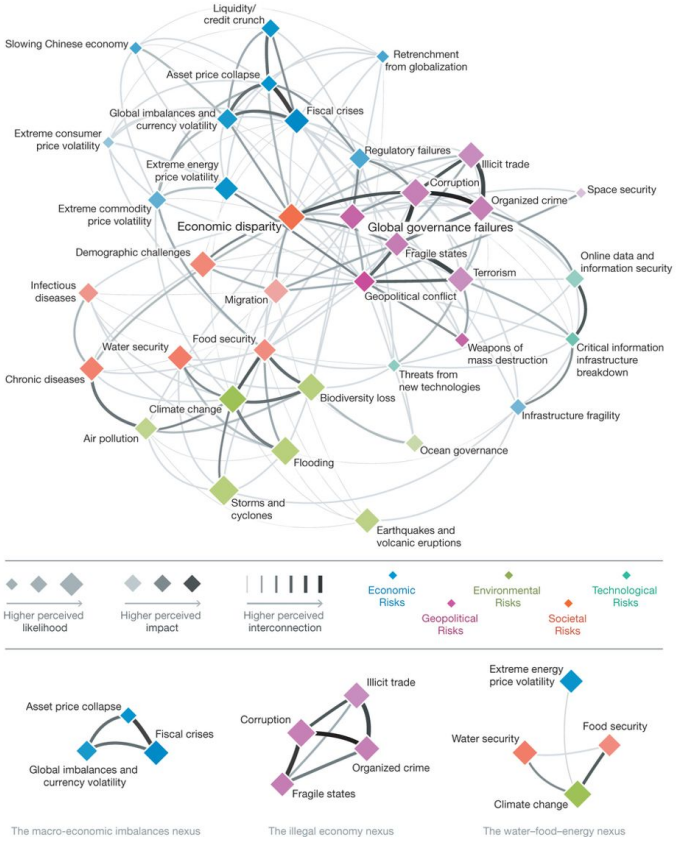

Figure 2: Global systemic risks and their interconnections according to the 2011 World Economic Forum report (reproduced in [52]). These risks are assessed by expert opinion and the importance attributed to them reflects in part cyclical concerns.

(often diffuse) pollutions of various kinds, and the capacity of our environment to absorb the related impacts. The induced environmental changes affect our socio-ecosystems, and are amplified by existing socio-political, economic and historical dynamics.

- **Short term, randomly triggered risks:** These risks occur on much shorter term (weeks to a few years). They are intermittent, random[1] and related to the high level of interdependence of many sectors of activity, to intrinsic instabilities produced by this interdependence, and to their propagation through all sectors of activity through a kind of domino effect. The occurrence of such risks is accelerating. In the last decade or so, one can mention the 2008 financial crisis, the COVID crisis and the russian-ukrainian conflict and its implication on global energy and food security. This acceleration is not coincidental, as these risks interact with and are amplified by long term trend ones.

The emblematic model of the first category is the World3 model developed by the Meadows group for its famous report on the limits to growth [57, 56]. The re-analyses of [61, 62] and [36] have renewed interest in this model while raising more specific questions about the robustness of the conclusions drawn from it. We approach these questions through an analysis on three complementary fronts:

1. An analysis of the choices of parameterization based on a sensitivity analysis that is much finer than the existing ones.

2. An analysis of modeling choices based on a sectoral and geographical disaggregation of the model.

3. Elements of epistemological analysis.

[1] As for the predictability of their time and order of occurrence, at least within the scope of our present knowledge.

The main practical interest of this research lies in the possibility of discerning the risks of collapse in the short term (pre-2050) or further out in time (post-2050), both of which require different mitigation and adaptation strategies that must be properly anticipated.

In terms of systemic contagion risks, and although an exhaustive analysis of all the categories of potential risks is impossible in an exploratory phase, the energy/macroeconomics nexus plays a particular role in our societies and presents a specific criticality. Sectoral or cross-sectoral analyses of certain aspects of this nexus already exist in the literature (see for example [51, 54, 38]), but apparently no overall model has been produced on this subject, and in particular no dynamic model. Such a realization would constitute in itself a significant advance.

This research question is presently pursued in two different but complementary directions: 1/ a reanalysis of the issue of peak oil supply and its relation to the energy transition; 2/ the development of an original energy/macroeconomics/financial speculation model. Finally, some steps towards a realistic model of domino effects are taken through the issue of a potential long-lasting (days or more than a week) black-out.

3.2 Research axis 2: Sociotechnical Alternatives

The main motivation of the STA axis is to help actors **produce narratives** of the future which are **consistent from a biophysical viewpoint** and which take into account indirect (systemic) impacts. In a more and more constrained world, this means being able to **identify and decide on trade-offs** relative to the different aspects of the problem. Another way of formulating the axis' goal is that we wish to design **planning tools** that would address social and ecological stakes, and reflect on their use by a variety of actors, in a **democratic context**.

Our work concerns three aspects: (1) description of current sociotechnical systems, (2) description and assessment of STAs, (3) participation.

1 – Description of sociotechnical systems. The cornerstone of the STA research axis are a method and associated software for multi-scale Supply Chain Material Flow Analysis (SC-MFA, see [43] for an overview and Figure 3 for a simple example). Material flows (production, transformation, exchanges, consumption, waste) are the basic building blocks of our supply chain studies. We designed methods and tools to model a supply chain (in terms of products, sectors and possible flows between them) and reconcile incomplete and/or inconsistent data. The flows allow:

- To apprehend up/downstream vulnerabilities of supply chains (e.g. dependence on imports),
- To question the use of natural resources and the possible problems of competition for use (e.g.: can the development of biofuels lead to competition between food and energy production?),

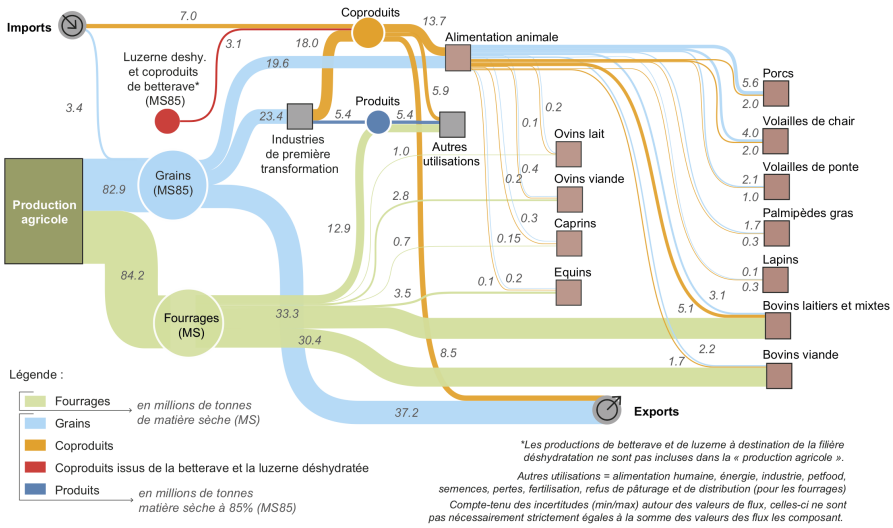

Figure 3: Example of a Sankey diagram resulting from a single-scale SC-MFA: Agriculture raw materials fed to livestock in France in 2015 (millions of tons) [41].

- And finally to estimate environmental footprints (e.g. carbon, energy, water, chemical pollution, land use, etc.).

2 – Description and assessment of sociotechnical alternatives. The most significant novelty compared to our pre-2018 work relative to territorial metabolism is to tackle the design and assessment of sociotechnical alternatives (STAs) for the future. The term alternative is used in place of scenario to emphasize that we currently describe possible points of arrival in the future and not pathways to move from today's situation to the desired outcome.

The objective of this research program is to help shed light on the debates around possible alternatives: what would a one-planet economy look like and what standards of living would it imply? What compromises will have to be made between socio-economic and environmental criteria, between resilience, equity and sustainability of territories?

Our work is structured around four main objectives:

- To propose a formalism to describe sociotechnical alternatives. In particular, we are working on extensions of physical supply/use tables, able to provide information on the interactions between materials and energy. We are also interested in coupling quantitative (technical dimension) and qualitative (social dimension) representations.
- To propose a methodology (and eventually a software) allowing groups of actors to imagine their own alternatives,
- To develop a methodology and associated tools to evaluate an alternative (cf. Figure 4):
  - What needs does it cover?
  - What are the local, remote or global pressures and impacts generated? How do they compare to local and global limits?
  - What would be the vulnerabilities of the system described?
  - What are the socio-economic performances of the system described (e.g., in terms of allocation of the workforce, allocation of added-value. . .)?
- To help comparing alternatives and structuring related debates.

3 – Participation. The work on STAs for the future motivated this last sub-axis which aims both at empowering local actors and to learn from them, in line with principles of post-normal science [50]. As explained above, one of our main objectives is to contribute towards having possible sociotechnical alternatives for a territory be co-constructed by all relevant stakeholders and be debated democratically. This covers all aspects, from the definition of what is at stake and of the criteria to use for assessing alternatives, to the actual co-construction and assessment of the latter. Furthermore, such participative processes may

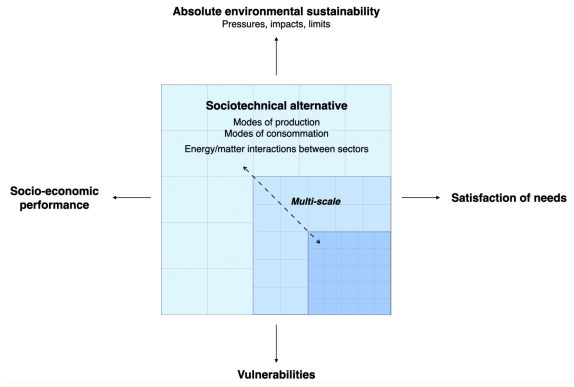

Figure 4: Schematic overview of research questions and concepts underlying sociotechnical alternatives. Center: targeted sociotechnical alternatives are typically of multi-scale nature. Borders: the four dimensions to be considered in evaluating sociotechnical alternatives (see text).

benefit from some form of training or awareness-raising on systemic issues. Our activities along these lines have started in 2021. The first large project we carried out is described in section 6.1.

4 Application domains

One of the characteristics and objectives of our research project is to try to provide integrated and systemic visions and approaches to reduce and prepare for the consequences (shocks, depletion of resources, etc.) due to the overshooting of planetary limits and to identify the room for manoeuvre and means of action available to us to act against them. It is an "applicative" project as such.

Most of our scientific activities aim at aiding the design of, and decision on, public policies. Another important general goal of our activities is to raise awareness of environmental and associated social issues, and of their interrelated and systemic nature, through dissemination, education and training activities. Indeed, we are convinced that decision aid is intrinsically intertwined with such dissemination activities.

In the following, we detail both of these aspects.

4.1 Decision aid for public policies

We pursue this goal through the development of scientific knowledge, models and tools that aim to be directly relevant to policy questions. Further, we do so, whenever possible, in direct collaboration with public authorities or other relevant partners (such as representative bodies for agrifood supply chains). Besides contributing to scientific production as such, we are also present in expert groups or scientific councils of public bodies (municipalities, regional parks, etc.).

In the following, we list a few examples of policy-relevant issues we address or have addressed in our work. This list is not exhaustive.

- Material and energy flow analysis (of supply chains or "entire" economies), or MFA. With applications for instance in:
  - Ecological accounting for sectorial pressure assessment.
  - Analysis of public policies dedicated to building waste.
  - Decision aid for territorial strategies in the agrifood, energy and other sectors. In collaboration with, or through our startup Terriflux.
- Land cover and land use modeling, urban economy and urban/periurban planning:
  - Modeling of land cover changes.
  - Integrated modeling of land use and transportation.
- Systemic risk modeling and analysis, both on global and local scales:
  - Studying global systemic risks, for instance by analyzing the iconic World3 model [58, 56].
  - Systemic risks on the health sector.
  - Systemic risks on a local territory (Grenoble metropolitan area).
- Nexus modeling:
  - Modeling and analysis of the energy/macroeconomics/finance nexus.
  - Assessing the feasibility of an energy transition.
  - Analysis of risk cascades (domino effects), for instance the consequences of a blackout, in particular on the health sector.
- Particaptory approaches, with applications to territorial foresight studies or to several of the above issues (such as for decision aid for territorial strategies in the agrifood, energy and other sectors):
  - Supporting citizen dialogue willing to transform their territories.
  - Include the previous models into serious games to help citizens to understand complexity.
  - Create new interfaces between academic research and society.

4.2 Raising awareness of environmental and associated social issues: Dissemination, training, teaching, popular education

We believe it to be important that scientists, based on scientific knowledge, engage themselves in raising awareness of the general public. As a matter of fact, we think that the systemic nature of environmental and social issues is not yet sufficiently developed in public discourse.

We try to contribute to awareness raising through tools available to scientists, and according to principles outlined for example in the MakeSEnS initiative we co-coordinated [37], the *Avis* "Between freedom and responsibility: the public commitment of researchers" (*Entre liberté et responsabilité : l'engagement public des chercheurs et chercheuses*) published in 2023 by COMETS (CNRS Ethical Committee) [42], or a similar report produced for the University of Lausanne in 2022 [49].

