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A transition support system to build decarbonization scenarios in the academic community

Short title: Decarbonization scenarios in the academic community

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N.B. Dear editor, this work implies dozens of co-authors (see section: Credit authorship contribution statement). At this stage, we would appreciate to save time, by submitting our original manuscript before filling in the addresses of the co-authors. Thank you for your kind understanding.
Abstract:

A growing portion of scientists realizes the need to not only alert about climate change, but also change their professional practices. A range of tools have emerged to promote more sustainable activities, yet many scientists struggle to go beyond simple awareness-raising to create concrete transition actions. Here we propose the game-based Transition Support System (TSS) Ma Terre en 180 Minutes, that has been designed to build scenarios of greenhouse gases (GHG) emissions reduction in the academic community, and present its deployment during the year 2021, including six hundred participants from nine countries and 50 cities. After building a common scientific background about the context (global warming, its causes and consequences) and challenge (50% reduction of our carbon budget by 2030), the participants immerse themselves into fictional characters, to simulate the behaviour of real research groups. Results show clear pathways for GHG reductions between 25 and 60%, and a median reduction of 46%. The alternatives allowing the greatest reduction are video communication tools (36%), followed by mutualization of professional activities and voluntary cancellation or reduction, that represents 22 and 14% of reduction, respectively. The remaining 28% of reduction is composed by the use of trains as a transport alternative, the relocation of professional activities, the duration extension of some missions, etc... In addition, the analyses pointed out the importance of guided negotiations to bring out some alternatives such as relocation, local partners and computing optimization. An added value of this TSS is that the information it collects (anonymously) will be used to answer pressing research questions in climate change science and environmental psychology regarding the use of serious games for promoting changes in attitudes and behaviour towards sustainability, and including broader questions on how network structures influence “climate 2behaviour”, knowledge, and the governance of the commons.
Keywords: climate change engagement, games, gamification, serious games, role-playing, research agenda

1. Author summary

For the last centuries, humans upscale their socio economic structures and globalized their interactions; and these unprecedented developments have been largely driven by our capacity to extract energy from the Earth. You and me were born in a carbonized world, were unlimited access to fossil resources and derived goods became the norms. Generations after generations, homo sapiens switched and installed themselves in the ideology of a no limit planet. For some decades now, scientists warm about the inadequacy between this commonly shared belief and the physical and biogeochemical limits. In simple world, the “carbonized sapiens” now know the threats but miss guidelines to reinvent himself. Modestly, Ma Terre 180’ offers an innovative game-based transition support system to build scenarios of greenhouse gas emission (GHG) reduction in the academic community. It is no question of tokens on a gameboard and adjustment of practices, it is a question of brainstorming about a possible and desirable way of remodelling research and teaching communities and embrace a new paradigm. After tens of workshops involving hundreds of participants from more than fifty cities and nine countries, our results show clear pathways for reaching up to 50% GHG reductions and stress the importance of guided negotiations to bring out alternatives to carbonated activities. This first attempt reinforce our belief that scientific engagement is at the heart of the international development agenda and a key way to remove the institutional barriers that inhibit the transformation needed to achieve a more sustainable society.

2. Introduction
Since the Paris agreement on climate change in 2015, and the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018[1]), 191 states have committed to set ever more stringent policies of greenhouse gas (GHG) reduction (UNFCCC report, 2021[2]). In this context, the European Union has set the target of achieving, at least, a 55% reduction in GHG by 2030, compared to 1990. On July 8 2021, the European Central Bank took a historic step by announcing, for the first time, the integration of climate change into its monetary policy.

Earlier in 2021, the International Energy Agency called on governments to ensure that their economic recovery plans focus on clean energy investments in order to create the conditions for a sustainable recovery and long-term structural decline in carbon emission (IEA report, 2021[3]).

At the global scale, a systemic change through moderate to low GHG emissions can only be reached if both individuals and communities endorse a dual responsibility to inform policy makers and citizens about the threatening situation for humans and life on Earth. It requires action to promote a form of frugality (Vaden et al., 2020[4]) and embody a socio-ecological transition toward low carbon societies (IPCC, 2018[1]; Otto et al., 2020[5]). In France, this dual responsibility is unavoidable since individual actions, such as commitments and financial investments, can at best reach a 45% reduction of GHG emission (Carbone4 report, 2019[6]).

GHG emissions of the academic activities can no longer be ignored. As highlighted by IPCC (2018), limiting global warming to 1.5°C or even 2°C requires a drastic and rapid reduction of GHG emissions that must concern all sectors of activity, particularly in developed countries (Mahlstein et al., 2011[7]). In this respect, the academic world is not an exception (Attari et al., 2016[8]). Besides, cognitive dissonance is high in all spheres and perhaps even more within the academic world, which can no longer afford to only raise awareness and alarm about the upcoming crisis, but must act as pioneers and embody changes (Schrems and Upham, 2020[9]; Whitmarsh et al., 2020[10]).
Defining a robust strategy of emissions reduction implies, firstly, to accurately monitor GHG emissions. In the academic sector, a group of French researchers, named Labos1point5 (https://labos1point5.org/), developed an open-source tool called ‘GES1point5’ to help research labs to calculate their carbon footprint (Mariette et al., 2021[11]). Monitoring is a first step but it is insufficient to lead to in-depth changes of our professional behaviour (Hulme, 2020[12]). Yet, a growing portion of the scientific community realizes the need to not only alert but also change their professional practices. Moreover, according to Attari et al. (2016), the credibility of scientists and of their warnings is increased when they behave in a non-dissonant manner. According to a study carried out among 6000 people (Labos 1point5, 2020), 88% of French researchers "completely agree" or "somewhat agree" that the climate emergency requires profound changes in their practices; however, the structural and functional framework of the academic sector and the evaluation of academic performances do not favour the emergence of sustainable trajectories. On the contrary, it largely promotes researchers’ behaviours that lead to high carbon pathways (e.g. international travel, promotion of international network, use of high-technology and unique scientific instruments).

Nowadays, whether for conferences, field surveys, highly specific instrument experiments, thesis defense or project meetings, the emissions linked to researchers’ mobilities are an important (and sometimes predominant) contribution of a laboratory GHG footprint (Whitmarsh et al., 2020). In addition, travel practices are inequitably distributed among individuals, reaching per instance for a professor 10.8 tCO\(_2\)e per capita on average at the University of Montreal, Canada, (Arsenault et al., 2019[13]) and 7.5 tCO\(_2\)e at the University of British Columbia (Wynes et al., 2019[14]). The use of aircraft is a predominant source of GHG emissions and according to some authors (Wynes et al., 2019), it would not necessarily bring a clear benefit in terms of career development and enhancement of professional relations.
A range of tools, of varying degrees of entertainment and constraint, are gradually emerging, but many of them struggle to go beyond simple awareness-raising to create concrete transition actions (Galeote, et al., 2021[15]). In France, as in many other countries, a growing number of researchers organize themselves to change their work habits and embrace more sustainable practices; a trend that was accelerated due to the COVID pandemic crisis and the increase of video communications. Some alternatives need to be done to enlarge the scientific community involved, but also to provide an overall vision of possible pathways of GHG emissions reduction. Ongoing approaches include incitative measures (carbon tax, ecological money), regulatory measures (carbon quotas, green charter, carbon offsetting) and gamification approaches (the Climate Fresk, ClimaTicTac, Carbon Lean, 2 Tonnes). The latter can take the form of serious games, which simulate multi-actor systems for tackling the complexity of environmental issues and their interplay with many other domains (Oliver, 2016[16]).

In the context of climate change, digital serious games have been used for almost forty years (Robinson and Ausubel, 1983[17]). In their literature review, comprising tens of gamified approaches, Galeote et al. (2021) showed that serious games stimulate cognitive engagement, affect the perception of climate change-related topics and behavioral engagement with others, by combining learning and entertainment. Serious games create a sphere of thinking around a complex topic while maintaining a playful atmosphere. As players, participants then embody positions or roles that are not necessarily their own, and relate more easily with issues that do not concern them directly or by which they did not think they were concerned. Moreover, serious games generate dynamics of opposition or cooperation involving the players’ emotions to immerse them further in their character and promote the players’ empathy towards roles different from their real-life conditions (Wiemeyer et al, 2016[18]). They favor moments that create links and encourage sincere exchanges. According to Gee (2008)[19], serious games need to be moderately funny or
“pleasantly frustrating” to be serious enough. This characteristic makes the adaptation of serious games on the theme of climate change or socio-ecological concerns perfectly appropriate. Indeed, these topics are surely some major concerns of our time, and at the same time the most postponed ones. In this context, there are more and more serious games being set up to raise awareness on these issues among the various social, political and economic stakeholders (Onencan et al., 2016[20]; Terti et al., 2019[21]; Undorf et al., 2020[22]).

