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RESEARCH ARTICLE

Concerned yet polluting: A survey on French research personnel and climate change

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Abstract

We present a survey of the French research community and climate change carried out in 2020. It is one of the largest surveys ever conducted on this issue: it is based on a sample of more than 6,000 respondents representative of the French public sector research community, regardless of their status and discipline. On the one hand, it measures practices that emit large amounts of greenhouse gases, such as air travel, and addresses the differences between disciplines and within them according to different individual characteristics (gender, status, location, etc.). On the other hand, it questions the representations of research actors concerning the climate emergency, and what they are willing to do to reduce their emissions. The survey highlights three results: first, an acute awareness of environmental and climate issues widely shared by members of the scientific community; second, a willingness to implement changes; and third, a clear gap between these attitudes and practices that still emit large amounts of greenhouse gases. This raises the question of the role of research institutions, whose support is required to implement profound reforms in the organization of research activities.

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Introduction

For several decades, researchers have highlighted the role played by human activities in greenhouse gas emissions and their effects on climate change. With the academic community working more than ever on these issues, researchers from several countries have in the last few years been investigating the environmental impact of their own occupational activities. These initiatives were initially led by climate and environmental scientists, underscoring the seeming paradox [1], or even hypocrisy [2], of polluting as part of their research while insisting that the population change its behaviour. Several studies have demonstrated that scientists emit more greenhouse gases (GHGs) than the average citizen [3,4], notably owing to their frequent use of air travel.

Climate and environmental researchers stand apart from other researchers as their credibility and ability to raise awareness of the urgency of reducing GHG emissions might hinge on their own behaviour [5]. But researchers in other disciplines are also paying increasing

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attention to the impact of their occupational activities ([6] in geography, [7] in astronomy, [8] in the history of transport).

As more such initiatives are rolled out, a better understanding is being forged of the actual impact of research activities on GHG emissions. But much remains to explore concerning differences between disciplines, and within the same discipline, stemming from individual characteristics (such as sex, status, and location), which is essential for implementing appropriate and effective changes. In addition, research on how research personnel perceive climate urgency, and what they are willing to do to reduce their emissions, is thin on the ground. In short, knowledge is lacking on the practices and characteristics of the groups with the highest GHG emissions, and on their perceptions, including their opinions on and understanding of climate issues and the reforms they deem acceptable or unacceptable.

The survey “Research personnel and climate change” we present here seeks to shed light on these grey areas. Conducted in 2020, it addresses practices before 2020 (pre-COVID) as well as perceptions. It is based on a large sample of over 6,000 respondents representative of French research personnel, regardless of their status or discipline (covering more than 70 disciplines). This article introduces the main themes and the initial results. Following a review of the literature, we present the survey questionnaire, the protocol, and the response rates obtained. We then focus on a few fundamental findings of the collected data concerning the opinions of research personnel on climate change, their GHG emissions, and the solutions that they are willing to implement to reduce those emissions.

State of the literature and contributions of the survey

For a little over a decade, a growing number of members of the academic community have explored the environmental impact of their research activities, from the standpoint of individuals [9], research programmes [10,11], and institutions [12,13].

While some works have addressed issues such as waste management, and in particular the pollution generated by plastic waste in laboratories [14,15], or, more globally, the concept of ‘green campuses’ [16], in this article we focus on the GHG emissions stemming from research activities and the effect of the latter on climate change.

Despite the growing interest in these issues, resulting from increasing awareness of the risks and the mounting urgency of taking action, the research published thus far provides what remains a fragmented review of the practices and perceptions of researchers.

Literature focused on air travel

Almost all the studies on the environmental impact of research concern the use of air travel [4,8,17]. This is justified by the fact that flights generate a large share of the GHG emissions of research activity. The University of British Columbia in Canada has estimated that flights account for 63% to 73% of total emissions [18]. At École Polytechnique Fédérale de Lausanne (EPFL), air travel accounts for one-third of total GHG emissions, equivalent to all the emissions generated by electricity consumption, heating, and commuting [12].

Many publications focus on the carbon impact of conferences [19], one of the main reasons for air travel. The GHG emissions generated by air travel range considerably, from 500 kg CO₂e per participant [20] to 950 kg CO₂e [21,22]. To put this into context, the European Commission objective to reduce emissions by 55% by 2030 relative to 1990 corresponds to 2.1 t CO₂e/year/inhabitant [23].

Solutions have been proposed [24] to reduce emissions, such as organizing fewer conferences, optimizing venue access, implementing regional hubs hosting participants at the same time, and increasing the use of videoconferencing.

But the emphasis placed on air travel should not obscure other sources of the GHG emissions generated by research, including IT equipment, commuting, the use of office space, catering (canteens and food stands), heating, the consumption of electricity (lighting, power for machines), and digital technology [25,26]. In some disciplines, scientific equipment stands as a major source of emissions, for example in astronomy [7], with its energy-intensive supercomputers.

While we have devoted considerable attention to the use of air travel in our survey, notably through a special bloc of questions (see next section), we have also addressed other GHG-emitting practices, such as commuting and the use of experimental equipment and IT equipment, for which it appears possible to initiate discussions and short-term actions.

The contributions of a large-scale survey

Literature review shows that most existing research is limited to specific populations, be they members of the same institution [12,27,28], discipline [3,7], department [29], or working group [11]. The homogeneity of the population studied in these cases prevents taking simultaneous account of characteristics such as status, discipline, or geographical location to measure their impact on GHG-emitting practices. Furthermore, the sample sizes are often modest.

Exceptions exist, among them a study conducted in 2017 with 1,400 scientists from a range of disciplines in several countries [30], which demonstrated that climatologists often fly more than their peers from other disciplines for occupational reasons but less for personal reasons.