Team members were involved, until it ended, in the French government's initiative Formation à la transition écologique, aimed at familiarizing all French public service executives with the challenges of an ecological transition. Since several years we teach interdisciplinary courses on the mentioned systemic issues; see also the Anthropocene FACTS initiative we have created and carried for several years. Our conference-debate series and YouTube-channel "Understanding and Acting" (see section 10.3.1) has been launched in 2015 and has featured a wide range of scientific presentations on environmental and social issues. We also intervene in many general audience actions and in popular education, through presentations, round tables, interviews, and the animation of our Global Systemic Risks fresco (see section 10.3.2).

Overall, we consider this as a contribution to Inria's mission of knowledge transfer to society.

5 Social and environmental responsibility

5.1 Footprint of research activities

While the team does not apply any strict formal rules concerning the following issues, it is probably safe to say that a good level of awareness on environmental issues that is natural given our line of work, guides many of our "daily" decisions. Examples of how environmental impacts are considered are provided in the following.

Contrary to what some might suspect, we do use computers, networks and other digital equipment for our research. . . , meaning that the direct footprint of our research activities is higher than if we were working with pen and paper only. Generally speaking, we aim at keeping our footprint as low as possible given the requirements of our work. For instance, computing equipment is used as long as possible (the current average age of our desktop computers for instance, is about 10 years; Peter, who writes these lines, uses laptops for an average of about 10 years, etc.). Criteria for choosing publication venues include where conferences are held (to lower the footprint of work travel). The number of trips by plane in the last years is probably way below Inria average (one flight in 2025, none in 2024). Many team members use the bicycle for home-to-work trips, sometimes for work trips as such. The ratio of vegetarian over meat-based dishes taken for lunch at the local cantine, is rather high compared to the national average. The majority of our collaborations, be they with academic or with other partners, are local (in Grenoble or within the Région). This is natural given that our work requires partnerships with territorial authorities for instance, but is also a matter of choice. Besides trying to limit the direct footprint of our work, some team members are also involved in initiatives whose general aim is to reduce the environmental impact of research, such as Campus d'après Grenoble and MakeSEns.

Having said all this, we think that on average, the environmental and social impact scientists have is dominated by the topics and applications they choose to work on, compared to the direct impact of their day-to-day work-related activities.

5.2 Impact of research results

All of the team's research activities are directly dedicated to environmental and social issues. On the one hand, this concerns both of our research axes – Global Systemic Risks and Sociotechnical Alternatives – and on the other, the type of collaborations we build to underpin these axes – partnerships with different territorial and environmental bodies and also more and more with civil society.

Besides research activites *per se*, we also pursue various dissemination activities related to social and environmental issues, towards general audiences, and give transdisciplinary university courses.

6 Highlights of the year

6.1 Territorial Dialogue about energy in the Pôle d'Équilibre Territorial et Rural (PETR) du Briançonnais, des Ecrins, du Guillestrois et du Queyras

This has been the first large scale participatory project STEEP has been involved in. It was commissioned by the PETR du Grand Briançonnais (Pôle d'Equilibre Territorial et Rural – Briançonnais, Ecrins et Guillestrois Queyras), a so-called intercommunalité (grouping of 3 *communautés de communes*, comprising a total of 36 municipalities), located in the French Alps. This territory experiences recurring conflicts around the construction of hydroelectric power stations in mountain rivers, usually opposing energy producers, elected officials and NGO's dedicated to nature preservation. On this background, the presidency of the PETR launched the initiative of a territory-wide participatory process, to be steered by STEEP and Nils Ferrand's group at INRAE, covering the issues of energy, biodiversity, water, and territorial development.

The project was initiated in 2022, through seed funding by a CNRS-MITI grant. After carrying out preparatory modeling work, interviews and workshops with local stakeholders, etc. during nearly two years, the actual territorial dialogue started in the beginning of 2024, thanks to a grant by the Banque des Territoires and co-funding by our LINDDA project. It lasted until its successful conclusion in the end of 2025.

This project was an extraordinary opportunity for STEEP to lead a full-scale territorial dialogue, directly relevant to the definition of public policies. For us, this constituted an action research allowing to combine participatory approaches with our expertise on material and energy flow analysis (see section 8.6). It involved many participants, some of which are cited in figure 5. More details on the project are provided in [25].

6.2 Action-research on the circular economy of construction and demolition waste

Quentin Desvaux defended his thesis on December 19, 2025 (see section 8.4 for more details). This interdisciplinary thesis between the STEEP team and CREG (political economics laboratory in Grenoble) was commissioned by Grenoble Alpes Métropole (GAM), a community of municipalities with about 500,000 inhabitants, to assist it in implementing local policy on construction and demolition waste (CDW). As this waste lies at the intersection of the construction and waste sectors, the specific focus of its management and treatment is characterized by a tangle of transition dynamics between these two sectors and the different territorial scales. The national policy resulting from the AGEC law (*loi anti-gaspillage pour une économie circulaire*) overlaps with the territorial measures introduced by inter-municipal authorities as part of their waste management responsibilities, thereby disrupting the construction waste sector.

This research work required efforts to mobilize and consult stakeholders on the issues of reappropriating resources and transforming the production system with the aim of structuring a territorial circular economy for construction materials. This action research (AR) process, carried out in immersion in the department responsible for the prevention, collection, and treatment of GAM waste, made it possible to analyze the dynamics of transformation in this sector. This thesis highlights several obstacles that hinder the transformation process, starting with the clash of organizational logics that oppose the links in this emerging sector.

From a research methodology perspective, this thesis, combining approaches from modeling (material flow analysis) and economics, through an action research approach, also demonstrates the relevance and originality of the interdisciplinary approach adopted by the STEEP team's project for analyzing and supporting public policies aimed at transforming complex socio-ecological systems. Figure 6 provides a chronological overview of this action research, showing its iterative trajectory alternating between activites and postures pertaining to classical academic respectively action research.

6.3 A framework for characterizing trade-offs in (re)localization choices for production–consumption systems

Questions surrounding the choice of organizational scale – particularly those related to the intensification or reduction of globalization – are highly prominent in public debate (e.g., discussions on the relocalization

of certain activities, self-sufficiency, etc.). These scale choices involve a variety of ecological, social, and economic trade-offs, and the main contribution of the PhD thesis of Léon Fauste, defended in September 2025, is to propose a framework for formalizing these trade-offs. First, we propose an analytical framework

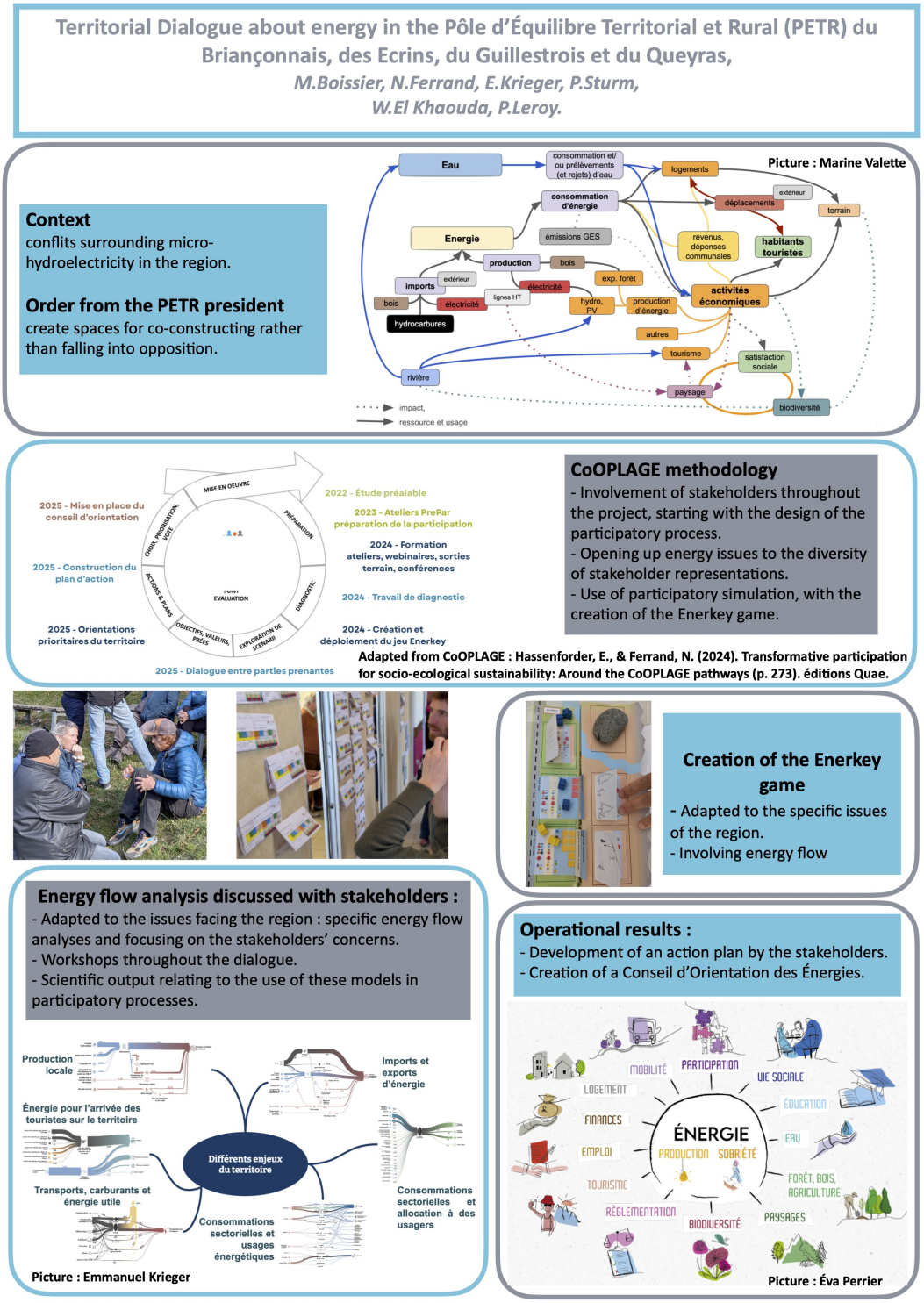

Figure 5: Overview of the Territorial Dialogue about energy in the Pôle d'Équilibre Territorial et Rural (PETR) du Briançonnais, des Ecrins, du Guillestrois et du Queyras.

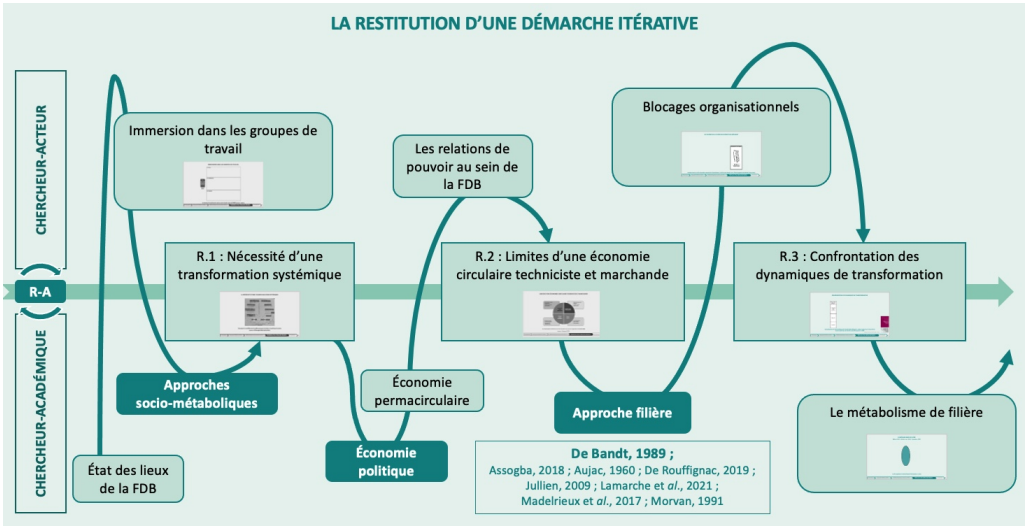

Figure 6: Chronological overview of the action research carried out during the PhD thesis of Quentin Desvaux, showing its iterative trajectory alternating between activites and postures pertaining to classical academic respectively action research. In this figure, FDB refers to the construction waste sector (*filière des déchets du bâtiment*).

to characterize the multiple organizational scales of a given activity. This framework is based on a literature review of concepts such as proximity, territory, globalization, relocalization, connectivity, dependence, self-sufficiency, supply basins, economies of scale, economic integration, concentration, specialization, short supply chains, and the notion of the "local". Certain relationships between these concepts are discussed. Second, we specifically examine the relationship between territorial specialization and the geographical concentration of activities, using empirical data, simulations, and mathematical analysis of indicators. The analysis shows that this relationship may be weaker than suggested by intuition and by part of the existing literature. Finally, we propose a constrained optimization method to explore the possible organizational scales of a production–consumption system under a set of constraints. This biophysical model ensures the consistency of material flows and accounts for certain associated environmental and socio-economic dimensions. We show how this approach could be applied to assessing the capacity for food relocalization in France and European countries, as a function of utilized agricultural area, irrigation water resources, labor time, and dietary patterns.

6.4 10 years of "Comprendre & Agir" conference-debates

In 2025 we celebrated the 10th anniversary of our Comprendre et Agir conference-debate series and of the associated YouTube channel (see also section 10.3.1). Through about 50 conferences so far, this series allowed to address various major socio-environmental issues. The aim is to foster the understanding of their evolution, of the underlying root causes, of the fact that all such issues are deeply connected in a systemic fashion. Our conviction is that without such an understanding, grounded in science, meaningful action is illusory. Besides “understanding”, the series also features conferences oriented towards “acting”, by providing examples of ecological planning, the sociological study of local initiatives etc.