In this perspective, we developed MaTerre180’ (i.e. MyEarth180’), a Transition Support System including a game-based participatory tool, that aims at raising awareness regarding the carbon footprint of the academic world, and identifying ways of reductions through social interactions. MaTerre180’ particularly focuses on the predominant proportion of air travel in the academic carbon footprint, but also includes other means of transportation (train, car or boat for oceanographic surveys) as well as additional sources of emissions such as numerical simulations and the access to highly technologic and unique scientific instruments (e.g., particle collider). MaTerre180’ goes beyond the mere framework of learning by first identifying solutions, then embracing action and bringing to light concrete solutions to reduce academic GHG emissions.

After a general description of the timeline, materials and methods, results focus on the analysis of the eighty five game-based phases played to date. These games have been analyzed in order to discuss the applicability of the suggested solutions for GHG emission reduction within the academic world. In particular, it has been possible to assess the robustness of the proposed alternatives through indicators of their spontaneity and popularity. Finally, we questioned the indicators used to measure academic performance and their consistency with the GHG emission reduction objectives in order to open discussions on the possible and most effective ways to implement the proposed strategies.

3. Results
From November 6th 2020 to June 18th 2021, eighty-five games ($N=85$) brought together more than six hundred participants (mostly academic professionals) from nine countries and more than fifty cities.

**a. Alternative categorization**

Fig 3 summarizes the categorization of alternatives in the form of a dendrogram sketch, the size of the circles being proportional to the number of alternatives that fall within each category, or subcategory.

**Fig 3. Circular dendrogram of the classified alternatives by categories.** All the lexical fields displayed are reported in the appendix. The frequency of appearance is described in the legend.
In total, 407 different alternatives were expressed; some of them being considered by many participants, so that the total individual number of actions (move of tokens) performed to reduce carbon footprint was 2141. The three most popular alternatives (by numbers) are video communication (35%), public transportation (i.e. train travels, 21%) and mutualization (18%). By nature, this latter alternative requires a degree of interaction between two, or more, characters, and thus covers a great lexicological plurality. More than one hundred (101) different wordings of this alternative were voiced by participants, as shown here above in Fig 3 (orange dots).

b. Trajectories of the different game tables

The GHG emissions trajectories are first presented through the absolute reduction of GHG of each game table (Fig 4a, CP); then, the relative reduction is shown (Fig 4b, R) to facilitate intercomparison given that not all the game tables/teams start with the same initial emission level (Table 1).
Fig 4. Virtual GHG footprint trajectories. (a) Absolute and (b) relative GHG trajectories for 85 game tables coloured by virtual teams. The horizontal solid black line represents the 50% reduction goal.

The x-axis reports the four successive sub-phases of the role-playing game, namely the initial footprint of the different virtual teams, as previously detailed in section IIA, the GHG footprint decrease after the free negotiation phase, ANR and ERC project grants, and the final reduction after the guided negotiation phase. Beyond the general decreasing trajectory of all broken lines observed in Figures 4a and 4b, we can emphasize a strong variety of initial budget (ranging from 42 tCO$_2$e to 78 tCO$_2$e per virtual teams), and of games trajectories.

Overall, all games managed to reduce their carbon footprint after the free negotiation phase. The variability of the final emissions at the end of the games overpasses the variability of initial GHG footprint, which clearly highlights the importance of the interactions between players during the game.

To compare the trajectories of the different tables, we displayed the relative reduction in GHG footprint (Fig 4b). Here, all tables start from 0% and reach between 5% and 45% reduction at the end of the free negotiation phase. As previously pointed out in Fig 4a, the successful application to ANR and ERC funding programs increases some of the footprints, sometimes wiping out the efforts that have been made during the free negotiation (e.g. one game of the Environment virtual team in brown). Finally, the range of reduction after guided negotiation is narrowed down to a final average reduction of 44% and a median of 46%.

The variability between games is high, the less efficient groups of participants reducing by 25-30% their emissions, while the most efficient ones reach reductions close to 60%. Despite the variety of situations, the virtual reductions obtained during all games are promising and show that substantial opportunities for GHG emissions reduction exist within the academic world. The high variability between games suggests that the reduction does
not depend on the intrinsic characteristics of the twelve virtual teams (initial carbon footprint, distribution of motives, psychological profiles, etc.), but rather on the way participants of a game interplay through the ten characters they embody. To go further in the analysis, it is interesting to show the density distribution of the final relative GHG reductions, which is represented in Fig 5.

On this figure, no color clusters are observable, suggesting that the final GHG footprint of virtual teams are approximately evenly distributed. For example, among the twenty games of the “Society and Environment” virtual team (blue squares), there is one at each extreme (-27.5% and -62.5%): the final result therefore depends more on social interactions that have been created during the game between participants, than on the characteristics of virtual teams played. However, in addition to this observation, there is a threshold effect related to the target of -50% proposed to win the game: before this target, the distribution increases gently and gradually, whereas after -50%, it suddenly drops. The target seems to affect the result obtained so that, as long as the target is not reached, the participants imagine solutions to reduce by 50% their emissions, but as soon as the target is reached, there is no reason to do more than necessary. The distribution peak, observed for a value of 50%, seems to indicate that the motivation of the participants is highly driven by the objective to be reached.
Fig 5. Density distribution of the final GHG reduction. It synthesized data presented in Fig 4b, for the 85 game tables colored by virtual teams.

Another interesting aspect concerns the impact of additional fundings on the final GHG footprint. In Fig 5, games that did not receive additional fundings (i.e. additional GHG emissions) have an average reduction of -46.5%, logically beyond the ones that were overloaded by additional emissions. For games receiving additional fundings, the corresponding additional GHG emission average 12.8%. If participants were not influenced by these “penalties” the reduction of GHG emission should be around -33.9%, which is actually not the case. After the guided negotiation phase, the average GHG emission reduction was established at -42.8%. It means that corresponding participants made a substantial effort (+8.9%) to reduce their footprint and tentatively reach the targeted -50%
of reduction. It is worth noting that none of the games with additional funding overpasses the target, while 14 of the 64 games without additional fundings overpass the target.

c. Alternatives chosen and motives

The previous section indicates that the interaction between the participants and the resulting synergies predominate in the achievement of the reduction objective. However, are the alternatives chosen by the participants of the different games the same or, on the contrary, are they very diverse and dependent on the synergies specific to each game table?

To answer the question, the games were also analyzed and compiled to emphasize the alternatives selected by participants, in the nine categories detailed previously (Table 4) and categorized in Fig 3. Results are reported in Fig 6.
Fig 6. Repartition of the total GHG reduction by categories. The GHG reduction is, by average, 44% of the GHG initial footprint. The alternative categories are the ones expressed by participants and synthesised in Fig 3.

The predominant alternative (36.1%) is the use of video communication tools. It is followed by the mutualization of some professional activities (22.3%) and by voluntary cancellation or reduction of research activities (14.4%). Train (6.9%), relocation (4.9%) and duration extension of journeys (4.7%) contribute a smaller part to the total virtual reduction. Finally, local partners (3.0%), IT optimization of numerical calculations (2.0%) and others (2.2%) account for a small share of the virtual emission reduction. Overall, almost 80% of the reduction is achieved through four categories of alternatives. Reduction of the GHG footprint through the implication of “local partners” category is believed to be underestimated, probably as a result of mixing with the mutualization category. The relatively low effect of IT optimization is attributed to the small fraction of emissions from computer simulations present in the 12 virtual teams considered. At a global scale, IT optimization is probably much more important.

Fig 7 shows which alternatives were chosen for each of major research activities, their corresponding alternative proportion, and how much GHG emissions were reduced.
Fig 7. Absolute GHG reduction distribution. The reduction is subdivided by alternative categories depending on the emission motives: air travel to reach a conference, to meet for a project, for field trip, jury, for training, oceanographic campaigns, air travel for institutional meeting, cost of numerical computing, air travel to make an expertise, to access to a large unique instrument.

Video communication (blue bars) is an efficient factor to reduce GHG footprint for six emission motives, by replacing physical meetings for conferences, projects, juries (PhD, staff recruitment, etc.) as well as training, institutional and expertise meetings by some distant video interactions. Field trips (on the continent or at sea), which are highly contributing to GHG footprint, are most often mutualized.

In general, the alternatives are dependent on the motives. A diversity of alternatives are required to maximize the reduction, which emphasizes the complexity and richness of interaction between participants.
Fig 8. Distribution of the GHG emissions from the role-play initial balance to the selected alternatives and the final balance. On this Sankey diagram, the initial distribution of emissions can be seen, to which the emissions generated by the funded ANR/ERC projects during the game can be added. The initial distribution according to the motives can be seen in the centre of the diagram. On the right-hand side are the selected alternatives and the remaining emissions. The flow bands indicate the distribution between motives and selected alternatives.

Fig 8 shows in more detail the distribution of GHG emissions and pathways for reductions. The grey vertical bars and colored bands are proportional to the global GHG emissions for the 85 games considered. This Sankey diagram complements the information given in Fig 7. It becomes clearer why the total emissions from conferences are predominant: it is also the largest share of the initial distribution. Some motives appear to be
difficult to substitute, for instance intensive computing and sea cruises, while others seem easier to reduce, juries in particular.

d. Frequency, spontaneity and emission intensity

As the role-playing phase takes place in two sub-phases of 20 and 25 minutes each, it is interesting to look at the influence of the time when the tokens are replace for a given alternative. Three characteristics are particularly meaningful: first, the spontaneity of an action, i.e. the minimum time of appearance of the variable (motive or alternative); secondly, its frequency of appearance on all the games and finally its reduction intensity in kg CO$_2$e per token.

Fig 9. Spontaneity of the different alternatives sized by reduction intensity.
Fig 9 depicts the frequency of appearance of each alternative as a function of its spontaneity. The size of the bubbles is proportional to the reduction effectiveness of the alternative in kgCO$_2$e per token. Overall, four clusters of bubbles can be observed. First is the “video communication” alternative, which is very spontaneous (less than 10 minutes for its first appearance), very frequent (proposed by 95% of games) and rather effective. Cluster two includes three alternatives, namely “mutualization”, “cancellation” and “train”, which also come fairly early during games and remain fairly frequent but are unequally effective in reducing GHG emission, especially “train” which is rather low as it cannot substitute long-distance air travels. The following cluster is composed of the “duration extension” and “local partners” alternatives, which are proposed later and are less popular (around 25% of occurrence) but rather effective in terms of intensity of reduction. The last cluster includes “relocation”, “IT optimisation” and “others”. It arrives very late in the games, on average during the guided negotiation phase (after 30 minutes on average), is infrequent and unequally effective: “relocation” is the most effective alternative, while “IT optimisation” appears to be poorly effective.
**Fig 10. Spontaneity of the different emission motives removal.** It is sized by reduction intensity. The size of the bubbles is proportional to the reduction effectiveness of the motive removal in kg CO$_2$ equivalent per token.

Fig 10 represents the frequency of each motive removal as a function of its spontaneity. The participation in international conferences is globally the only motive to be withdrawn frequently (more than 95% of games played) and getting a high spontaneity (<10min). In contrast and logically, flight to access to “unique instruments” are the least frequently removed (just over 50% of game tables initially having them), which is understandable as it is the core of some research activities and cannot be substituted. Finally, IT optimization is less spontaneously mentioned (beyond 30 minutes of play).

The effectiveness of reduction, represented by the size of circles, is also rather variable, ranging from more than 1500 kg CO$_2$e per token for projects and conferences meetings, to less than 500 kg CO$_2$e equivalent per token for computing.
4. Discussion

a. Synergy during the games and influence of the target

According to Pohlmann et al. (2021)[23], the normalisation of climate-friendly behaviors in a given social group will not occur through the sum of individuals. Gamification thus often provides interactive spaces where reality can be experienced and transformed, which is a rich basis for knowledge creation (Kolb, 2014[24]).

Our study shows that most of the variability of the results can broadly be explained by two independent factors: the synergy that was created between the participants during each game and the target that is given to win the game (in our case -50% of GHG footprint). As far as synergy between participants is concerned, an in-depth anthropological and sociological work would be needed to assess the brakes and leverages to GHG footprint reduction (Whitmarsh et al., 2020). An in-depth analysis of this hypothesis in this study goes beyond our scope but is a key perspective for further analysis of the data collected during the games.

Focusing on a more quantitative analysis, some interesting elements can be deduced from final GHG footprints (Fig 5). In this figure, the density distribution shows an asymmetry, which corresponds to a threshold effect: below 50% of reduction, the game tables are distributed rather gradually, but once the objective is reached, the density distribution suddenly drops. Thus, as long as the objective is not reached, the participants make all the efforts they can and as soon as the objective is reached, the participants stop making efforts. The question then arises whether setting a target of 75% would also result in this threshold effect with an average reduction slightly below the target. We may hypothesize that a reduction of 50% finally remains acceptable and reachable, but a target at 75% would probably discourage participants and require more profound and systemic changes of the academic sector practices. It is worth noting that the final reduction was
about 45% (mean and/or median) which is believed to be a positive signal for reaching significant reduction of GHG emission in real life.

b. Frequency, spontaneity and effectiveness of alternatives

Here, our interest was to identify how to articulate the emission motives and the alternatives, as expressed in Fig 8, in order to build realist scenarios for reducing the carbon footprint of the academic world. In order to analyze the reduction choices made by the participants, it was decided to focus the study's attention on specific characteristics. To do this, it is important to understand which emission motives are favoured for reduction and towards which alternatives by looking at the frequency, spontaneity, effectiveness and efficiency of these choices (Figures 9 and 10). However, passing from the virtual space of a role playing game to the real world of research, may introduce unexpected difficulties due to the current functioning of research, which promotes individual performance and competition (van Dalen, 2021[25]) instead of building bridges toward global sustainability (Irwin et al., 2018[26]).

Our results showed that 80% of the GHG reduction was possible thanks to four alternatives, namely video communication, mutualization of means or activities, cancellation of activities and lower carbon emission transportation (train). The use of video communication is the most spontaneous and frequent proposal, which enables the greatest reduction (16.2%), because it can be adapted to a large number of activities, with the notable exception of field/sea campaigns. The spontaneity and efficiency for video communication have probably been propelled by the COVID-19 pandemic crisis that has recently imposed such means of communication due to lockdowns and remote working (Nguyen et al. 2020[27]). Video communication practice had however already been raised within the scientific community as an alternative to conferences (Jordan and Palmer, 2020[28]). Nevertheless, the advantages and disadvantages of virtual conferences are debated. Another suggested option is to attend
conferences in person, but to be more selective (see below, cancellation). The second option is the mutualization of activities or means, which also leads to a strong overall reduction of GHG footprint (10.0%) by combining several field trips of different purposes or by delegating specific tasks to limit the number of participants during field/sea campaigns. Yet, experts of oceanographic campaigns consider that a reliable mutualization of onboard activities is an uneasy task. In real life, one can anticipate non-negligible organizational obstacles and an expected resistance of researchers and their stakeholders (community, hierarchy, partners) for such suggestions. While grouping several activities on a personal basis is not excessively complex, mutualization between colleagues requires a high degree of communication, preparation and trust. At present, mutualization is not sufficiently recognized by academic institutions to become popular, in view of the time required and the risks involved for careers, in case of failure of uneasily rescheduled campaigns. According to Shove and Walker (2014)[29], individual actions are embedded in institutional, social and infrastructural frameworks, which ensure that climate-damaging behaviors remain the norm. The academics need to be proactive to shift these norms through more mutualized and frugal research. The third alternative concerns cancellation or rationalisation of research activities. It is by nature very simple to be done technically, but seems to be over-represented in our results. The main limitation is the psychological acceptance by participants, in link with social habits and pressures (Gifford, 2011[30]). The lack of institutional recognition of the efforts made and risk-taking by researchers in the case of a cancellation or drastic reduction of field/oceanographic surveys seems also to be a limitation. It is the same in the case of limitation to in-person meeting participation. As long as the carbon quota or any other indicator, based on the sustainability of activities, is not put in place by academic institutions, reducing one’s activity brings at best a saving of time and an improved work-life balance, at worst, a devaluation of research performance and researcher’s recognition. An in-depth analysis of costs and benefits for the society should be
considered. The fourth alternative is train travel, which is often mentioned in the literature as a solution for decarbonizing research. However, train travel quickly reaches its limits in the sense that it is neither easily accepted to take the train if several train changes are required or heavy/cumbersome equipment needs to be transported. Trains cannot substitute long-distance air travel. For most regional activities however, train is even very efficient (Ciers, et al., 2019[31]). The train must thus be promoted both as an efficient practice on a regional scale, and as a marker of change in our practices.

The remaining 20% of the reduction is made up of solutions that occurred less frequently and were less spontaneous, but which can compensate for the limitations of the first four. Relocation, coupled with the use of train, is thus very efficient as it directly addresses long-distance air travel, particularly for conferences. The extension of the mission duration is similarly very interesting but is proposed more specifically for field trips or sea cruises which allow for more expatriation. Local partners and expatriation are specific to some research groups and thematics. Reducing the corresponding GHG footprint will require first understanding people’s beliefs, values and norms, second to engage in depth discussions between all actors and policy makers to break psychological and other limits (Gifford, 2011).