Here is a selection of the general topics, with examples of conferences:

Collapse of societies and the biosphere: Conferences that clarify the mechanisms of societal collapse, by Emmanuel Prados and Pierre-Yves Longaretti or that address the collapse of the biosphere, by Denis Couvet.

Imaginaries and social change: Alexandre Monnin and Diego Landivar propose new imaginaries for the Anthropocene, Sophie Wahnich explains the role of imaginaries in sociopolitical transitions, Paul Guillibert discusses social change in relation to ecology and labor.

Neutrality of science and scientists: The fact that science and scientists are not neutral, is explained and demonstrated by Marlène Jouan and Gabrielle Bouleau.

Impacts of digital and screens: Conferences by Servane Mouton on impacts on health and by Françoise Berthoud on environmental impacts.

Technosolutionism: Sophie Dubuisson-Quellier on technosolutionism and François Jarrige on technoscientific controversies.

Democracy and commons: Conferences on democracy, its current crisis and ways of overcoming it by Sophie Wahnich, Jean-Paul Jouary and Loïc Blondiaux, on the concept of commons and its relation to democracy by Christian Laval.

Power and geopolitics: Several conferences analyze issues of power and geopolitics, for instance Christophe Bonneuil presents a historical analysis of links between environmental protection, colonialism and geopolitics, Christophe Bouillaud describes political mechanisms underlying climate change and environmental destruction, and Asma Mhalla analyzes the issue of power in the era of Artificial Intelligence.

Action and inaction: Some conferences investigate causes and mechanisms of inaction (e.g. Denis Dupré and Peter Sturm) whereas others present examples of collective action in the face of environmental and social degradations (Cécile Renouard, Julien Milanesi, Denis Dupré).

Ecological accounting and planning: Conferences by Clément Féger and Cédric Durand, the latter with a discussion on green capitalism and post-growth.

Finance and money: Several conferences examine the links between the financial system and environmental collapse (Alain Grandjean, Marc Chesney, Denis Dupré and a second conference by Denis Dupré) and Jean-Michel Servet explains the concept of money as a commons.

Food and agriculture: Denis Dupré addresses the possibility of producing healthy nutrition for 9 billion people, Gilles Billen proposes alternative schemes for organizing the agriculture–food system, and Frédéric Thomas explains the intricacies and implications of property rights on seeds

Health: Valérie d'Acremont explains the impacts of climate change on health and presents insights on the links between health, technology, environment and climate derived from field works in the global South. Charlotte Brives reveals deep systemic issues underlying the growth of antibioresistance

Energy and raw materials: Olivier Vidal discusses the energy transition by highlighting and quantifying the mutual dependencies between energy and raw materials, Benoît Pelopidas investigates nuclear energy under the angles of security and democracy, and Grégoire Chambaz discusses the possibility of a large blackout and what its consequences might be.

Our YouTube channel currently has about 15,000 subscribers, cumulates over 1.2 million viewings, for a total of over 270,000 hours of viewing time. We are proud that without external support and a low budget, we were able to contribute to making scientific discourse on these important issues audible.

7 Latest software developments, platforms, open data

7.1 Latest software developments

7.1.1 Sankeytool

Name: Web app for drawing Sankey diagrams

Keyword: Sankey diagram

Scientific Description: A Sankey diagram is a visualization of sectors that are arranged in layers: in each layer, sectors are represented by nodes which are organized and aligned vertically. Flows are only possible between distinct layers, therefore they are mainly horizontally oriented. Each flow is represented by a graphic link (e.g. a Bézier curve) having a width corresponding to the flow volume. The main objective is to visualize an economic sector or another structure in the most efficient way, in other words the representation of the elements must facilitate human understanding of the structure. Literature offers several criteria which can be used and optimized to achieve this objective. This software generates Sankey diagrams automatically. The creation includes several steps, each of them focuses on the resolution of a specific optimization problem. The formulation of these is inspired by the article "Optimal Sankey Diagrams via Integer Programming" written by Zarate et al. in 2018. The software includes an implementation of this and several new methods. They are based on solving linear programming optimization problems.

Functional Description: The software is an online web app that allows manual and automatic sankey diagram plotting. Among the functions these diagrams can be exported in svg or pdf format.

A Sankey diagram is a type of visualization of flows (of data, physical entities, money, etc.) between sectors (for example, economic sectors). The main entries of the software are a table comprising a description of these sectors and the flows, as well as the flows' volume. The software contains functions that aim at computing an optimal disposition of the flow diagram (position of sectors and flows on the produced chart), according to different possible criteria. For instance, a disposition that minimizes the number of crossings between flows or that contains as horizontal as possible flows.

URL: http://terriflux.fr

Contact: Jean-Yves Courtonne

Participants: Jean-Yves Courtonne, Julien Alapetite

7.1.2 STAX

Name: Socio-Technical Alternative eXplorer

Keywords: Decision aid, Ecological transition scenarios

Functional Description: It provides both a command-line interface and a graphical user interface (GUI) to explore, validate, and visualize scenarios of ecological transition.

The software is a decision support tool that allows to:

* Describe an economic model, in different territories with different types of actors, in terms of bio-physical exchanges (to take into account the interactions between sectors, for example the fact that renewable energies consume materials which in turn require energy to be extracted and transformed)

* Describe a Socio-Technical Alternative (STA), i.e., an arrival point in the future that is coherent from a biophysical point of view (as opposed to the description of a past situation)

* From this description, the software allows the alternative to be evaluated by "reconciling" by optimization the parameters controlling the value of the flows rather than the flows themselves.

URL: https://gitlab.inria.fr/steep/stax

Contact: Jean-Yves Courtonne

Participants: Jean-Yves Courtonne, Alexandre Honorat, Roger Pissard-Gibollet, Albin Petit, Peter Sturm, Thibaut Coudroy

7.1.3 TransKey

Keywords: Serious game, Flow visualization, Collaborative science

Functional Description: TransKey is a framework for modeling and serious games for transition support, based on a generic model to support new transition game designs, adapted from previous MFA (material flow analysis) games and goals. The framework is under development. A first playable game has been produced and tested with users (tag v0), and a multi-player client/web server version v1.0 (tag v1.0) is now available. General target features for TransKey are: representing multiple resource stocks and flows, their dynamics, stakeholders' constraints and control, exogeneous drivers, multi-scale representations, player friendliness, data fitting when required, connecting material and digital version. A general description is given in https://hal.science/hal-04231486.

URL: https://gitlab.inria.fr/steep/transkey

Publications: hal-04231486, hal-04867680

Contact: Mathilde Boissier

Participants: Mathilde Boissier, Nils Ferrand, Roger Pissard-Gibollet, Laurence Boissieux, Thibaut Coudroy, Nicolas Revilla Lopez

7.1.4 EnerKey

Keywords: Serious game, Flow visualization, Participatory process support

Functional Description: EnerKey is an implementation of the framework TransKey adapted to a real territory situation. This game has been created to support a dialogue about energy in le PETR du Briançonnais, des Écrins, du Guillestrois et du Queyras. It represents the main stakes of the dialogue with a focus on nexus and energy flows.

Contact: Mathilde Boissier

Participants: Marine Valette, Mathilde Boissier, Nils Ferrand, Emmanuel Krieger

8 New results

8.1 Evaluation of the robustness of the World3 model and the validity of its conclusions

Participants: Antoine Cordoba, Serge Fenet, Pierre-Yves Longaretti.

A scientific collaboration was launched in 2024 between the STEEP team (Pierre-Yves Longaretti and Serge Fenet) and the Tripop team (Arnaud Tonnelier). In this context, Antoine Cordoba began an 18 months postdoc contract in the Tripop team in September 2024, to pursue the work initiated by Mathilde du Plessix on the iconic World3 model before her thesis was interrupted in 2022. The interest in the model grew again in the last decade or so, in light of the growing concerns about planetary limits and the impact of human activities on natural systems. We aim at re-evaluating both the robustness of the model and the validity of its conclusions. During her thesis, Mathilde performed an extensive analysis of the parameterization choices made by the authors of the model, based on a comprehensive sensitivity analysis made possible by modern computing power. This analysis allowed us to identify the most influential parameters in an objective way. In the continuation of this work, Antoine is working on an analysis of the relative importance of the model feedback loops, taking over the incomplete work of Mathilde du Plessix on this topic. More specifically, Antoine has been implementing the loop eigenvalue elasticity analysis method (LEEA) on the World3 model. It is well-known in the system dynamics community that application of this method (the most rigorous to date) to a large model such as World3 is an unresolved challenge. We have been successful in resolving

this issue, thanks to Antoine's reimplementation of the various steps of the methods. In the process, new error-free algorithms have been devised, and some formal proofs of the literature have been simplified and clarified. Antoine also elaborated a new reimplementation of the model World3 itself in Python for this task. This result is particularly important in a moment where the model gathers renewed importance in the environmental science community. Antoine's post-doc will end in February 2026, but this work will be extended by analyzing the relative importance of loops on targeted model variables, and focusing next on the level of endogeneity of the model. We also plan to produce a Python package devoted to the use of the LEEA method for large system dynamics models, as new, more sophisticated models of the World3 type have been recently produced (e.g., Earth4all).

8.2 Feasability of the energy transition

Participants: Antonin Berthe, Pierre-Yves Longaretti, Emmanuel Prados, Olivier Vidal.

Louis Delannoy's thesis [46] showed that the question of peak oil, largely forgotten since the 2008 crisis, needs to be addressed afresh. On the one hand, oil is the most critical of the three fossil fuels, both in terms of its range of uses and of the difficulty of its fast substitutability. On the other hand, oil supply will start to decline considerably by 2030/2040, due to falling energy returns on investment combined with falling gross production, even assuming that untapped resources will be brought on stream as quickly as possible in the future. The question is not about reserves, which are considerable, but about flows. From an economic point of view, the problem posed is whether demand will fall as fast or faster than oil supply, particularly from a long-term growth perspective. Both public discourse and the vast majority of integrated models from the scientific community assume that this is the case under the impact of the energy transition, but this assumption is not self-evident. The aim of Antonin Berthe's thesis, which was defended in December, is to quantify the tension dynamics of oil supply and compare it with the possible deployment speed of a transition to electricity, particularly in transport (which accounts for more than half of our oil use), in order to assess the possibility of avoiding a long-term global structural macroeconomic crisis. The main result of the thesis is that a gap between oil demand and supply necessarily arises around 2030 in a BAU (business as usual) scenario in terms of global economic growth where the saturation of the fraction of electric vehicles in the world fleet reaches 25%, and delayed only by a few years (2035-2040) when this saturation level is increased to 50%. These two saturation levels are shown in the thesis to bracket all reasonable expectations on the electric vehicle market share in the future.

8.3 CRISIS model

Participants: Pierre-Yves Longaretti.

The CRISIS model (Cascading Reactions in Society's Interconnected Systems) is designed to address the role of energy tensions amplified by financial speculation on structural macroeconomic crises. In particular, this model aims at pinpointing the dynamical conditions leading to long term economic decline and its consequences. This work is a direct continuation of the theses of Louis Delannoy and Antonin Berthe in terms of global risks associated to the upcoming oil supply contraction, although the focus shifts from "physical" models to macroeconomic ones. The model relies on the stock-flow consistent macroeconomic modeling framework, which is a self-consistent approach to macroeconomic dynamics. The framework enforces all macroeconomic identities, while making no specific choices for the behavioral equations characterizing the different sectors of a specific model (banking, production, households, etc). As such the framework accomodates as well orthodox or heterodox economic theories, although it is mostly used by the heterodox post-keynesian school of economic thought. The model is now in its advanced production stage. A central BAU scenario has been calibrated and simulated, without any tension on resources or any financial speculation. This idealized setting has been used to bracket the relevant domain of variation of the main parameters of the model. The speculation module of the model is now also calibrated. Preliminary runs performed in presence

of speculation have been partially analyzed, in particular with the objective to characterize the spectrum of financial market variations on the production sector, from normal, sedate fluctuations to large magnitude crises, and comparison with data on real financial markets behavior. A very comprehensive report detailing the model has been written, as well as an article preprint on the sensitivity analysis of a simpler but somewhat related macroeconomic dynamical model, as a stepping stone to produce a sensitivity analysis of the much more complex CRISIS model. However, this work has been put on hold since Hugo Martin (post-doc who worked on the model) has left academia.

8.4 Action-research on the circular economy of construction and demolition waste

Participants: Jean-Yves Courtonne, Quentin Desvaux, Catherine Figuière, Guillaume Mandil.

Quentin Desvaux defended his thesis on December 19, 2025. This interdisciplinary thesis between the STEEP team and CREG (political economics laboratory in Grenoble) was commissioned by Grenoble Alpes Métropole (GAM), a community of municipalities with about 500,000 inhabitants, to assist it in implementing local policy on construction and demolition waste (CDW). As this waste lies at the intersection of the construction and waste sectors, the specific focus of its management and treatment is characterized by a tangle of transition dynamics between these two sectors and the different territorial scales. The national policy resulting from the AGEC law (*loi anti-gaspillage pour une économie circulaire*) overlaps with the territorial measures introduced by inter-municipal authorities as part of their waste management responsibilities, thereby disrupting the construction waste sector.