Regarding the emission motives, they are globally withdrawn from the playmat in proportion to their initial distribution within the eighty five tables. Conferences are naturally removed the fastest and most often, but this should not overshadow the other motives for the teams’ emissions, as is often the case in scientific works that consider conferences for the most part. However, this raises the question of the acceptability of replacing a conference with a videoconference or cancelling it, and the valuation of conferences in the research indicators. There are also many motives that can be played on. Indeed, one motive in particular is over-reduced: thesis juries, essentially carried out by videocommunication, for which there is a greater propensity to reduce activity, with a gain in personal life quality.
Conversely, certain motives are under-represented, like oceanographic surveys, intensive computing or travel for the use of unique instruments, as they are specific to the activity of the research labs and so more difficult to reduce, which may explain the lower spontaneity and frequency for the latter two.

c. Steps and timetable for achieving the -50% target by 2030

The key point now is to consider how to transform the virtual pathways of GHG, expressed during the role play phase, into real measures. In the virtual format, participants detach themselves from their emotions but have the difficult task of projecting themselves into the skin of a fictional character. Some participants may find it difficult to make this change of posture and to become imbued with the personal motivations, posture and convictions of the embodied characters. The difficulty is even greater when each participant plays two characters, and when these characters’ behavior and profile are different from their own (for instance when a PhD student must play a senior researcher). The complexity therefore lies in knowing to what extent the proposals emanating from fictional discussions can be directly transposed into the everyday life of an actor in the academic world. Nevertheless, no justification could discredit an alternative a priori. It is still necessary to encourage their implementation in order to judge their acceptance in the framework of a functional research group. Two main directions for their implementation can be distinguished:

First, promoting and recognizing the efforts made by individuals to reduce one's GHG footprint would be a preliminary step. One point that came up several times in the discussions during the debriefing phases was the importance of indicators of academic performance. Indeed, the current indicators encourage productivity and do not take into account the social and ecological impact of research and education activities, in particular in terms of GHG footprint. It seems inappropriate to keep the same evaluation criteria for academia in the
context of the socio-ecological transition. We know that conferences play a major role in the
dissemination of work and the construction of a professional network. They are all the more
important for young researchers compared to senior ones who have already obtained
permanent positions and built up their network. Nevertheless, it is the latter who travel the
most to participate in international conferences (Wynes, 2019). The evolution of indicators
and evaluation criteria therefore appears to be a relevant option for taking better account of
criteria compatible with global limits.

The second option is for the functional teams to take control of the results. The digital
interface used during the role-playing phase of MaTerre180’ constitutes a powerful tool for
developing new techniques of communication and negotiation between peers. We can
imagine that some research groups could take advantage of this TSS to experiment with
various strategies of research projects and define the ones that best balance benefits for
society and sustainable GHG footprint.

In their exhaustive review, Flood et al. (2018)[32] reported various climate related
games or role playing focusing on water management, long term farming or risk disasters; but
none of them was dedicated to the academic world and its non-negligible GHG footprint.
Knowing the peculiar role of scientists in Society, we may hope that the use of a tool such as
Ma Terre en 180’ could accelerate a shift in the scientific community and provide a persuasive
argument for a broader shift in other sectors.

Transition support system could certainly facilitate the transition, but this will depend
on our capacity to follow at least two recommendations (Galeote et al., 2021): first, it is
important to promote interventions in emerging and developing countries and to extend the
target to young students and more social, political, and economic actors. Secondly,
gamification and TSS techniques should be massive and lead to large data series in order to
get statistically robust and unbiased scenarios of reduction. Some collaboration with widely
distributed research institutions, could favorably help for reaching these recommendations.
5. Conclusion

The authors of this study are convinced that the state of scientific knowledge on the current and coming social and ecological crises, caused or enhanced by global warming, is not enough to bring about a systemic and rapid change that is commensurate with the issues at stake (Hulme, 2020). In this context, the academic world is not an exception and must act and embody changes (Attari et al., 2016; Whitmarsh et al., 2020). For that purpose, authors created a game-based TSS, Ma Terre en 180 minutes (https://materre.osug.fr/), to build scenarios of GHG emissions reduction in the academic community. The TSS has been deployed during the year 2021 with around 600 participants. The analysis of all the games played is encouraging and expresses clear pathways for reductions: the range of GHG reduction at the end of the game-played phase is between 25 to 60% with a median reduction of 46%, independently of the virtual research team played and given a target of 50% reduction. This result highlights that, virtually, the objective of 50% of GHG emission reduction in 2030 is reachable for the academic world.

More in-depth analyses were conducted in order to understand the dynamics of reduction, the remaining obstacles to endorse a reduction strategy, and to spark all ideas about possible alternatives. The alternatives allowing the greatest reduction are the video communication tools (36%), followed by the mutualization of the professional activities and the voluntary cancellation or reduction that represents 22 and 14% of reduction, respectively. The remaining 28% of reduction is composed by the use of trains as a transport alternative, the relocation of professional activities, the duration extension of some missions, the optimization of the information technology and other marginal ideas. Our results also confirm the necessity of alternatives adapted to specific research activities: the most effective tool to
reduce the GHG emissions from conferences, projects and juries is, as expected, the video communication tool whereas mutualization and duration extension are the most important alternatives for field trips. The initial footprint of the research activities explain the dominance of some activities to the total emission that remains even after the game phase (like conferences). It also shows the small part of cancellation in the GHG emission reduction from the different categories, except for conferences, and thus shows the relatively easy way for the academics to reduce their emissions without tremendously affecting their research activities. Finally, the analyses of all the game dynamics, i.e. when, which and how often the alternatives are proposed, show some obstacles to use some types of alternatives and the necessity to have a person that guides the discussion (second part of the game phase): relocation, local partners and computing optimization need more guided discussions than individual choices of video communication, and free discussion for mutualization.

Diverse game reviews from the last decade show that the tendency of gamification has only grown in recent decades (Reckien and Eisenack, 2013[33]; Flood et al., 2018; Galeote, 2021). However, to the best of our knowledge, this is the first time that such a role-playing game is deployed and used to determine the possible scenarios to reduce GHG emissions in the academic world. Gamification is relevant because it allows participants to fail with low consequence (Plass et al., 2015[34]). Some further session of MaTerre180’ need to be performed in order to consolidate the results and explore the participants sociological synergies during the workshops: changing the 50% target of GHG emission reduction, using virtual teams exploring other field of research, adding other kinds of virtual characters, incorporating the purchases (consumables, materials and equipments) into the initial carbon budget, etc.. Additionally, deploying MaTerre180’ at different scales and within varied academic contexts (universities vs. national research institutes, students vs.university staff) will help to tackle possible biases. Last but not least remains the transition between virtual
and real world, i.e. to find the method to adapt the scenarios imagined with the virtual game-based tool into the real world of academic research. This probably requires the participation and involvement of the institutional governance of research organizations.

6. Material and methods

a. Ethics statement

All aspects of the experimental procedures were reviewed and approved by the “scientific board” of the French National Research Institute for Sustainable Development (IRD-France, approval n° D2S-2022-002. All participants gave consent to the facilitators prior to their participation: once the online session was opened, the facilitator of each table asked to each participants of the workshop for the right to record the videos as a source of raw data for further non-profit research. When the agreement was not obtained for all individual participants, the session was not recorded and the corresponding table was not considered for further analysis. When the agreement was obtained the session was recorded and the facilitator notify it by signing a letter agreement. We do remind that each participants role-play two fictive characters; no personal information on individuals were collected, only on the actions of their fictive characters during the game.

b. MaTerre180’, a game-based participatory tool

MaTerre180’ is a Transition Support System organized in four distinct phases, through which an academic institute/group will seek to change the organisation of its academic work to reach a target GHG emission reduction. Fig 1 summarizes the timeline. The deployment of MaTerre180’ lasts 180 minutes (+ a 30 minutes debrief time). It runs over two half-days, to help the participants gain sufficient introspection and encourage their cognitive engagement.
As an adaptation to the COVID pandemic, MaTerre180' has been designed to be deployed online, which proved to be particularly useful for the massification and the digitization of this game-based approach.

In this paper, the analysis focuses only on the role-playing phase of the MaTerre180' workshop (phase 3 in Fig 1).

Each MaTerre180' individual workshop gathers a facilitator, (four to) six participants, one of them playing the role of team leader, and an advisor.

**Fig 1. Timeline of the MaTerre180' Transition Support System (TSS).** Each workshop is composed of four phases to raise awareness (phase 1), make some introspection (phase 2), participate to a role-playing serious game (phase 3) and debrief about results and postures (phase 4).