This research work required efforts to mobilize and consult stakeholders on the issues of reappropriating resources and transforming the production system with the aim of structuring a territorial circular economy for construction materials. This action research process, carried out in immersion in the department responsible for the prevention, collection, and treatment of GAM waste, made it possible to analyze the dynamics of transformation in this sector.

The challenges of diagnosis, stakeholder mobilization, and transformation of a complex subject of study, requiring in-depth knowledge of the socio-technical dimensions that govern the circulation of material flows, led to the design of an eclectic ad hoc methodology rooted in an open disciplinary approach. The thesis, the result of several years of immersion, was constructed through successive iterations between the development of detailed empirical knowledge and the questioning of the theoretical concepts used, in particular that of sector metabolism, which quickly emerged as the cornerstone of the analysis.

By considering the sector as a social construct, whose architecture depends as much on technical linkages as on the relationships and strategies that compose it, the analysis offers an interpretation of structural transformations at the crossroads of upward and downward dynamics, between sectors and territories. This single-sector, multi-level perspective extends the analysis of the system beyond the territory studied to capture the confrontation between the geographical and sectoral logics that govern metabolism. The methodologies borrowed from action research, focused on understanding and transforming social reality, break down the barriers between academic and operational knowledge by combining the theoretical contributions of researchers with the technical expertise of practitioners. This cross-disciplinary approach leads to the co-production of *transformation knowledges*, actionable knowledge that supports the circular and sustainable transformation of metabolism.

This thesis highlights several obstacles that hinder the transformation process, starting with the clash of organizational logics that oppose the links in this emerging sector. Closing the loop, originally designed by integrating a reuse link, requires a systemic transformation of the sector to ensure the effective reintegration of used materials into the building stock. The transformation process, delegated to pioneering players without the necessary resources being deployed, is struggling to move beyond its experimental phase, despite having demonstrated the viability of alternative construction and deconstruction models. The political support required to scale up these practices is nevertheless still geared towards manufacturers and producers, who dictate how the sector is organized, thereby accentuating the power imbalance. The fundamental difference in orientation that distinguishes incremental transition designs from disruptive transformation designs is therefore hindering the momentum generated by GAM.

Ultimately, from a research methodology perspective, this thesis also demonstrates the relevance and originality of the interdisciplinary approach adopted by the STEEP team's project for analyzing and supporting public policies aimed at transforming complex socio-ecological systems.

8.5 Systemic crisis propagation: study of the health sector

Participants: Enzo Baquet, Valérie d'Acremont, Serge Fenet, Pierre-Yves Longaretti.

In January 2022, Enzo Baquet started a PhD thesis focusing on the analysis of the dynamics of the propagation of intra- and inter-sectoral disruptions in the context of short-term crises (week to year). While this work should ultimately lead to the creation of a generic modeling methodology, it first focuses on the thread given by a particular case study: in the context of civil health infrastructure, how can the impact of an electrical blackout spread to different subcomponents of the health sector, and impact health services. In order to answer to this questions, Enzo spent one year (from september 2023 to september 2024) at the Unisanté center of the University of Lausanne, our partner in this project. He deployed a participatory approach based on semi-directive interviews with several actors of the civil health system and key stakeholders of the Vaud district. The goal was to gather caregivers' perceptions of an interruption of electricity supply, the direct and indirect impacts they could identify, their willingness or unwillingness to act, and the actions they might already be taking. Interviewees also explored the role that they would see themselves playing in possible continuity plans that might be put in place by the health sector.

An article was submitted in the fall of 2025 to a special issue "Disaster health convergence: better integration of public health and disaster medicine" of the International Journal of Public Health with the title "Perceptions and needs of primary healthcare workers regarding electricity shortages and blackouts: A qualitative study using a realistic narrative approach". It outlines the methodology employed during the research project, which included the creation of scenarios that closely relate realistic deterioration in access to electricity in the Canton of Vaud (Switzerland). It explores the reactions of caregivers to such a crisis and outlines several recommendations for dealing with it.

8.6 Energy flow for the Briançonnais area

Participants: Mathilde Boissier, Nils Ferrand, Emmanuel Krieger.

The participatory process in the PETR du Grand Briançonnais (Pôle d'Equilibre Territorial et Rural – Briançonnais,Ecrins et Guillestrois Queyras) has reached its end. After the formal launch with the *Banque des Territoires* funding in 2024, followed by a sensitizing phase, a game creation (EnerKey, see section 7.1.4) and the construction of energy flow analysis, the year 2025 has seen the deployment of the game EnerKey, a priorization phase, the construction of a citizen action plan. Meanwhile, an Energy Policy Council (*Conseil d'Orientation des Énergie* – COEn) has been created with six colleges (energy professionals, public institutions, citizens, environmental NGO's, citizen NGO's, socio-professionals). This COEn should extend the participatory process by keeping some dialogue between the colleges, keeping the citizen action plan in mind. A scientific evaluation of the process in its globality is expected in 2026 with an article to be written.

Along this project, a modelling work was carried out by Emmanuel Krieger, a PhD student in the team, to represent the energy flow diagrams of the PETR of Briançonnais, Écrins and Guillestrois-Queyras, in order to support the debates in a concertation process on the territory's energy policy (see section 6.1). The aim is twofold: for the inhabitants of the territory, it is to provide information on how it operates in order to inform the decisions, and for our team, it is to test the use of these diagrams. Most of the diagrams have been constructed using open data. However, these data do not cover all the energy-related issues identified for this territory, so modelling was carried out to quantify the missing parts. These include electricity imports and exports, the disaggregation of sectoral energy uses, the breakdown of final energy into useful energy, the allocation of energy to different categories of users, and the energy used by tourists to enter and leave the territory. These models have been produced in various ways: by generalisation from sub-regional data,

by down-scaling from national data, through harmonisation by making data comparable, etc. All the data produced in this way were then reconciled with the open data already collected to produce the energy flow diagrams. Workshops and presentations have been conducted and given at different moment of the process (December 2024, January 2025, February 2025, during the construction of the action plan in March and April 2025). There is now an ongoing work to evaluate this work: how did these diagrams presentations influence the dialogues between participants? How did they support their decisions? Taking a reflexive step on these diagrams construction, what scientific posture has been used during this work? From this experience, what are the insights for improving scientific support to stakeholders? This should result into scientific article production in 2026.

8.7 Reducing discrepancies in agricultural trade flow analysis

Participants: Enora Barrau, Jean-Yves Courtonne, Tara Pacurar-Leroux.

In this study, we are assessing how reliable international trade data are when used to analyze agricultural trade flows, particularly in the context of sustainability transitions. Conducted as part of an applied internship hosted by the STEEP Team at Inria Grenoble-Alpes, the research addresses the following challenge: the inconsistency of reported trade data across raw sources, which complicates the modeling of agricultural material flow, its trades, and their impact on the environment, and employment. The approach involves collection, cleaning, and preparation of trade databases, followed by an analysis of their characteristics. Through the selection of relevant indicators, the study assesses data consistency and selected two major databases to rely on: COMTRADE, for raw data, and BACI. A critical step involved comparing the discrepancies observed between exporter and importer declarations, highlighting the importance of reconciliation procedures to harmonize data for robust analysis. In order to support future data exploration, interactive visualization tools were developed. Multiple levels of granularity are considered; by product and by country, facilitating the identification of patterns, anomalies, and potential biases in the data. In terms of methodology, this work demonstrates how combining statistical analysis with econometric modelling, and statistical validation and results' visualization facilitates the interpretation of complex trade data. It also emphasizes the value of documenting the construction of selected datasets to ensure transparency and reproducibility. One of the main outcomes of the study is that the BACI database, developed by CEPII, provides a more consistent representation of international agricultural trade, serving as an effective reference between conflicting international reports. While a full analysis of BACI's reliability could not be completed within the internship timeframe, the development of reproducible tools for data validation and visualization lays the groundwork for more detailed assessments. Finally, the findings underscore the critical role of harmonized and high-quality trade data in evaluating environmental footprints, resource use, and employment effects across agricultural supply chains.

8.8 What frameworks and methodologies enable a needs-oriented approach to territorial ecology?

Participants: Julien Cambonie, Thomas Gotteland, Emmanuel Prados, Renaud Metereau.

In 2025, we began research with an intern (Julien Cambonie) seeking to propose a new framework for a needs-oriented approach to territorial ecology.

Before rethinking our socio-political modes of organization and looking at the transformations in the means of production of our material conditions of existence, we felt it was necessary to question what we really need to live well in society in a specific geographical and cultural space. We therefore focused on the question of needs at the level of a particular living area, that of the Grenoble region. In this reflection, we drew on two theoretical approaches to needs: that of Doyal and Gough [48], and the complementary approach based on Max-Neef's matrix [55]. We then explored the tools, linked to these theories and applied to the

Grenoble area, which enable us to measure or evaluate the satisfaction of a number of specific needs. These tools are the Grenoble donut, based on Kate Raworth's theory [60], and the IBEST well-being indicator.

Our student also attempted to describe, on a regional scale, the functioning and organization of the supply system for our needs satisfiers in order to identify its vulnerabilities to risks related to collapse processes, as well as the levers for addressing them. He was then able to propose a set of methodological tools from territorial ecology, accompanied by the concept of territorial metabolism, to provide an initial response to this issue. However, this attempted response, applied to the Grenoble region, remained limited and incomplete. It remains necessary to continue developing methods and tools that provide more detailed and comprehensive answers concerning the satisfaction of needs, based on territorial metabolism, with a view to strengthening our capacity to adapt to future shocks.

This work will be continued as part of the work of Thomas Gotteland, who began his PhD thesis in December 2025.

8.9 Serious games for the exploration and analysis of sociotechnical alternatives

Participants: Mathilde Boissier, Matthieu Planchot.

Accounting in terms of biophysical flows is one grid of analysis providing insights on the sustainability of socio-technical alternatives. These tools are indeed relevant to highlight systemic effects (interdisciplinary understandings, spatial and temporal scales) on resources and important pressures to consider for the transformation of territories. Yet, this biophysical flow vision remains for expert use only, whereas one of the challenges of transition territories is to involve the populations in participatory processes. Among diverse participatory tools, serious games have long since proven their ability to sensitize to sustainability issues, facilitate learning and support changes. We aim to develop several games to play with material and energy flows while discussing the futur of their territories. This involves every stage of modeling (capturing reality into a biophysical and governance model, making this model simple enough to be played with, and bring back this model into the real world to collectively transform a territory's organization), game design as well as lab and field experiments. After developing two simple games in 2022 (see our 2022 Activity Report), we have designed a modeling framework – TransKey (see section 7.1.3 and [2]) – based on social metabolism. In 2024, the game had been developped enough (both in a software and a material version) to start the evaluation (and publication) process. In 2025, Matthieu Planchot, a master student in TEET (ENSE3, Grenoble INP), has joined the team for an internship. The objective was to define and design a rigorous process to evaluate the game, as well as the use of Sankey diagrams in the players' strategies. The evaluation itself is planned for 2026, and a publication is expected.

8.10 Participatory research on energy sufficiency

Participants: Mathilde Boissier, Jonathan Coignard, Angèle Demarquilly, Sacha Hodencq, Jessica Zaphiropoulo.

Launched in 2024, thanks to an IRGA exploratory funding (Université Grenoble Alpes), this activity involves researchers from different disciplines (energy modeling, spatial planning, participatory research). it aims at exploring how to discuss energy sufficiency collectively in the society as well as at documenting about interdisciplinary research work, with a reflective dimension about academic research. 2024 has been the beginning of the project with and analysis of the literature, sharing knowledge and methods between the members, and testing a first workshop design to make participants consider collective sufficiency. In 2025, Angèle Demarquilly, student in *Master de Design de la Transition*, has joined the team during a 6-month internship. She has worked on the literature, characterizing interesting participatory actions about sufficiency, worked on new workshops and realized the first steps of a field work with the city of Saint Martin d'Hères, with formalized observations and interviews. The insights gained from this two year project are the following:

- an interdisciplinary consideration on the notion of limits, going beyond planetary boundaries, to explore localized energy limits that can be acted upon by local organizations, in order to make sufficiency a structuring principle of socio-technical systems and to equip action.
- contacts with territories, challenging the energy focus to involve other issues. For example, local authorities wishing to reduce the energy consumption of public buildings must consider issues such as the sharing of equipment, usage slots, social ties, and public services. Thus, sufficiency requires the engineering of sharing and transparent decision-making procedures, according to two methodological requirements: approaching sufficiency through uses and at scales relevant to the partner territories; and making participation a tool for knowledge production and regulation, rather than simply a means of ensuring acceptability.
- a partial mapping and categorization of a set of projects aimed at promoting energy sufficiency through participatory approaches.

Applications for further fundings have been made to keep working on this topic in 2026.

8.11 Analysis of the science-society interface in the Grenoble area

Participants: Mathilde Boissier, Souraya Mahamoud.

With the aim of launching a research project on science-society interfaces and creating new spaces to formalize them (e.g., science shops – *boutiques de science*), Souraya Mahamoud, a master's student in transition design, joined the team for six months in the spring. The aim of this internship was to initiate a situated analysis of the relationships between science and society in the Grenoble area, identifying the actors who already bridge the gap between academic research and civil society and characterizing how they bring these interfaces to life. Thesis funding under the PEPR EcoNum program has been obtained to continue this work at the latest from 2028 onwards.

8.12 Reflexivity on the use of material and energy flow analysis models with stakeholders

Participants: Mathilde Boissier, Jean-Yves Courtonne.