**Phase 1: the awareness-raising phase.**

This first phase intends to build a common background on the topic among participants, and to offer them the opportunity to know each other, a key prerequisite before the further discussions and negotiations. Phase 1 is based on a set of documents containing general ecological statements: the crossing of four of the nine global limits (Rockstrom et al. 2009[35]...
and the theory of the doughnut economy (Raworth, 2012[37]). Then follows a more specific section on climate change, with an overview on global temperatures (https://showyourstripes.info/) and their possible evolution in France (Bador et al, 2017[38]). The rest of the awareness-raising documents deal more specifically with the academic world, presenting the carbon footprint of some French research groups (IGE, ISTerre and LOCEAN), the impact of some research activities at the individual scale (Berthoud et al., 2019[39]) and the results of the survey on academic practices and awareness "Les personnels de la recherche face au changement climatique" conducted by Labos 1point5 (Labos 1point5, 2020[40]). Emerging initiatives in some French research groups are then presented. The awareness-raising phase ends with a debrief time for sharing feelings, reactions, personal experiences and opinions through discussions. The next phases of MaTerre180’, including the role-playing phase, are also introduced during this first ninety minutes session.

**Phase 2: the intersession phase.**

Participants are invited, in the few days between the two sessions, to calculate their personal carbon footprint with an open access simulator (https://avenirclimatique.org/micmac/simulationCarbone.php). They also familiarize themselves with the two characters (char.) they will play during the role-playing (i.e. game-based) phase, each related to a technicien, researcher, or professor profiles (see below).

**Phase 3: the role-playing phase.**

During the role-playing phase, five out of the six participants play the roles of two different characters resulting from a fictitious research group. The sixth participant takes on the role of team leader, which will be detailed hereafter.

Up to now, twelve virtual research teams, each composed of ten characters, have been designed to simulate groups working on distinct topics with distinct approaches (laboratory
experiments, numerical simulations, field surveys...). Each of them has its own characteristics and has been inspired from a real research group.

Their full description is available at [https://materre.osug.fr/-Les-jeux](https://materre.osug.fr/-Les-jeux). Table 1 lists the different virtual teams available so far, the team’s initial GHG footprint and some keywords related to the scientific topics addressed.

Table 1. List of the 12 available virtual teams with their characteristics.

<table>
<thead>
<tr>
<th>Name of the virtual team</th>
<th>Initial GHG footprint (sum in tCO$_2$e/year for ten characters)</th>
<th>Topics and keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climatology</td>
<td>42.0</td>
<td>Climate change, local field studies, glaciers, snow science</td>
</tr>
<tr>
<td>Geophysics</td>
<td>62.0</td>
<td>Earthquakes and volcanoes, near and far field studies, databases, modelling</td>
</tr>
<tr>
<td>Earth Dynamics</td>
<td>43.5</td>
<td>Near and far field studies, geochemistry, partnerships with southern countries</td>
</tr>
<tr>
<td>Environment</td>
<td>48.0</td>
<td>Environmental sciences, geochemistry, mineralogy, unique instrument, near and far field studies</td>
</tr>
<tr>
<td>International Joint Laboratory</td>
<td>78.0</td>
<td>International laboratory, partnerships with southern countries (e.g. in South-eastern Asia), oceanography campaigns, numerical</td>
</tr>
<tr>
<td>Field</td>
<td>Rating</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Society and environment</td>
<td>68.0</td>
<td>Sociology, anthropology, ecology, near and far field studies, collaborations with Southern partners</td>
</tr>
<tr>
<td>Ocean &amp; Climate</td>
<td>70.0</td>
<td>Oceanography, high sea missions, high performance computing</td>
</tr>
<tr>
<td>Computer science (Informatics)</td>
<td>58.0</td>
<td>Parallel programming, artificial intelligence, image processing</td>
</tr>
<tr>
<td>Water Resources</td>
<td>63.0</td>
<td>Hydrology, critical zone, field studies (e.g. in Patagonia), with strong partnership with European partners (e.g. France and Germany)</td>
</tr>
<tr>
<td>Development &amp; Environment</td>
<td>53.0</td>
<td>Near and far field studies</td>
</tr>
<tr>
<td>Air quality</td>
<td>61.0</td>
<td>Geochemistry, near and far field studies, biological and chemical analysis</td>
</tr>
<tr>
<td>Technology &amp; transition</td>
<td>63.0</td>
<td>Automation, signal processing, control</td>
</tr>
</tbody>
</table>

During phase 3, each participant received two cards describing his/her fictive characters' and their respective activities. The set of 10 characters per virtual team includes senior and junior permanent researchers, PhD and postdoc students, engineers, technical and
administrative staff. Their links with the other team members, their academic reputation and
lastly, their "ecological awareness profile" (EAP). There are five types of EAP, ranging from a
person fully concerned about climate change and already involved in collective actions
(profile "Time for actions"), to someone considering that his/her career and duties justify a
high carbon footprint (profile "I make the difference"). A game facilitator is in charge of
animating the game, and an advisor (ideally chosen outside of the academic community)
brings his/her external vision on the discussions and comments on the final results of the
negotiations. In total, eight people are involved during the role-playing phase: the game
facilitator, five participants that embody the 10 characters, one participant acting as team
leader and one adviser, which ensures rich and open-minded social interactions. In case of
registered participants not showing-up during the role-playing phase (or unable to attend),
the game can be played with down to four participants (instead of six), with some participants
playing up to three characters and the team leader. Tokens, with a surface area proportional
to the GHG emission (Table 2), visually represent the carbon footprint of various activities,
each of them being symbolized by a specific icon.

Table 2. Token sizes, related CO\textsubscript{2}e emissions and corresponding characteristics of emission
sources considered so far (Mariette et al., 2021). Details on tokens can be found in appendix A.

<table>
<thead>
<tr>
<th>Token Size</th>
<th>CO\textsubscript{2}e emissions (in kg)</th>
<th>Characteristics of emission sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>20</td>
<td>● 500 km journey by train</td>
</tr>
<tr>
<td>Medium</td>
<td>100</td>
<td>● 500 km journey by car</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● 2500 km journey by train</td>
</tr>
<tr>
<td>Large</td>
<td>500</td>
<td>● Short and medium-haul journey by plane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● 300,000 hours of CPU calculation</td>
</tr>
</tbody>
</table>
The activities considered in the different virtual teams available so far are listed in Table 3. They will be further referred to as “emission motives”.

Table 3. Emission motives considered in the 12 virtual teams available so far

<table>
<thead>
<tr>
<th>Emission Motives / Scientific activity</th>
<th>Description</th>
<th>Icon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conference</td>
<td>Travel to a conference or workshop</td>
<td>🗻</td>
</tr>
<tr>
<td>Jury</td>
<td>Travel to be part of a jury (thesis, accreditation to supervise research, recruitment)</td>
<td>🎓</td>
</tr>
<tr>
<td>Institutional meeting</td>
<td>Travel related to meetings in the field of research organisation</td>
<td>📈</td>
</tr>
<tr>
<td>Project meeting</td>
<td>Travel related to the setting up of projects and their implementation</td>
<td>🔄</td>
</tr>
<tr>
<td>Field trip</td>
<td>Travel to acquire field data on a specific area</td>
<td>🏝</td>
</tr>
<tr>
<td>Instrument</td>
<td>Travel and use of (very) high technology and unique scientific instruments (e.g. particle collider)</td>
<td>🛠️</td>
</tr>
<tr>
<td>Expertise</td>
<td>Travel related to consultancy for a state, an NGO, etc.</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Training, capacity building</td>
<td>Travel for teaching, capacity building and summer school etc.</td>
<td></td>
</tr>
<tr>
<td>Oceanographic campaign</td>
<td>Campaign at deep-sea or coast for measurements</td>
<td></td>
</tr>
<tr>
<td>Computing</td>
<td>Modelling using high performance computing facilities</td>
<td></td>
</tr>
</tbody>
</table>

The role-playing phase is described in Figures 1 and 2. It takes place in three sub-phases: a free negotiation phase (20 min), a phase of publication of results of research funding applications (about 10 min), and a guided negotiation phase (25 min).
Fig 2. Digital interface used during the role-play phase. Example for the geophysics research team. The upper left hand panel is the bank of tokens, the lower left hand panel is the project’s related tokens, the right hand panel is the area for low carbon alternatives. All research teams’ interfaces are freely available from http://51.178.55.78/MT180/mt180.htm (the digital interface is coded in javascript).

During the “free negotiation” sub-phase, the virtual characters played by the participants discuss how to reduce by half the GHG footprint of their virtual research team. Each decision leads to an action: the game facilitator moves tokens on the virtual play mat, in or out of the game board and writes down the suggested alternatives through the digital interface (Fig 2). Tokens can be substituted by others of smaller sizes, for instance if an intracontinental (or domestic) travel by plane is substituted by a train journey. All proposed alternatives are eligible as long as they are accepted by the game facilitator, and co-opted by the participants and the advisor. The free negotiation phase ends by a short debriefing (5-10 minutes) during which the mid-term GHG footprint is presented by the advisor. The advisor also comments on the negotiations, shares his/her feelings and motivates the team to go beyond the efforts already undertaken.