Following the Scalable project (2021-2024), some reflexive work has been done to propose an evaluation framework to the use of material and energy flow analysis models with stakeholders. Complementing the Scalable case study with the interviews of researchers involved in 3 other projects, a step back has been taken, until the production of a book chapter about metabolism studies. This chapter is currently under review.

8.13 On computing and exploring multiple consistent metabolisms in Material Flow Analysis

Participants: Thibaut Coudroy, Jean-Yves Courtonne, Alexandre Honorat, Peter Sturm.

In Thibaut Coudroy's PhD thesis we currently focus on how to compute and explore bio-physically consistent metabolisms for foresight scenarios using Material Flow Analysis (MFA). MFA tools usually output a single solution or a posterior distribution. We consider another option, particularly for the iterative construction of foresight scenarios, by proposing to compute and then explore several close-to-optimal but widely different solutions. This work is embedded in the development of the STAX software (see section 7.1.2).

In the following, a **model** is an oriented bipartite graph relating resources/products and activities/sectors through flows. Model variables comprise flows/funds, nodes (e.g. total supply of a product), and coefficients (e.g. transfer coefficients of a production sector, proportion of alternative production modes in a sector). A (foresight) **scenario** consists of a set of hypotheses on these variables, in the form of constraints and user-defined target values, the latter given through probability distributions. An **alternative** is a valuation of all variables satisfying all constraints; that is a consistent metabolism. A scenario may be:

1. Uniquely specified. A single alternative conforms to all hypotheses.
2. Ambiguous. Parts of the model may be subject to one or both of:
   (a) Over-specification, i.e. there are too many hypotheses on the same variables. Incompatible constraints must be removed by the user, then data reconciliation is used to find consistent metabolisms.
   (b) Under-specification, i.e. there are not enough hypotheses to define the values (even though intervals for admissible variable values may still be determined).

Data reconciliation in 2.a. can be done through solving an optimization problem under constraints. Such problems may have a non-convex cost function (resulting from distributions such as log-normal) and/or non-linear constraints (e.g. resulting from transfer coefficients), leading to multiple locally optimal solutions. The global optimum can be found using a global solver, and the latter is also useful to explore close-to-optimal solutions, as shown below. A global solver is an alternative to sample-based approaches such as MCMC-based ones, which are more common in the MFA literature. While the latter compute an approximation of the variables' complete posterior probability, the former is potentially more efficient and may also be used to bootstrap the posterior's computation (not explored yet by us). In our work, we use the SCIP solver which turns out to handle well the cost functions and constraints mentioned above.

By default, SCIP outputs a single solution. We propose an algorithm that builds on top of this in order to explore a scenario's option space, by computing multiple solutions, requiring them to be not too far from the global optimum in terms of cost function as well as to be as different from one another as possible. First, the global optimum is found using SCIP. Then, the user sets a maximum bound for other solutions based on the optimum's cost function. We then alternate between two steps: (i) Candidate identification, which is finding the furthest solution from the already known ones and that is within the bound on cost. (ii) Local minimization starting from that solution; the result is added to the list of computed solutions.

In future work, we will focus on an interactive step-by-step exploration where the user adds constraints successively, restricting the option space (including the update of intervals) until the scenario becomes uniquely specified. This will be especially useful for case 2.b.

We also carried out an in-depth study of different options of cost functions for MFA, with an analysis of the multiplicity of solutions. The results will be published in a forthcoming technical report.

9 Partnerships and cooperations

9.1 International initiatives

9.1.1 Participation in other International Programs

Chaire en diplomatie scientifique climatique

Participants: Mathilde Boissier, Pierre-Yves Longaretti, Emmanuel Prados, Peter Sturm.

Duration: 2026 - 2031
Partners: Université de Sherbrooke (Canada), Université Grenoble Alpes
Abstract: This international university chair is coordinated by Professors Annie Chaloux (Sherbrooke) and Amélie Favreau (Grenoble). It is funded by the two universities, Inria and Fonds de recherche du Québec. The scientific programme is structured in four axes: (i) Mechanisms and dynamics of science diplomacy in an

era of technological transformation technological, (ii) Legitimization and mediation of scientific knowledge in climate governance, (iii) Inclusion and co-construction of knowledge in climate science diplomacy, (iv) Mobilizing knowledge and developing tools for climate science diplomacy. Peter Sturm is a member of the chair's team and Mathilde Boissier, Pierre-Yves Longaretti, and Emmanuel Prados are collaborators.

9.2 International research visitors

9.2.1 Visits to international teams

Research stays abroad

Mathilde Boissier

Visited institution: Kassel Institute for Sustainability, Kassel University

Country: Germany

Dates: 7 October 2025

Context of the visit: Mathilde Boissier visited Andra-Iona Horcea-Milcu, professor in Kassel Institute for Sustainability, Kassel, Germany. Recently awarded with an ERC funding, her and her team now work on transformative research and the role of values in the creation of knowledge for transformation.

9.3 National initiatives

9.3.1 LINDDA – Living INfrastructure to Design responsible Digital technology for Agroecological transition

Participants: Mathilde Boissier, Thibaut Coudroy, Jean-Yves Courtonne, Nils Ferrand, Emmanuel Krieger, Guillaume Mandil, Peter Sturm.

Project funded by the PEPR program "Agroecology and ICT"
Duration: 2022-2027 (5 years)
Coordinator: Muriel Mambrini (Learning Planet Institute), Peter Sturm for Inria partner.
Partners: Learning Planet Institute, CY School of Design, STEEP, Conservatoire National des Arts et Métiers, ITAP/Inrae, G-EAU/Inrae.
Keywords: agroecology, design, transition, participation.
Abstract: The project is part of a program on Agroecology and ICT. It subtends our work on participation in the STA axis (Section 3.2) and provides the opportunity to collaborate with experts in Design (for games, interfaces, intermediation).

9.3.2 SOCLE

Participants: Enora Barrau, Jean-Yves Courtonne, Tara Pacurar-Leroux.

Project funded by Ademe
Duration: Dec. 2024 - Nov. 2027
Partners: INRIA, INRAE, TerriFlux, Le Basic, IDELE, CTIFL, IFCE.
Keywords: Agri-food sectors, Material Flows, Footprints, Employment, Co-design
Abstract: The development of the bioeconomy raises questions about the competition for the use of agricultural resources, which must meet food (human and animal), energy, and material needs. Furthermore, the observation of planetary boundaries being exceeded makes it urgent to precisely identify the causes of environmental impacts, which can be difficult to disentangle due to globalized production-distribution networks. Beyond these environmental issues, French agriculture must today address economic and social

challenges to renew itself and meet consumer demands. At the intersection of all these concerns, the SOCLE project aims to improve knowledge of the biophysical structure of agricultural product flow networks in France and abroad, as well as their environmental impacts and employment implications. To this end, it brings together research partners, supply chain stakeholders, and two consulting firms.

The primary scientific objective of the project is to provide, for a recent year, a database describing:

- National and international flows of agricultural products, leveraging the highly detailed knowledge of a Flow Reference Framework that has been updated and expanded to describe French industries,
- The environmental pressures exerted by French industries in terms of energy, nitrogen, land use, and blue water (irrigation) use with a footprint perspective, i.e., focusing not only on what happens within French territory but also in the supplying countries,
- The direct and indirect employment linked to French industries.

From an operational standpoint, the project aims to enrich discussions on sectoral strategies that simultaneously consider planetary boundaries, international dependencies, and social and economic realities. Collaboration with industry stakeholders is planned throughout the project.

9.3.3 WOODYN

Participants: Jean-Yves Courtonne, Alexandre Honorat.

Project funded by Ademe
Duration: Jun. 2025 - Jun. 2030
Partners: Univ. Gustave Eiffel, Inria, TerriFlux, FCBA, CSTB, IFPEN.
Keywords: MFA, LCA, dynamic model, wood supply chain
Abstract: Climate change mitigation often relies on maintaining the forest carbon sink and increasing the use of wood products as substitutes for fossil-based resources.

However, the rapid and large-scale increase in demand for wood products may place significant pressure on forest resources. Due to their short lifespans, some wood products re-emit carbon into the atmosphere more quickly than forests are able to reabsorb it. These differing temporal dynamics can therefore contribute to an increase in net CO_2 emissions rather than a reduction. Moreover, large-scale deployment introduces competition for the resource among different sectors (energy, materials, packaging), whose products have very different lifespans.

Finally, the temporal dynamics of carbon storage in forest soils must be considered through silvicultural practices and in interaction with biodiversity. A temporally explicit life cycle assessment (LCA), applied not to individual wood products but to the forest–wood sector as a whole, is therefore essential.

The WOODYN project is structured into six work packages. The first work package concerns project coordination. The second work package aims to integrate the temporal dimension into material flow analysis (MFA) representations of wood flows within the sector. To address this challenge, two approaches are envisaged: the integration of new data derived from LCA-based flow representations, and the redefinition of the reconciliation method. The third work package aims to extract information from available LCA databases on wood processing technologies in order to feed the sectoral MFA. This involves both restructuring a non-allocated database and adapting LCA calculations to this specific context. The fourth work package aims to translate the information contained in the dynamic MFA into life cycle inventories of sectoral processes, as well as to design integrated computational tools linking MFA and LCA. The fifth work package aims to develop a dynamic environmental indicator for climate change. This work package will also examine the notions of resource renewability and will integrate the mass and causal relationships identified within the sector. The sixth work package aims to build a methodological framework for a dynamic land-use indicator, based on species richness across land-use typologies and linked to soil management parameters, while accounting for regeneration processes. The method will be conceptual, in order to ensure its applicability to all land-use types (forest, urban, agricultural, etc.). The expected outcomes include a set of openly and freely available datasets, software tools, and methods enabling the current assessment of temporally

explicit environmental impacts related to climate change in the forest–wood sector. This framework will allow stakeholders across the sector to conduct prospective assessments by testing various development scenarios. A theoretical framework for establishing a temporally explicit land-use change indicator will also be proposed, enabling, in the longer term, the integration of interactions between forest management practices, climate change, and biodiversity. A case study based on existing scenarios for the forest–wood sector will be implemented and disseminated in order to raise awareness among sector stakeholders of temporal issues and of the links between climate change and biodiversity.

Project results will be disseminated through scientific publications and conference presentations. Data and tools will be made openly and freely available on dedicated platforms. Several webinars will be organized throughout the project to present the developed data, tools, and methods, and to promote their uptake by academics and sector stakeholders.

9.3.4 Research collaboration agreement with the PETR du Briançonnais

Participants: Mathilde Boissier, Nils Ferrand, Emmanuel Krieger, Peter Sturm.

Duration: Dec. 2023 - Dec. 2025
Partners: Inria and Pôle d'Équilibre Territorial et Rural du Briançonnais, du Pays des Écrins, du Guillestrois et du Queyras.
Abstract: This bilateral collaboration agreement formalises and finances the activities described in section 6.1.

9.3.5 FORESEE Programme

Participants: Peter Sturm.

Duration: 2025 - 2032
Partners: Université Grenoble Alpes, CNRS, INRAE, Université de Lille, Université de Montpellier Paul-Valéry, Université de Bordeaux.
Abstract: The FORESEE programme explores the experiences of individuals, organizations, territories, and public action in dealing with the consequences of climate change. It is a large research programme dedicated to human and social sciences. STEEP (through Inria) is an associated partner.

9.4 Project submissions

In 2025, Emmanuel Prados increased his interactions with various civil society actors (including artists and associations) in the Grenoble area (but also, to a lesser extent, at the national level), as well as with researchers working in various disciplines (particularly the social sciences and humanities, health, and environmental sciences) with the aim of setting up action research projects that would be jointly supported by these actors. These interactions led, for example, to the submission of small projects that were unfortunately not accepted (and which continue to be refined for future submission). One example is the "Faire Face, Faire Cinéma" project, set up with film directors in response to the 2026 call for projects of the SFR Création (*Structure Fédérative de Recherche*) at the University Grenoble Alpes.

Mathilde Boissier submitted several projets by end 2025, with partners of other labs in Grenoble (results in 2026):

- POESI, submitted to the special call for doctoral grants of University Grenoble Alpes
- FOLIS, sublitted to the call for post-doctoral grants of LabEx EnergyAlps
- SECOREEP, sublitted to the call *Résilience et Robustesse* of CNRS-MITI.

9.5 Public policy support

9.5.1 Supporting the dialogue on energy, PETR du Grand Briançonnais

Noting the difficulties in reconciling the Climate and Energy Plan (PCAET), the expectations of environmentalists and the management of local authorities, the President of the Pôle d'Équilibre Territorial et Rural du Briançonnais, du Pays des Écrins, du Guillestrois et du Queyras (PETR) asked the INRIA STEEP and INRAE G-EAU teams to set up and coordinate a research-intervention to support the territorial stakeholders (see the associated website). The aim of this dialogue is to define the region's energy policy, considering resource management and environmental impacts, while involving stakeholders throughout the process: in the construction of a participation plan and its implementation, including participatory modeling and the creation of an action plan to be implemented in the future. This collaboration involves a number of challenges, such as a joint search for funding, the mobilization of citizens and the decision-making nature of the process, as well as the scientific production (on the mobilization of biophysical accounting on territories) associated with the project (see 6.1 for further details). Following the researchers' support of the PETR's application to a funding from the Banque des Territoires, a convention between INRIA and the PETR has been signed to formalize this partnership both institutionally and financially (see section 9.3.4).

9.5.2 Supporting the building waste policy of Grenoble Alpes Métropole

This public policy issue was addressed by the PhD thesis of Quentin Desvaux, defended in December 2025, carried out through a CIFRE funding scheme with Grenoble Alpes Métropole. Quentin was involved in the organization and animation of several workshops gathering stakeholders from public and private backgrounds and aiming at understanding concrete lock-ins for increasing building waste reuse. See section 8.4 for more details.

9.5.3 Supply-chain modeling, material flow analysis, and data visualization

Our startup TerriFlux, with which we still closely collaborate, offers its expertise in supply-chain modeling, material flow analysis, and data visualization to public and private stakeholders. Its clients and partners come from a wide range of sectors (waste, energy, agriculture, forestry) and operate at different scales, both national – such as representatives of national agricultural supply chains, IGN, and CNRS – and local, such as the Pays Voironnais.

9.5.4 Local Risk Report for the Grenoble Metropolitan Area

The local authorities of Grenoble and adjacent territories[2] have launched a long-term initiative entitled *l'Atelier des Futurs*. Its goal is to reconsider public action with regard to the complexity of current and coming issues (social, economic, environmental) and often contradictory injunctions between the urgencies of the short term and the uncertainties of the long term. To be able to better understand the changes linked to the climate and social degradations, and the associated public action methods, to share knowledge and experiences: these are the expectations expressed by elected officials faced with the complexity of territorial issues. STEEP was the first academic partner to join the initiative and sign (through Inria) its charter. We are particularly interested in aspects related to territorial prospective, participation, and risk analysis which are at the heart of the initiative.

The first concrete action launched within *l'Atelier des Futurs* is concerned with the creation of a "Local Risk Report" for the area (about 500,000 inhabitants), nicknamed RARRe (Rapport annuel sur les risques et la résilience dans la région Grenobloise). STEEP has been involved since the beginning in 2022, to provide scientific and general expertise. The idea of this action is to identify vulnerabilities and especially, systemic links between them, as well as attenuation or preparation measures, in order to inform public policies. The report is planned to appear on an annual basis. The methodology used is inspired by the Davos Economic Forum's annual Global Risks report. Our Systemic Risk Fresco (see Section 10.3.2) was used, among other approaches, to fuel preparatory discussions.

[2] Grenoble Alpes Métropole, Département de l'Isère, EP SCoT de la Grande Région de Grenoble, Ville de Grenoble, Massif du Vercors, Pays Voironnais, Le Grésivaudan, Parcs de Chartreuse et du Vercors, Agence d'urbanisme.

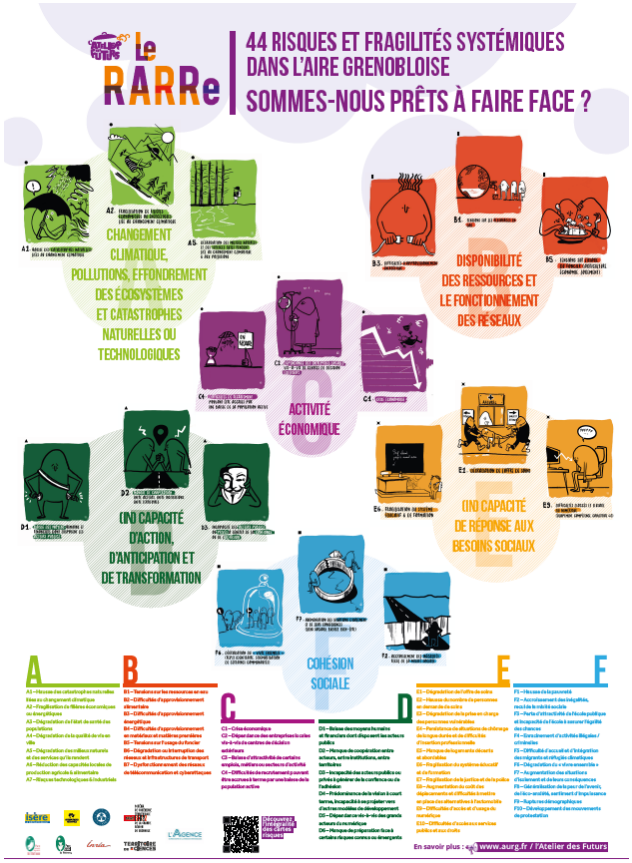

Figure 7: Overview of the 6 families of risks identified in the *l'Atelier des Futurs* initiative.

In 2023, 44 risks were identified as relevant to the Grenoble area. They are grouped into 6 thematic families (see Figure 7):

- Climate change, pollution, ecosystem collapse and natural or technological disasters
- (Un) availability of ressources and (dys) functioning of networks
- Economic activities
- (In) ability to act, anticipate and transform
- (In) capacity to respond to social needs
- Social cohesion

A questionnaire was created, tested, and then submitted to four panels of stakeholders (elected officials, citizens, business owners, local development councils). The goal was to understand how these risks are perceived by the population, in terms of gravity, likelihood (or being already in existence), possibility to act against them, the effect of actions already in place, the differentiation between local and global impacts of risks, etc.

The first edition of the RARRe was published in 2024, the second one in 2025. It contains a description and documentation of the above-mentioned risks and an analysis of the responses of the poll carried out based on the above questionnaire. In 2025, STEEP participated in the following events around this report:

- Peter Sturm participated in the *Forum du RARRe*: forum for elected officials on the annual report on risks and resilience of the greater Grenoble area (RARRe – *Rapport Annuel sur les Risques et la Résilience dans la Région Grenobloise*). Side-event of the Biennale des Villes en Transition, May 2025.

- Peter Sturm participated in the animation of a prospective exercise of the Pacte Économique Local, gathering over 50 business leaders of the larger Grenoble area. The exercise focused on risks and resilience and built on the annual report on risks and resilience of the greater Grenoble area (RARRe – *Rapport Annuel sur les Risques et la Résilience dans la Région Grenobloise*).

10 Dissemination

10.1 Promoting scientific activities

10.1.1 Scientific events: organisation

Atoll days 2025.

Participants: Mathilde Boissier, Serge Fenet, Renaud Metereau, Emmanuel Prados, Peter Sturm.

In order to maintain community ties between the biennial editions of the Archipel conference, we decided to organise intertwined workshops in order to ensure at least one meeting per year. This is how the Atoll days came about, the first of which were held at the end of June 2023 at INSA Lyon. The second edition was co-organised by STEEP members and Marie-Pierre Escudié (INSA Lyon), Anne-Laure-Fougères (Lyon 1 University), and Jean-François Trégouët (INSA Lyon), and was held in june 2025 at the Camille Jordan Institute on the LyonTech-la Doua campus. The workshop lasted two days and gathered almost 60 participants. The content of these two days was oriented towards development and consultation, which will enable the submission in 2026 of mini symposiums for collective reflection and/or action workshops and/or multidisciplinary articles.

STEEP members co-organized two two-day workshops within the Atoll days. A first one around the *Contremodélisation* research group (see next item) and a second one on the theme of Food, Health, Social Security, and Territory. The latter workshop brought together around thirty persons from the worlds of research and civil society.

Archipel conference 2026.

Participants: Enora Barrau, Serge Fenet, Peter Sturm.

Enora Barrau and Serge Fenet are members of the organization committee of the 2026 edition of the Archipel conference, to be held in Compiègne (France). This will be the third edition of this biennial conference initiated by STEEP in 2022. Serge Fenet and Peter Sturm are members of the programme committee of the 2026 edition.

Research group "Contremodélisation".

Participants: Enzo Baquet, Mathilde Boissier, Serge Fenet, Emmanuel Krieger, Guillaume Mandil.

Created during the conference Archipel 2022, the group Contremodélisation focuses on reflective and critical view on models and modeling. Around 15 researchers meet up once a month (around 30 times since the group's creation) to collectively open up a critical and constructive space for questioning a model's life cycle in its entirety (order, context and design choices, use and impacts), right up to the very relevance of modeling. This group provides an opportunity to share practices and analysis grids in order to build an inter- and trans-disciplinary framework for putting modeling to the test. Finally, the aim is to involve the modeling community and society in this critical work through practical, training and teaching activities. Besides regular meetings, the group organized a two-day workshop during the 2025 Atoll days (see previous item).

Desectorization workshop.

Participants: Renaud Metereau, Emmanuel Prados, Sophie Wahnich.

This workshop brought together members of the civil society and researchers from the Grenoble area with the aim of setting up transdisciplinary action research activities in the area. The general goal is to develop such activities with a systemic focus on the energy, health, and food sectors. This event took place in Grenoble on February 11, 2025, and brought together around fifty participants.

ReGEE – Grenoble Ecological Economics Meetings

Participants: Albert Bouffange.

Together with Nicolas Laurence and Johan Milleret (both at Université Grenoble Alpes), Albert Bouffange coordinates the ReGEE series (Grenoble Ecological Economics Meetings – *REncontres Grenobloises d'Economie Ecologique*). It constitutes a locally based but open forum for discussion on socio-ecological issues, bringing together different fields of economic and social sciences. These meetings are also open to people from the engineering and natural sciences who wish to address the socio-economic dimension of sustainability issues. The aim is to create a sustainable and friendly group dynamic, with regular meetings and original formats.

10.1.2 Scientific events: selection

Member of conference program committees

Participants: Mathilde Boissier, Jean-Yves Courtonne, Emmanuel Prados.

Mathilde Boissier, Jean-Yves Courtonne, and Emmanuel Prados are members of the scientific committee of the Archipel 2026 conference (see above).

10.1.3 Invited talks

- Mathilde Boissier was invited to the workshop Realworld labs vs Solutions, in Leipzig, October 8 to 11, where she gave a talk on "Playing with flows in transition territories". This workshop will result into a special issue in Nature+Culture, in which Mathilde Boissier will contribute (short article currently under review).
- Jean-Yves Courtonne gave an invited talk on non-monetary environmental assessment at ReGEE (Grenoble Ecological Economics Meetings – *REncontres Grenobloises d'Economie Ecologique*).
- Sophie Wahnich gave an invited talk "Guerre civile et révolution : du spectre à la hantise, enjeux théoriques et pratiques politiques 1789-1794" at the Colloque international. Frontières de la guerre civile, Campus Condorcet, Aubervilliers, 15 May 2025.
- Sophie Wahnich participated (with Christophe Bonneuil, Jean-Baptiste Fressoz and Louise Gentil) in a round table on the question "What can history do in the face of the ecological crisis?" (*Que peut l'histoire face à la crise écologique ?*) at the colloquium Faire face aux instrumentalisations de l'histoire. Le CVUH, 20 ans d'engagement, Sorbonne, Paris, 3 October 2025.
- Peter Sturm participated to a panel on the question *How to adapt our XR research practices in times of ecological crisis?* at the 32nd Ieee Conference on Virtual Reality and 3D User Interfaces, St Malo, France, 2025 (with Ludovic Hoyet (Inria), Marc Macé (CNRS), Solène Lambert (Sorbonne Université), and Marlène de Bank (the Shift Project)).

- Peter Sturm gave a talk on the "Socio-environmental roadmap of the Inria Research Center at Grenoble", MaTerrathon, Sciences-Po Grenoble, October 2025.
- Peter Sturm gave a webinar on "Research committed to socio-environmental sustainability" (*Une recherche engagée pour la soutenabilité socio-environnementale*), Inria Alumni network, September 2025.
- Peter Sturm gave a talk on "Research in sustainability sciences and an overview over obstacles to environmental action", ISTerre lab, Grenoble, April 2025.
- Peter Sturm gave a talk on "Territorial metabolism: Concept and usage in participatory modeling through serious games", ITAP lab, Montpellier, April 2025.
- Peter Sturm gave a talk on rebound effects and systemic risks to bachelor students of ENS Lyon (École Normale Supérieure), Le Pleynet, France, January 2025.

10.1.4 Scientific expertise

- Jean-Yves Courtonne initiated a 3-days training program on Material Flow Analysis with Aristide Athanassiadis (Metabolism of Cities) and Julien Alapetite (TerriFlux). Nine trainees attended the first edition in October 2025. The first day is dedicated to general notions on environmental assessment and social metabolism in particular, the second day to territorial MFA and the third day to supply chain and substance flow analysis.
- Emmanuel Prados carried out an expert assessment of the InSyTe research unit (Interdisciplinary research on Society-Technology-Environment interactions) as part of a broader initiative to evaluate all research units of University de Technologie de Troyes (UTT).
- Pierre-Yves Longaretti is coordinator of the scientific committee of the Idée project (Innovation et Développement pour une Economie Environnementale, Grand Annecy).
- Emmanuel Prados is a member of the Climate and Transition Scientific Council (*Conseil scientifique Climat et Transition*) of Grenoble Alpes Métropole and the AURG (Grenoble urban planning agency).
- Jean-Yves Courtonne is a member of the Steering Committee (COPIL) of the Territory consortium.
- Guillaume Mandil is member of the scientific committe of the Parc Naturel Régional de Chartreuse since September 2020.
- Peter Sturm is member of the Steering Committee (COTECH) of *Atelier des Futurs* (see section 9.5.4).
- Guillaume Mandil is part of a group, at UGA, of trainers in charge of the training of teachers on the topic of systemic écological transition.
- Peter Sturm acted as expert for professorship promotions, The University of Hong Kong.