The funding application sub-phase then begins. Before the free negotiations sub-phase, the characters were given the possibility to apply for French (ANR) or European (ERC) research funds. Each application has a $\frac{1}{6}$ probability of being awarded, close to the current real life situation in France. Handling such projects implies additional travels that were estimated at 4.0 and 8.0 tCO$_2$e per year for French (ANR) and European (ERC) projects, respectively. During the research funding application sub-phase, the results of the applications are published and presented by the facilitator. The success (or failure) of project application is determined by simply rolling a digital dice. Additional tokens are then granted
to the successful characters for each awarded project and displayed on the playmat, so that
the GHG footprint of the team is increased.

Thirdly, the “guided negotiation” sub-phase led by the team leader takes place. He/she
manages the negotiation phase as a research group leader and is free to choose his/her
management strategy (authoritarian, consensual, persuasive...). This guided negotiation
phase is also timed and lasts 25 minutes. At the end of the three sub-phases, the final GHG
footprint is presented and a debriefing period starts.

The objective for the team is to perform their research while reducing the carbon
footprint of their virtual team to a given target of fifty percent (50%). In MaTerre180' TSS, the
role-playing phase allows participants to put their own research activities and professional
constraints into perspective. Working in groups stimulates context-specific abstraction and
active experimentation (Morris, 2020[41]).

Phase 4: the debriefing phase.

This last 30-minutes phase closes the workshop. During the debriefing phase, the advisor
gives his/her opinion on the suggested alternatives, on the way the characters were played
and on the highlights of the role-playing phase. The team, the facilitator and the advisor come
back to the highlights, share their opinions on the game-based phase and discuss the
relevance and robustness of the proposals made to reduce the research team GHG emissions.

c. Database management

The role-playing can take place in a classical – i.e., physical – way around a table with
all the material previously prepared (game board, character cards, tokens). The role-playing
can also be performed online on an open access digital interface (Fig 2 and
http://51.178.55.78/MT180/mt180.htm).
In the digital interface, game information is recorded automatically. Each action (e.g., removing a token) is associated with the name of the character to whom the token belongs, the motive for the removal of the token and its value in kg CO$_2$e. Some additional information concerns the phase of negotiation (free or guided) during which the action was played, and whether the token was attributed as a success to a research project application (ANR or ERC projects), the name of the alternative to which the token was moved, the reduction in kg CO$_2$e induced by this alternative and the time in seconds at which the token was last moved.

Each record is then concatenated in a database to group together all the games that have been played. Four meta information are thus added to identify individual games. Lastly, the category of the alternative (see section on “alternative categorization” below). The database obtained is then cross-referenced with another one containing information specific to each virtual team as described in section II A (initial CO$_2$ balance, characters, psychological profiles, etc.) for further analysis. This makes it possible, for example, to analyse the results by table, by character, by sessions of the workshop, or by alternatives, in order to pay attention to specific points and decision processes.

d. Alternative categorization

As mentioned above, the suggested alternatives that emerged were expressed freely by each individual participant. They cover a rich and varied lexical field that had to be categorized in order to analyse them. These alternatives (translated in the appendix B from French to English) were classified in nine categories that were neither too general nor too specific in order to obtain a fair balance in the information provided. This categorization stems from reading the recorded games by some experts, which consequently involves a degree of subjectivity. Categories are described in Table 4.
<table>
<thead>
<tr>
<th>Alternative category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video communication</td>
<td>All telecommunication activities between people, whether or not there is interaction. This includes video conferencing/communication, teleworking, e-learning such as Massive Open Online Courses (MOOCs), webinars, etc.</td>
</tr>
<tr>
<td>Mutualization</td>
<td>Pooling of a large diversity of activities. It includes the use of the terms: mutualization, merging, combination, pooling, association, grouping, etc.</td>
</tr>
<tr>
<td>Reduction/cancellation</td>
<td>Covers voluntary reduction of activity. It includes the words: cancellation, deletion, reduction, halving, etc.</td>
</tr>
<tr>
<td>Train / public transportation</td>
<td>Contains all plane or car trips replaced by train, long-distance buses and all types of public transportation.</td>
</tr>
<tr>
<td>Relocation</td>
<td>Brings the location of an activity at a closer distance, for example by preferring regional conferences or local field areas. This can be associated with the use of public transportation. The words used by participants can be: relocation, bringing closer, regional, local, etc.</td>
</tr>
<tr>
<td>Duration extension</td>
<td>Includes extension of the time spent on-site after travelling to avoid returning to the same place several times, or combination of several missions. Can sometimes be related to mutualization. This includes the terms: extension, expatriation, prolongation, long, duration, etc.</td>
</tr>
</tbody>
</table>
IT (Information Technology) optimization

Any solution that aims at reducing the energy consumption of intensive calculations, for example by making the codes less complex and/or better optimized. It covers the words: calculation, optimization, computing, data, etc.

Other

Includes some hardly classified alternatives and some original but infrequent ones. For example, the use of sailing boats for missions at sea, volunteer work or carbon offsetting inspired by Miyawaki forest restoration methods, etc.

Local Partners

Explicitly cite some local partners from foreign countries to mutualize some activities

---

e. Studied parameters

i. Trajectories of the different games, in terms of GHG footprint

For each game, we look at the evolution of its GHG footprint according to the modifications (increase or reduction) of the absolute quantity of emissions $Q^i_j$ in tCO$_2$e, where subscripts refer to each specific sub-phase $j$ and superscripts to the individual game number $i$

Here, the potential emissions added or removed during the game, linked for instance to new funded projects or to behavioural changes are taken into account in $Q$(e.g. using train instead of aircraft for a domestic journey both introduces several tokens of 20 kgCO$_2$e for the train, the number depending on the distance, and removes the 500 kgCO$_2$e token for the plane).
• Initial time \((j = 0)\): the initial carbon footprint of the virtual team is equal to the initial GHG emission assigned to each game (see Table 2):

\[
CF \quad ^i_0 = Q \quad ^i_0
\]

• After the free negotiation phase \((j = FN)\): the new carbon footprint \(CF \quad ^i_{FN}\) is obtained by subtracting the emission reductions \(Q \quad ^i_{FN}\) that were proposed during the free negotiation phase

\[
CF \quad ^i_{FN} = Q \quad ^i_0 - Q \quad ^i_{FN}
\]

• After results of ANR/ERC project calls \((j = ANR/ERC)\): depending whether research projects are granted or not, an emission surplus \(Q \quad ^i_{ANR/ERC}\) can be added to the carbon footprint before the guided negotiation phase:

\[
CF \quad ^i_{ANR/ERC} = Q \quad ^i_0 - Q \quad ^i_{FN} + Q \quad ^i_{ANR/ERC}
\]

• After the guided negotiation phase \((j = GN = f)\): the final (index \(f\)) carbon footprint is calculated by subtracting the additional emission reductions \(Q \quad ^i_{GN}\) suggested

\[
CF \quad ^i_{GN} = CF \quad ^i_{f} = Q \quad ^i_0 - Q \quad ^i_{FN} + Q \quad ^i_{ANR/ERC} - Q \quad ^i_{GN}
\]

These absolute \(CF\) can be converted into a cumulative relative reduction \(R\), for the corresponding phase \(j\), using:

\[
R \quad ^i_j = \frac{CF \quad ^i_j - CF \quad ^i_0}{CF \quad ^i_0}
\]

ii. Alternatives and motives: frequency, spontaneity and intensity of reductions

We also consider the amount of CO\(_2\)e avoided from the emission motive \(m\) to the alternative \(a\). This allows us to describe in more detail pathways of GHG reductions for each emission motive and thus to deduce the total amount of GHG avoided by each alternative. It
will also help to describe whether the emission motives are removed to alternatives or retained in the final GHG footprint of the team.

We define the frequency of a given alternative (see Table 4) as the ratio between the number of games that have used this alternative and the total number of games. For motives (Table 3) a weighted calculation of the frequency of appearance is applied, since games present various initial types and numbers of activities.

Then, the spontaneity of the alternative (respectively motive) preferentially chosen (respectively removed) is defined as the minimum time before it first appears (respectively, is removed) in the game. This minimum time is then averaged for each variable to deduce its average spontaneity.

Finally, we are interested in the GHG reduction intensity caused by an alternative or motive, i.e. the ratio between the total absolute reduction and the number of tokens moved. This allows us to estimate the ability of an alternative or the reduction motive to decrease the team’s GHG footprint more or less efficiently. Thus, the more this ratio tends towards 3000 kg CO$_2$e per token (activity of maximum CO2 emission for X-Large token, as presented in Table 2), the more efficient the variable considered is, in terms of reduction intensity.

7. Competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this article.

8. Credit authorship contribution statement

9. Acknowledgments

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10. References


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11. Supporting information

S1. Details on tokens and characters of the "geophysics" research team.