10.1.5 Research administration

- Guillaume Mandil is elected member of the *Conseil d'Administration* (Board of Directors) of Université Grenoble Alpes
- Emmanuel Prados and Guillaume Mandil are members of the Campus D'Après initiative: a cross-disciplinary collective of academic researchers of the grenoble area who share a common goal: to better understand and reduce the direct and indirect environmental impact of research.
- Peter Sturm is member of the direction of Laboratoire Jean Kuntzmann since 2023.
- Jean-Yves Courtonne represents Inria at the Council of UFR IM2AG (Teaching Department *Informatique, mathématiques et mathématiques appliquées* of Université Grenoble Alpes).

- Peter Sturm represents Inria at the council of the PAGE research cluster (particle physics, astronomy, earth and environmental sciences, ecology) of Université Grenoble Alpes, since 2025.
- Mathilde Boissier is a member of the scientific council of the axis "ICT-S - Numérique et soutenabilité" (Digital and Sustainability) of LabEx Persyval.
- Several members of STEEP (Thibaut Coudroy, Emmanuel Krieger, Peter Sturm) participate in the core group mandated to coordinate the establishment and implementation of a socio-environmental roadmap for the Grenoble Inria Center. This involved among other activities, the organization of workshops with the Center's personnel and of a general assembly.
- Peter Sturm participates in the Inria mentorship programme. In 2025, he mentored a younger tenured scientist.

10.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

10.2.1 Supervision

- PhD defended this year: Antonin Berthe, "Etude de la faisabilité de la transition énergétique. Modélisation des couplages énergie-matière.", supervised by Pierre-Yves Longaretti, Emmanuel Prados, Olivier Vidal (ISTerre). 18 December 2025. External jury members: Paul Brockway (University of Leeds, reviewer), Francesco Contino (UC Louvain, reviewer), Oreane Edelenbosch (Utrecht University, examiner), Bernard Tourancheau (Université Grenoble Alpes, president).
- PhD defended this year: Quentin Desvaux, "Re-conception de systèmes de production durables et territorialisés - apports croisés de l'écologie territoriale et de l'économie politique", supervised by Catherine Figuière (CREG), Guillaume Mandil, Jean-Yves Courtonne. 18 December 2025. External jury members: Muriel Maillefert (CRGA-EVS, reviewer), Sylvie FERRARI (BSE-CNRS, reviewer), Franck Dominique-Vivien (CRIEG, president), Arnaud Buchs (PACTE, examiner), Renaud Metereau (LADYSS, examiner).
- PhD defended this year: Léon Fauste, "Relocalisation d'industrie productive : une approche par les graphes et les contraintes", supervised by Christine Solnon (Lyon University), Mathieu Mangeot, and Jean-Yves Courtonne. 26 September 2025. External jury members: Olivier Thérond (INRAE, reviewer), Anne-Laure Fougère (Univ. Lyon 1, reviewer), Nadia Brauner (UGA, president), Catherine Darrot (Institut Agro Rennes-Angers, examiner).
- PhD in progress: Enzo Baquet, "Analyse de la dynamique de propagation des perturbations intra et inter-sectorielle dans le contexte de crises à court terme", supervised by Serge Fenet, Pierre-Yves Longaretti, and Mathieu Mangeot.
- PhD in progress: Albert Bouffange, "Penser les contractions matérielles pour la France en liant économie politique et flux de matière et d'énergie", supervised by Agnès Labrousse (Sciences-Po Lyon), Emmanuel Prados, and Pierre-Yves Longaretti.
- PhD in progress: Thibaut Coudroy, "Optimisation et gestion de contraintes pour la modélisation et l'évaluation d'alternatives socio-techniques", supervised by Peter Sturm.
- PhD in progress: Hannah Gelblat-Laugier, "Ressources humaines et transformation sectorielle dans le contexte des limites planétaire : analyse quantitative et qualitative de scénarios contrastés pour le système de santé", supervised by Valérie d'Acremont (Unisanté, Université de Lausanne) and Jean-Yves Courtonne.
- PhD in progress: Thomas Gotteland, "Modélisation de futurs sous contraintes du système agroalimentaire sur la région grenobloise", supervised by Emmanuel Prados, Mathilde Boissier, and Jean-Yves Courtonne.
- PhD in progress: Jérémie Klein, "Outils numériques de modélisation fonctionnelle pour l'aide à la décision dans l'évaluation des transitions sous contraintes", supervised by Guillaume Mandil, Jean-Yves Courtonne, Peter Sturm, and Bernard Tourancheau (LIG).

- PhD in progress: Emmanuel Krieger, "Modélisation socio-technique de territoires : modèles numériques et jeux sérieux", supervised by Peter Sturm, Nils Ferrand, Mathilde Boissier and Jean-Yves Courtonne.
- PhD in progress: Damien Rieutor, "Implémentation locale du concept des 'Limites Planétaires'. Méthodologie de transposition territoriale des spécificités du concept de Limites Planétaires pour évaluer la criticité environnementale locale", supervised by Guillaume Mandil, Gwendoline de Oliveira Neves (Universidad Pablo de Olavide, Seville, Spain).

Sophie Wahnich (co-)supervises several PhD theses outside of STEEP, two being related to our considerations on territorial issues:

- Karla Candeia, "Le mouvement des sans terre au Bresil", EHESS.
- Nour Khatib, "La crise de l'hospitalite libanaise : l'accueil des réfugiés syriens au Liban (2014-2022)", UGA, defended on 11 March 2025.

10.2.2 Juries

- Sophie Wahnich chaired the PhD jury of Jean Loup Kastler ("Les métamorphoses de la cité idéale en pays de montagne (1768-1788) : De l'utopie philosophique de Versoix à l'écologie morale de la Journée des Tuiles"), Université Paris 1 Panthéon-Sorbonne, December 2025.
- Peter Sturm was a reviewer of the PhD thesis of Pierre La Rocca ("Modélisation conséquentielle et territoriale de l'empreinte carbone d'équipements numériques pour l'agriculture et du réseau mobile associé"), University of Bordeaux, December 2025.
- Jean-Yves Courtonne is member of the CSI (*Comité de Suivi Individuel*) of the PhD theses of Adrien Fauste-Gay (UGA ISTerre, CIRED), Yatina Calixte (UGA PACTE), and Fanny Lacroix (LGC Toulouse).

10.2.3 Teaching

- Guillaume Mandil and Serge Fenet have regular teaching duties at the universities employing them. As for Guillaume, since 2020 all his teaching duties deal with socio-ecological issues and are taught to students from L1 to PhD level. These courses are offered both in disciplinary fields and as part of cross-disciplinary programs.
- Mathilde Boissier, Jean-Yves Courtonne, Guillaume Mandil, Emmanuel Prados: 18 hours of courses for Master 1 students (master *Transitions écologiques*, Sciences Po Grenoble).
- Mathilde Boissier: Ingénierie de la transition, 24h, ENSE3, Grenoble.
- Jean-Yves Courtonne, Serge Fenet, Guillaume Mandil, Emmanuel Prados, and Peter Sturm: Les véritables enjeux environnementaux – compréhension, modélisations et outils quantitatifs, 30 hours, course plus project work, Master course, Ecole Centrale Méditerranée, Marseille.
- Jean-Yves Courtonne, Serge Fenet, Pierre-Yves Longaretti, Guillaume Mandil, Emmanuel Prados, and Peter Sturm: Les véritables enjeux environnementaux – compréhension, modélisations et outils quantitatifs, 24 hours course plus project work, MSTII Graduate School and L3 Computer science, UGA.
- Jean-Yves Courtonne, Pierre-Yves Longaretti, Emmanuel Prados: Limites Planétaires et insoutenabilité, 18 hours of courses and tutoring for master students, ACT (PISTE/TEET, ENSE3, Grenoble INP).
- Jean-Yves Courtonne, Guillaume Mandil: Science, Environnement, Société, Doctoral School (CED) UGA.
- Jean-Yves Courtonne: modélisation quantitative et analyse de flux de matière, 10 hours of tutoring for Master 1 students, IDDAT (IUGA, UGA).

- Jean-Yves Courtonne: intérêts composés et croissance exponentielle, 20 hours of courses and tutoring for Master 1 students, MIAGE (IM2AG, UGA).
- Jean-Yves Courtonne, Mathilde Boissier, Guillaume Mandil, Emmanuel Prados, and Pierre-Yves Longaretti: Green University, a thematic school offering a systemic approach to anthropocene trajectories, open to 35 M1, M2 and PhD students from all UGA establishments. (UGA, 24h)
- Pierre-Yves Longaretti: 6 hours on global change, systemic risks and socio-economic obstacles to socio-political change. Taught to masters students (Green University) and independently to first year students.
- Jean-Yves Courtonne, Quentin Desvaux: Enjeux territoriaux – Introduction aux filières agri-alimentaires, forêt-bois, et déchet. 12 hours of courses for master students (TEET, ENSE3, Grenoble INP)
- Jean-Yves Courtonne, Mathilde Boissier, Emmanuel Prados: Industrie et économie circulaire, 18 hours of courses for master students (master Transitions, Sciences-Po Grenoble).
- Mathilde Boissier: Un aperçu de la participation dans la transformation soutenable des territoires. 3 hours of courses for master students (Green University week, UGA)
- Mathilde Boissier, Emmanuel Krieger, Jeremy Klein: Ingénierie de la transition. 24 hours of master students projects supervision (ENSE3, Grenoble INP)
- Mathilde Boissier: Mise en participation des analyses de flux de matières et d'énergie sur les territoires. 4 hours of courses for master students (TEET, ENSE3, Grenoble INP)
- Enora Barrau: Ingénierie et limites planétaires, 18 hours of licence students projects supervision (L2 Civil Engineering, Mechanical Engineering, UGA)
- Alexandre Honorat: Programmation C, modularité et Makefile. 24h. L2, Département licence sciences et techniques, UGA.
- Thibaut Coudroy: Algorithmique et structures de données. 27h. L3, Ensimag, Grenoble INP.

10.3 Popularization

10.3.1 Conference-debate series and YouTube-channel "Understanding and Acting"

In view of the global issues described in section 2.1, we initiated in 2016 a series of conference-debates entitled "Understanding and Acting" (*Comprendre et Agir*) that examines these issues in order to help researchers and citizens to increase their awareness of the various issues at stake in order to initiate relevant individual and collective actions. From now on, the scientific community at large must realize that its duty also lies in helping citizens to better understand these issues. If the fraction of people in society whose privilege is to be paid to think about society's problems do not seize this opportunity in the critical times we face, who will? Researchers must become more involved in the search of socioeconomic alternatives and help citizens to implement them. The interactions between researchers and citizens have also to be reinvented.

Presentations typically last between 45 to 60 minutes; they are followed by a 45 minute public debate with the audience. The presentations are captured on video and then made accessible on the YouTube channel *Comprendre et Agir*. As of January 2026 the channel has about 15,100 subscribers and reached a total of over 1,200,000 viewings.

In 2025, we had the following conference-debates.

- Sophie Dubuisson-Quellier (CNRS and Science-Po Paris), Problems posed by the solutionist approach, 9 January 2025.
- Agnès van Zanten (CNRS and Centre de Recherche sur les Inégalités Sociales), The new faces of meritocracy in the educational system, 19 June 2025.

- Denis Couvet (Muséum national d'Histoire naturelle), Collapse of life – What do we do now?, 25 September 2025.
- Julien Milanesi (Université de Toulouse and CERTOP), How can an alternative ecosystem transform its territory? A Basque investigation, 11 December 2025.
- Denis Dupré (retired associate professor, former STEEP member), "Understanding and Action" -— 10 years already! Findings, assessment... What do we do now?, 18 December 2025.

10.3.2 Productions (articles, videos, podcasts, serious games, ...)

Articles.

- Sophie Wahnich wrote an article entitled Utopie nécessaire : Des lignes de vie à tracer, published by Revue Projet.
- Jean-Yves Courtonne and Guillaume Mandil wrote an article entitled Points de vigilance sur l'économie circulaire et recommandations, published on the website of the Auvergne-Rhône-Alpes region's circular economy network (*Réseau de l'économie circulaire de la région Auvergne-Rhône-Alpes*).

Media.

- Sophie Wahnich was interviewed by L'Humanité, together with economist Jean-Marie Harribey. The interview gave rise to the article Le capitalisme, un horizon indépassable ? (1/4).
- Hannah Gelblat-Laugier was interviewed on her PhD work by the online media Curieux !. The interview gave rise to an article entitled Science can help rethink health in the face of health crises, environmental crises, and austerity policies. (*La science peut aider à repenser la santé face aux crises sanitaires, environnementales et aux politiques d'austérité*).
- Interview with Serge Fenet and Pierre-Yves Longaretti by Oma-Radio about the publication of the book "World3 et le rapport Meadows, les limites à la croissance ; questions raisonnées pour aujourd'hui" co-authored and edited by the STEEP team [17], March 25, 2025.
- Denis Dupré, Serge Fenet and Peter Sturm were guests in the radio show "La Télé au placard" of Radio Grésivaudan, to give an interview on the 10 year anniversary of the Understanding and Acting conference-debate series (see section 10.3.1). The interview is accessible here.
- The territorial dialogue described in section 6.1 was covered in several newspaper articles:
  - The creation of the Energy Policy Council (*Conseil d'Orientation des Énergie*) was reported in
    - Le Conseil d'Orientation des énergies sera lancé ce mercredi, Le Dauphiné Libéré, 02/07/2025
    - Naissance du Conseil des Energies Locales, Alpes et midi, 30/06/2025
    - Conseil d'orientation des énergies un appel à candidatures, Le Dauphiné Libéré, 23/05/2025
  - The construction of the territorial action plan was covered in
    - Dialogue Territorial Energie : Retour sur la journée de travail, Alpes et Midi, 14/04/2025
    - Dialogue Territorial Énergie : Définir ensemble la stratégie énergétique du territoire, Alpes et Midi, 10/03/2025
  - General articles on the project:
    - Les rencontres publiques sur l'énergie se poursuivent, Le Dauphiné Libéré, 22/02/2025
    - Rencontre publique sur l'energie, Le Dauphiné Libéré, 24/01/2025
    - Ateliers, carnaval, théâtre, conférence : février est en fête, Le Dauphiné Libéré, 06/02/2025.