The twelve research teams follow the same template
**Details of character cards (typologies)**

<table>
<thead>
<tr>
<th>Recognition</th>
<th>Psychological profile of character</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I make the difference</strong></td>
<td>Leader in his community, an active and structuring member, who can (or must) think that his dynamism escapes him from the everyday. He/she believes in technology to get us out of the climate read.</td>
</tr>
<tr>
<td><strong>What's the point?</strong></td>
<td>Rather follows. Sensitive to environmental issues, but positive. What’s the point? If all other countries do not get involved, the efforts will be in vain.</td>
</tr>
</tbody>
</table>

**Scientist:**
- Bibliometry, h_i grade, etc.

**Teacher Researcher:**
- Science + Courses

**ST/SA:**
- Skills recognition by peers

**Activist**
- Concerned: Aware of the climate emergency. He/she has started to question his practices, but not sure where to start.
- Calibr: Every single drop: Sensitive to environmental issues, and involved in practical and conscience changes.

**Function**
- Env. and Society

**Ethnologist**
- Area of research: France

**Ecological profile**
- 2000 km
- 500 km

**Teacher**
- Field mission, on large instruments or in other labs
- Measurements, data collection, surveys, etc.
- Institutional: Meeting, in the field of research and its organization.
- AMR member, etc., project review, specialist commission
- Jury
- Thesis defence, recruitment, jury, HDR
- Expertise
- For a NGO, a state, etc. Scientific application.

**Travel goals**
- Conferences, International workshops
- Formations en présentiel, Ecoles d’été, rft capacités
- Setting up (and monitoring) of projects
- Meetings (co-writing, monitoring, feedback including conferences)

**Other emitting activities**
- Sea missions
- Modelling

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**Comment**

- I used to think I'd never make it back to life with long-term field trips to work near my home, to an accessible field a few hours from the lab. Another field?
<table>
<thead>
<tr>
<th>Expressed alternative by recurrence (in french)</th>
<th>Expressed alternative (translated in english with DeepL ©)</th>
<th>Categories of alternatives</th>
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<tr>
<td>visio</td>
<td>videoconference</td>
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<td>thesis jury made in visio / conference in visio</td>
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<td>replacement plane by train</td>
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<tr>
<td>avion vers train</td>
<td>plane to train</td>
<td>public transportation</td>
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<tr>
<td>avion &gt; train</td>
<td>plane -&gt; train</td>
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<td>regroupement dépalcement</td>
<td>grouping of depalletment</td>
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<td>mutualisation cotutelle thèse</td>
<td>pooling of thesis co-tutoring</td>
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<td>fusion de mission</td>
<td>merger of missions</td>
<td>mutualization</td>
</tr>
<tr>
<td>je ne vais pas à la conf (David y va)</td>
<td>I don't go to the conference (David goes)</td>
<td>mutualization</td>
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<td>missions regroupées</td>
<td>grouped missions</td>
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<td>mutualisation avec collègue</td>
<td>mutualisation with colleague</td>
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<td>mutualisation et délégation</td>
<td>mutualisation and delegation</td>
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<td>mutualisation formation terrain</td>
<td>mutualisation of training in the field</td>
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<td>coupler</td>
<td>coupling</td>
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<td>moitié présentiel moitié distanciel</td>
<td>half face-to-face and half distance learning</td>
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<td>deux missions en une</td>
<td>two missions in one</td>
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<td>choix doctorant ou encadrant</td>
<td>choice of doctoral student or supervisor</td>
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<td>mutualisation pour une conférence</td>
<td>pooling for a conference</td>
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<tr>
<td>regrouper les missions</td>
<td>group the missions together</td>
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<td>plusieurs présentations sur meme conférence</td>
<td>several presentations at the same conference</td>
<td>mutualization</td>
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<tr>
<td>mise en commun formation</td>
<td>pooling of training</td>
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<td>représentation autre collègue</td>
<td>representation of other colleagues</td>
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<tr>
<td>mutualisation avec collègue/visio</td>
<td>pooling with colleague/visio</td>
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<tr>
<td>en meme temps qu'une conférence</td>
<td>at the same time as a conference</td>
<td>mutualization</td>
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<tr>
<td>combiner 2 terrains</td>
<td>combining 2 fields</td>
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<tr>
<td>avec le post doc sur le terrain</td>
<td>with the post doc in the field</td>
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<td>étudiant présentant les résultats</td>
<td>student presenting results</td>
<td>mutualization</td>
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<td>héloise le représentera</td>
<td>héloise will represent him</td>
<td>mutualization</td>
</tr>
<tr>
<td>French</td>
<td>English</td>
<td>Reductions</td>
</tr>
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<td>------------------------</td>
<td>----------------------------------------------</td>
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<td>mission réalisée par étudiant</td>
<td>mission carried out by student</td>
<td>mutualization</td>
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<td>mutualisation personnelle</td>
<td>personal sharing</td>
<td>mutualization</td>
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<td>optimisation des activités</td>
<td>optimisation of activities</td>
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<tr>
<td>rester plus longtemps sur place</td>
<td>stay longer on site</td>
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<td>le post doc assure le remplacement</td>
<td>the post doc provides a replacement</td>
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<td>regroupement de missions</td>
<td>grouping of assignments</td>
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<td>reorga des terrains</td>
<td>reorga of land</td>
<td>mutualization</td>
</tr>
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<td>vers julien</td>
<td>to julien</td>
<td>mutualization</td>
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<td>annullation</td>
<td>cancellation</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>suppression</td>
<td>cancellation</td>
<td>reduction cancellation</td>
</tr>
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<td>annulation 1 conf internationale/personne</td>
<td>cancellation 1 international conference/person</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>supprimer</td>
<td>delete</td>
<td>reduction cancellation</td>
</tr>
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<td>annulé ?</td>
<td>cancelled!</td>
<td>reduction cancellation</td>
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<td>suppression conférence</td>
<td>deletion conference</td>
<td>reduction cancellation</td>
</tr>
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<td>réduction activité</td>
<td>reduction of activity</td>
<td>reduction cancellation</td>
</tr>
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<td>renseigner aux dépalcements</td>
<td>no more depalitising</td>
<td>reduction cancellation</td>
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<td>moins de simulations</td>
<td>fewer simulations</td>
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<td>restriction activité</td>
<td>activity restriction</td>
<td>reduction cancellation</td>
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<td>réduction nb conférences</td>
<td>reduction in number of conferences</td>
<td>reduction cancellation</td>
</tr>
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<td>suppression mais ?</td>
<td>suppression but?</td>
<td>reduction cancellation</td>
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<tr>
<td>1 campagne tous les 2 ans</td>
<td>1 campaign every 2 years</td>
<td>reduction cancellation</td>
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<td>quota</td>
<td>quota</td>
<td>reduction cancellation</td>
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<td>renonce aux missions en mer</td>
<td>renounces missions at sea</td>
<td>reduction cancellation</td>
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<td>une année sur deux</td>
<td>every other year</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>annulation/reduction de missions</td>
<td>cancellation (reduction of missions)</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>alternance un an sur deux</td>
<td>alternating every other year</td>
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<td>annulation de déplacement</td>
<td>cancellation of travel</td>
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<td>partage ou réduit 50%</td>
<td>split or reduced by 50</td>
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<td>retour à la mission ini</td>
<td>return to original assignment</td>
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<td>diminution</td>
<td>reduction</td>
<td>reduction cancellation</td>
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<td>règle 1 conf/an</td>
<td>rule 1 conf/year</td>
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<td>partage 1 an /2</td>
<td>sharing 1 year / 2</td>
<td>reduction cancellation</td>
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<td>reduction</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>conf 1 an /2</td>
<td>conf 1 year /2</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>Tan sur 2</td>
<td>1 year out of 2</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>1 année sur 2</td>
<td>1 year out of 2</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>1 fois sur 2</td>
<td>1 time out of 2</td>
<td>reduction cancellation</td>
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<tr>
<td>1 seul auteur à la conférence</td>
<td>only 1 author at a time</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>report d'achat</td>
<td>postponement of purchase</td>
<td>reduction cancellation</td>
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<td>suppression d'une présence sur manip,</td>
<td>suppression of a presence on manipulation,</td>
<td>reduction cancellation</td>
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<td>mutualisation encadrement</td>
<td>mutualisation of management</td>
<td>reduction cancellation</td>
</tr>
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<td>abandon de conférence</td>
<td>abandonment of conference</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>mission à discuter si mainteunue ou pas</td>
<td>mission to be discussed whether to continue or not</td>
<td>reduction cancellation</td>
</tr>
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<td>consignes internes</td>
<td>internal instructions</td>
<td>reduction cancellation</td>
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<td>report 1 sur 2</td>
<td>postponement 1 on 2</td>
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<td>étaler dépalcements (1 an /2)</td>
<td>spread the shifts (1 year/2)</td>
<td>reduction cancellation</td>
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<td>règle : une conf long courrier par an</td>
<td>rule: one long-distance conference per year</td>
<td>reduction cancellation</td>
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<td>suppression formation</td>
<td>suppression of training</td>
<td>reduction cancellation</td>
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<td>abandon délégation au doctorant</td>
<td>abandonment-delegation to doctoral student</td>
<td>reduction cancellation</td>
</tr>
<tr>
<td>French Term</td>
<td>English Term</td>
<td>Technology Area</td>
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<tr>
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<td>compte rendu</td>
<td>report</td>
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<td>supprime conference</td>
<td>delete conference</td>
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<td>waiver</td>
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<td>espacement</td>
<td>spacing</td>
<td>reduction cancellation</td>
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<td>idée du RE avoir 1 long courrier autorisé</td>
<td>idea of BR having 1 long mail allowed</td>
<td>reduction cancellation</td>
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<td>conf &gt; journal</td>
<td>conf &gt; journal</td>
<td>reduction cancellation</td>
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<td>activité une année sur deux</td>
<td>activity every other year</td>
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<td>formation complète dans 2 ans</td>
<td>full training in 2 years</td>
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<td>#ERROR!</td>
<td>#NAME?</td>
<td>reduction cancellation</td>
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<td>1 année sur 2</td>
<td>1 year out of 2</td>
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</tr>
<tr>
<td>moins de simus</td>
<td>less simus</td>
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<td>renoncer au montage de projets nationaux</td>
<td>give up on national project development</td>
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<tr>
<td>terrain 1 année sur 2</td>
<td>field 1 year out of 2</td>
<td>reduction cancellation</td>
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<td>datacenter responsable</td>
<td>responsible datacenter</td>
<td>Information technology</td>
</tr>
<tr>
<td>optimisation temps de calcul</td>
<td>optimize computing time</td>
<td>Information technology</td>
</tr>
<tr>
<td>chercher centre de calcul plus faible</td>
<td>look for a lower computing centre</td>
<td>Information technology</td>
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<td>mutualisation ménage stockage</td>
<td>pooling of household storage</td>
<td>Information technology</td>
</tr>
<tr>
<td>faire durer le matériel/efficacité</td>
<td>make hardware last/efficiency</td>
<td>Information technology</td>
</tr>
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<td>cluster informatique</td>
<td>computer cluster</td>
<td>Information technology</td>
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<td>mise en commun des simus</td>
<td>pooling of simus</td>
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<td>formation optimisation calcul</td>
<td>training in computing optimisation</td>
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<td>bonnes pratiques calcul</td>
<td>good computing practices</td>
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<td>formation pour optimisation du code</td>
<td>training for code optimisation</td>
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<td>importation des calculs au centre externe</td>
<td>importing calculations to the external centre</td>
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<td>rationaliser</td>
<td>streamline</td>
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<td>partenariats et opti pour le calcul</td>
<td>partnerships and opti for computing</td>
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<td>améliorer la gestion des données</td>
<td>improve data management</td>
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<td>optimisation temps de calcul</td>
<td>optimisation of calculation time</td>
<td>Information technology</td>
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<td>optimisation moins de calcul</td>
<td>optimize less computation</td>
<td>Information technology</td>
</tr>
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<td>optimisation de code</td>
<td>code optimisation</td>
<td>Information technology</td>
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<td>réduction calcul</td>
<td>calculation reduction</td>
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<td>mutualisation calculs</td>
<td>calculation mutualisation</td>
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<td>amélioration calcul</td>
<td>calculation improvement</td>
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<td>transfer intensive calculation</td>
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<td>modèle plus rentable et plus efficace</td>
<td>more cost-effective and efficient model</td>
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<td>mieux préparer ses simulations</td>
<td>better preparation of simulations</td>
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<td>sharing of simulations</td>
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<td>mutualiser modélisation</td>
<td>mutualisation of modelling</td>
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<td>stockage sur le Laboratoire mixte international (quoi de la sécurisation)</td>
<td>storage on the International Joint Laboratory (what about security)</td>
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<td>optimisation code info</td>
<td>optimisation of info code</td>
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<td>code/acceleration optimisation</td>
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<td>non-renewal</td>
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<td>data management charter</td>
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<td>French Term</td>
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<td>Domain</td>
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<td>travail mutualisation calcul</td>
<td>work sharing calculation</td>
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<td>mix energétique meilleur</td>
<td>better energy mix</td>
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<td>Utilisation rationnelle du réseau</td>
<td>rational use of the network</td>
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<td>optimisation code info</td>
<td>optimisation into code</td>
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<td>Optimisation informatique</td>
<td>IT optimisation</td>
<td>Information technology</td>
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<td>renoncement gros calculs</td>
<td>renunciation of large calculations</td>
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<td>data center plus écolo</td>
<td>greener data centre</td>
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<tr>
<td>Utiliser les serveurs locaux</td>
<td>use local servers</td>
<td>Information technology</td>
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<tr>
<td>covoiturage ou train</td>
<td>carpooling or train</td>
<td>Others</td>
</tr>
<tr>
<td>covoiturage</td>
<td>carpooling</td>
<td>Others</td>
</tr>
<tr>
<td>missions aux plus jeunes</td>
<td>missions to young people</td>
<td>Others</td>
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<tr>
<td>mission bateau moins emettrice</td>
<td>less emissive boat mission</td>
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<tr>
<td>dans l'année pour échanger</td>
<td>in the year to exchange</td>
<td>Others</td>
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<td>avancée techni (capteurs)</td>
<td>technical progress (sensors)</td>
<td>Others</td>
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<tr>
<td>mutualisation perso des déplacements</td>
<td>personal sharing of journeys</td>
<td>Others</td>
</tr>
<tr>
<td>voiture</td>
<td>car</td>
<td>Others</td>
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<tr>
<td>choix selon arbre de décision</td>
<td>choice according to decision tree</td>
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<td>covoiturage terrain</td>
<td>carpooling in the field</td>
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<td>ordinateur plus éconoe en énergie</td>
<td>more energy efficient computer</td>
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<td>télétransmission de données</td>
<td>remote data transmission</td>
<td>Others</td>
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<td>transport public</td>
<td>public transport</td>
<td>Others</td>
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<td>changement de techno</td>
<td>change of technology</td>
<td>Others</td>
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<tr>
<td>vélo électrique (châteaux de la loire!)</td>
<td>electric bike (châteaux de la loire!)</td>
<td>Others</td>
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<tr>
<td>transmission à Boris</td>
<td>transmission to Boris</td>
<td>Others</td>
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<td>Innovation technologique</td>
<td>technological innovation</td>
<td>Others</td>
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<td>bénévole !</td>
<td>volunteer</td>
<td>Others</td>
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<td>compensation (impact ?)</td>
<td>compensation (impact ?)</td>
<td>Others</td>
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<td>compensation (plantation miyawaki)</td>
<td>compensation (miyawaki plantation)</td>
<td>Others</td>
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<td>covoiturage mission</td>
<td>carpooling mission</td>
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<td>déplacement domicile travail</td>
<td>commuting to work</td>
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<td>prendre en compte le carbone projet lors soumission</td>
<td>take into account the carbon project when bidding</td>
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<td>vacances ?!</td>
<td>holiday ?!</td>
<td>Others</td>
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<td>vélo électrique (châteaux de la loire!)</td>
<td>electric bike (châteaux de la loire!)</td>
<td>Others</td>
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<tr>
<td>mission longue durée</td>
<td>long term mission</td>
<td>Duration extension</td>
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<td>mission longue durée</td>
<td>long term mission</td>
<td>Duration extension</td>
</tr>
<tr>
<td>une année sur deux durée plus longue</td>
<td>every other year longer</td>
<td>Duration extension</td>
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<td>longer field work</td>
<td>Duration extension</td>
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<td>rallongement timing mission (télétravail)</td>
<td>longer mission timing (teleworking)</td>
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<td>extension of the duration on site</td>
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<td>plusieurs missions à mission longue durée</td>
<td>several long-term assignments</td>
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<td>rallonger les missions</td>
<td>lengthen missions</td>
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<td>encourage long duration in the field</td>
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<td>séjours longs</td>
<td>long stays</td>
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<td>missions plus longues dans le temps</td>
<td>longer missions in time</td>
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<td>rallonger les missions terrain</td>
<td>extend field missions</td>
<td>Duration extension</td>
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<td>extension of missions</td>
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<td>passer un an de thèse en islande</td>
<td>spending a year of thesis in Iceland</td>
<td>Duration extension</td>
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<td>Expatriation de trois ans</td>
<td>Three-year expatriation</td>
<td>Duration extension</td>
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<td>Un projet moins loin, ou le supprimer</td>
<td>A project less far away, or compress it</td>
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<td>remplacer par moyen courrier</td>
<td>replace by mid-distance flight</td>
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**S3 Gender distribution by sessions**: female and male for both facilitators and participants are reported in orange and green horizontal bars, respectively.

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