Systemic Risk Fresco. Systemic risks emerge from interactions within a system in which vulnerabilities are present. If elements of a system are sensitive and sufficiently intertwined, disrupting one or several of them can spread over the whole system, triggering chain reactions and feedback. Systemic thinking is not straightforward [63]. Courses in education are often specialized, focusing on one or few themes or objects. Students often go from one subject to the other, without linking them. "All other things being equal" type reasoning then implicitly arises. This kind of reasoning is consequently blind to interactions with – and vulnerabilities to – changes in other elements of a system.

Studying Global Systemic Risks logically implies systemic thinking. Four PhD students of the team (Alexandre Borthomieu, Antonin Berthe, Léon Fauste, and Mathilde Jochaud du Plessix) created a game to vulgarize this kind of thinking. The Global Systemic Risks fresco (*Fresque des risques systémiques globaux*) is a serious game aimed at broadening the understanding of this aspect. It enables participants to explore interactions within a system and the spreading of disruptions. The game is a visual and spatial representation of the core elements of western societies.

A session takes place in three stages: (i) the construction of the fresco, (ii) the exploration of breakthrough scenarios and (iii) a time of "return to reality". In the first stage, participants are invited to construct a map of elements they consider important for society; they are guided to first think about primary needs, then means to answer such needs (such as education or a construction sector) and finally, "sectors" allowing to realize these means (energy and materials, finance and geopolitics, "the environment"). Links between all these elements represent dependencies (see figure 8 for a sample outcome).

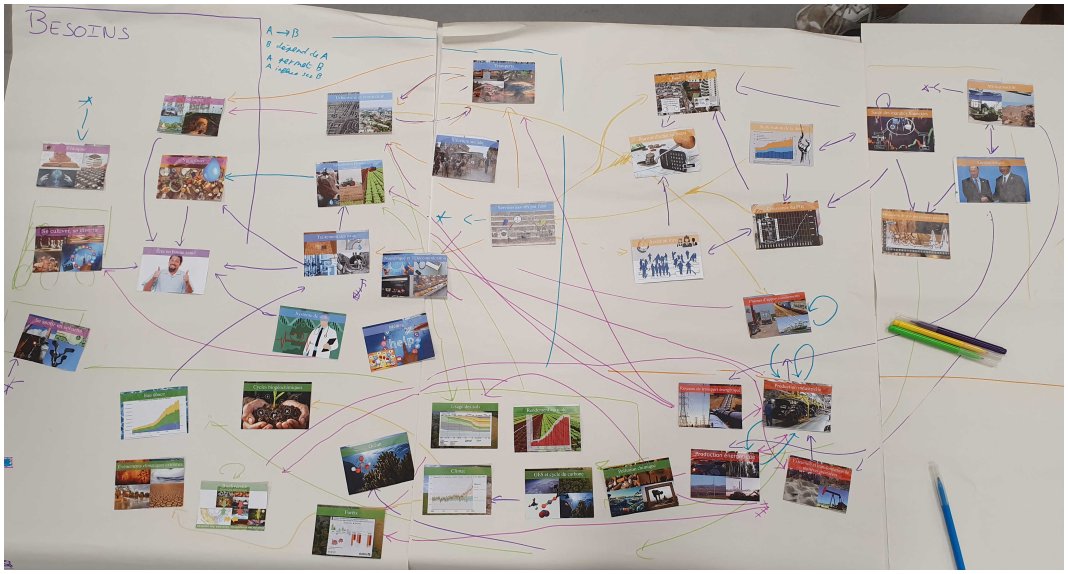

Figure 8: Structure designed by a group after phase I of the Systemic Risk Fresco workshop.

In the second stage, the thus established map allows to explore scenarios and questions such as how disruptions in one of the elements are links can spread through the system. The goal is to foster insight in the systemic nature of our socio-ecological system and to encourage participants to think about our needs in a new way, adapted to a degraded environment, and then eventually to create or imagine more resilient alternatives. As these topics are sources of discomfort and strong emotions, a workshop ends with a third stage, to share feedback on what they have just experienced, as well as a time for sharing emotions, which we believe is now essential for any research or knowledge creation around social and environmental issues that affect each person in different ways. Moreover, we believe that this time allows participants to be accompanied in the "return to reality" and to limit the feeling of powerlessness.

The Global Systemic Risks fresco has been employed in various workshops with different types of audience (scientists, students, general public) and we use it now routinely in several courses at university. It has also been demonstrated to members of the public authorities involved in the *l'Atelier des Futurs* initiative (section 9.5.4), as an input to the preparation of the Local Risk Report for the Grenoble area.

For more details on the fresco, please refer to this report.

10.3.3 Participation in Live events

- STEEP participated through different activities in the 2025 edition of the Biennale des villes en transition, organized by the Grenoble municipality (see also the article by Inria and LinkedIn).
  - Mathilde Boissier gave a conference entitled "Discussing energy policy together: scientific support for regional dialogue in the Greater Briançon area" (*Discuter ensemble la politique énergétique : accompagnement scientifique du dialogue territorial dans le grand briançonnais*), related to the territorial dialogue she co-animated (see section 6.1).
  - Two sessions of the TransKey serious game on the management of biophysical resources (water, cereals, etc.), were animated by Mathilde Boissier and Matthieu Planchot.
  - A session of our Systemic Risk Fresco (see section 10.3.2) was animated by Emmanuel Krieger, Antonin Berthe and Alexandre Borthomieu.
  - During the Biennale, the second annual Forum on the Grenoble Risk and Resilience Report (*RARRe – Rapport Annuel sur les Risques et la Résilience dans l'aire grenobloise*, see section 9.5.4) was held. This Forum is a special opportunity for elected officials and other territorial stakeholders (e.g. directors of municipal or communal technical services) to discuss the situation in the Grenoble area in terms of risks. This year's forum was a major step prior to the production of the second edition of the Report. Peter Sturm animated one group of participants, through a simulation based on a prospective scenario and a prospective discussion.
- Emmanuel Prados gave the opening keynote speech at the MathC2+ "Research, Openness, and Encounters" workshop held on June 24, 2025, at the Inria Grenoble center, co-organized by Inria Grenoble, the Académie de Grenoble, and IREMI. Title of the keynote speech: Doing Math in a World in Transition.
- On March 25, 2025, Sophie Wahnich, Pierre-Yves Longaretti, Emmanuel Prados, and Serge Fenet took part in a photo exhibition and workshop organized by the INSA Lyon library in relation to the publication of the book "World3 and the Meadows Report, Limits to Growth: Reasoned Questions for Today," co-written and edited by the STEEP team [17].
- Guillaume Mandil took part in the round table on "Critical minerals: geological and geopolitical challenges and drivers of circularity" at the *Assises de la logistique urbaine durable – Les Rencontres Circul'Alpes* (Conference on sustainable urban logistics), organized by Grenoble Alpes Métropole and Circul'Alpes. With Hugo Le Boulzec (CNRS) and Nicolas Géraud (CEA).
- Sophie Wahnich intervened on the topic Revolutionary crowds, the beating heart of history (*Foules en révolution, le cœur battant de l'histoire*) in the frame of the exhibition "Comme des moutons ?" at Quai des Savoirs, Toulouse.
- Sophie Wahnich gave a presentation on the topic "Democracy, conflict, compromise – What can popular education do ? The revolutionary example" (*Démocratie, conflit, compromis, que peut l'éducation populaire, l'exemple révolutionnaire*), Collectif Avenir de l'éducation populaire, Grenoble, 12 March 2025.
- Sophie Wahnich gave a performance "Mild apocalypse" (*L'apocalypse douce*), Le Garage, Romainville, May 2025.
- Emmanuel Prados and Peter Sturm gave a talk Pourquoi sommes-nous impuissants face aux processus d'effondrement ?, to a forum of entrepreneurs, Hub des Alpes, Challes-les-Eaux, France, 21 January 2025.
- Peter Sturm participated in the *Forum du RARRe*: forum for elected officials on the annual report on risks and resilience of the greater Grenoble area (RARRe – *Rapport Annuel sur les Risques et la Résilience dans la Région Grenobloise*). Side-event of the Biennale des Villes en Transition, May 2025.

- Peter Sturm participated in the animation of a prospective exercise of the Pacte Économique Local, gathering over 50 business leaders of the larger Grenoble area. The exercise focused on risks and resilience and built on the annual report on risks and resilience of the greater Grenoble area (RARRe – *Rapport Annuel sur les Risques et la Résilience dans la Région Grenobloise*).
- Antoine Cordoba (a post-doc in the TRIPOP Inria team co-supervised by STEEP (Serge Fenet and Pierre-Yves Longaretti)), gave a talk on "The report to the Club of Rome on Limits to Growth" at the *Pizza Tech* popularization series organized by Inria Grenoble. September 2025.
- Hannah Gelblat-Laugier gave a talk on "What human resources are needed to provide healthcare in the face of multiple shortages, public health challenges, and planetary constraints?" at the *Pizza Tech* popularization series organized by Inria Grenoble. March 2025.
- Angèle Demarquilly animated a workshop within the framework of her internship, around the topic "Our attachments to energy consumption" (*Nos attachements autour de la consommation énergétique*), Centre Inria de l'Université Grenoble Alpes, September 2025.

10.3.4 Arts and Science

Since several years, STEEP members are involved in various Arts and Science initiatives. In 2025, this concerned the following:

- Sophie Wahnich participated in the theatrical production POLIS, under the auspices of the Hexagone theatre (a French *Scène Nationale*) based in Meylan, next to Grenoble. This involved one week of cooperation with 3 stage actors as well as the on-stage participation in the actual performance on 14 May 2025. The production aimed at helping to "understand where our historical situation comes from and imagine ways to refine our ways of voting, resisting, dreaming" (see this article and also the article in Dauphiné Libéré).
- Emmanuel Prados and Peter Sturm participated in the scientific committee of the 2025 edition of the Festival du jardin du pont de Chartreuse, Grenoble. This yearly event brings together artists, scientists and members of the civil society in a community garden. Emmanuel Prados also intervened during the festival (testimonials and debates).

10.3.5 Other science outreach relevant activities

Mathilde Boissier was interviewed by Inria's scientific outreach network, in order to produce a video portrait in the series *Archétypes – Femmes scientifiques*. Mathilde's portrait, entitled *Épisode 7 – Archétypes : La médiatrice* is available on YouTube.

Emmanuel Prados and Peter Sturm were interviewed by sociologist Antoine Hardy as part of a project led by the Center for the Sociology of Innovation (Mines Paris – PSL) aimed at understanding how the consideration of the environment in computer science research is helping to redefine this scientific field.

11 Scientific production

11.1 Major publications

[1] M. Bevione, J.-Y. Courtonne, B. Nicolas, P.-Y. Longaretti and Q. Desvaux. 'Analyzing the vulnerabilities and capabilities of wealth creation activities in the Maurienne valley in the French Alps'. In: *Regional Environmental Change* 22.64 (4th May 2022), pp. 1–44. DOI: 10.1007/s10113-022-01908-0. URL: https://hal.science/hal-03560831.

[2] M. Boissier, N. Ferrand, E. Krieger, J.-Y. Courtonne and P. Sturm. 'Playing with flows in transition territories'. In: *Nicolas Becu. Simulation and Gaming for Social and Environmental Transitions.: Proceedings of the 54th Conference of the International Simulation and Gaming Association. 2023, 979-10-415-2760-1.* ⟨*halshs-04209935*⟩. ISAGA 2023 - 54th edition of the International Simulation and Gaming for Social and Environmental Transitions. La Rochelle, France, Sept. 2023. URL: https://hal.science/hal-04231486 (cit. on p. 25).

[3] T. Capelle, P. Sturm, A. Vidard and B. Morton. 'Calibration of the Tranus Land Use Module: Optimisation-Based Algorithms, their Validation, and Parameter Selection by Statistical Model Selection'. In: *Computers, Environment and Urban Systems* 77 (Sept. 2019), 101146:1–13. DOI: 10.1016/j.compenvurbsys.2017.04.009. URL: https://hal.inria.fr/hal-01519654.

[4] J.-Y. Courtonne, J. Alapetite, P.-Y. Longaretti, D. Dupré and E. Prados. 'Downscaling material flow analysis: The case of the cereal supply chain in France'. In: *Ecological Economics* 118 (Oct. 2015), pp. 67–80. DOI: 10.1016/j.ecolecon.2015.07.007. URL: https://hal.archives-ouvertes.fr/halshs-01321742.

[5] J.-Y. Courtonne, J. Alapetite, V. Wawrzyiak and M. Bevione. 'The AF Filières project: application of PSUT frameworks for regional analyses of agriculture and forestry supply chains and footprints in France'. In: *ESEE 2019 - 13th International Conference of the European Society for Ecological Economics*. Turku, Finland, June 2019, pp. 1–4. URL: https://hal.inria.fr/hal-02430898.

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