The limited scope of most studies largely results from the conditions in which they are produced. Many of them are undertaken by researchers on the margins of their main research activities, as part of their own examination of their environmental impact, and/or in the context of a given institution, as a preliminary medium for implementing measures to reduce environmental impact. In short, few dedicated and wide-ranging research projects have focused on this issue.

To our knowledge, our survey is the largest ever to be conducted in terms of sample size (over 6,000 respondents) and scale, as it covers all types of status and disciplines in French research. It is also the sole sociological study of these questions and includes an array of variables for characterizing individuals, serving ultimately to understand—looking beyond discipline and status—variations in practices and opinions, as well as their determinants. Among other aspects, we take account of sex, age, seniority and career stage, occupational activity venue, number of children, living standard, awareness of environmental issues, and international aspects.

The interest of considering practices and opinions

Some of the existing research is devoted solely to practices, notably the use of air travel. Several studies have drawn on the processing of data collected by the institution funding air travel (laboratories, universities, research consortiums) to quantify its GHG emissions [10,31]. While this approach serves to accurately measure travel, it is not always able to identify the reason for travel or to put into perspective the use of air travel and knowledge of and opinions on climate issues. More broadly, these studies do not help us to understand the meaning placed by individuals in their practices or their more general opinions on climate change and the necessity, or otherwise, of implementing change.

Research on the overall population suggests a weak link between knowledge of environmental issues and practices [32,33]. This result has been verified for researchers in the environment, economics, and health based on their personal practices (personal use of air travel, consumption of meat, etc.) [34].

The questionnaire

Our survey was designed as part of Labos 1point5, an interdisciplinary collective created in March 2019 bringing together research professionals with the objective goal of reducing the environmental footprint of research activities (<https://labos1point5.org>).

The survey questionnaire was disseminated online from June to December 2020, immediately after the first COVID-19 lockdown in France. To reduce any COVID-19 disruptions on occupational practices, the respondents were asked about their practices in 2019. The survey does not aim to describe changes in the world of research generated by the epidemic.

The data are available to French and international researchers (doi:[10.21410/7E4/T3YYMS](https://doi.org/10.21410/7E4/T3YYMS)) via the Quételet PROGEDO Diffusion platform (<http://quetelet.progedo.fr/>).

The survey is based on a questionnaire administered online using the LimeSurvey software. Respondent's consent was obtained via a checkbox on the introductory page of the questionnaire. Compliance with the European General Data Protection Regulation was validated by the CNRS Data Protection Officer (CNRS-Service Protection des données— 2 rue Jean Zay— 54500—Vandœuvre lès Nancy, dpd.demandes@cnrs.fr).

The aims of the questions are to:

1. Gather the perceptions of research personnel on environmental issues, climate change and ecology in general.
2. Measure practices generating substantial GHG emissions, both individually and collectively (primarily transport, equipment, and energy consumption), and understand their contexts and determinants.
3. Explore solutions and their acceptability.
4. Assess the occupational and personal situation of the respondents.

The questionnaire was designed to take a reasonable amount of time to complete, at around 30 minutes. To prevent excessive completion times, two sets of questions identified as more time-consuming and unlikely to be crossed in the same analysis (professional flights on the one hand, and commuting and IT equipment on the other) were put in modules. Each respondent had to answer only one of the two modules, drawn at random. To limit the risk of respondents stopping the survey at an early stage, it begins with more consensual questions on occupational activity, and ends with more potentially sensitive questions concerning personal aspects. The questions were organized into nine groups (for more details, see the English translation of the questionnaire in [S3 Appendix](#)): position relative to the environment and research, individual and laboratory practices, transports in an occupational setting (focusing mainly on air travel and commuting; owing to their length, the most detailed questions in this section are organized into two separate modules posed randomly to one respondent in two), use of video-conferencing, concrete solutions in research, personal opinions on ecology in general (based among others on standard questions from the 'environmental attitudes inventory' [35]), personal activity and situation, and a quiz on GHG emissions.

Sample and non-response bias

Building the sample: Draw and reminders

The Centre National de la Recherche Scientifique (national scientific research centre, CNRS) is the largest public-research institution in France. Working alone or together with other institutions, such as universities, the CNRS coordinates the activity of over 1,100 research laboratories across the country. Our population includes all the employees of CNRS regardless of their

activity (including technical and administrative staff), as well as researchers and professors from other institutions (universities, private and public research institutes, etc.), PhD students and postdoctoral researchers, and any other type of personnel who are members of these structures.

To build a representative sample of this population, we used the CNRS directory, Labintel, which includes the 130,000 people affiliated with a CNRS unit or service. In all, it covers around half of the 250,000 public-research employees listed in 2018 in France by the Ministry of Higher Education and Research (including part-time employees; authors calculations based on [36]).

In June 2020, 30,000 email addresses were drawn at random (simple random sample) and the address holders were sent a message at the end of June asking them to respond to the questionnaire, along with a unique access link. Out of the 30,000 addresses, 4.6% generated an error when the questionnaire invitation was sent. However, it is probable that a much higher proportion of the invitations was never received, as servers do not systematically issue an error message when an email is unable to be delivered, anti-spam filters may block messages, and some email accounts are not used (notably those of non-permanent personnel, whose addresses do not appear to be systematically withdrawn or updated when they leave or change status). The quality of the survey database varies according to the status of personnel. It is excellent for paid CNRS staff, good for regular staff not paid by the CNRS, and average for other personnel, notably PhD students.

Ultimately, 6,723 people, corresponding to 23.6% of the invitations sent without error, went beyond the homepage of the questionnaire and 6,469 people (or 22.7% of invitations) completed the first page of questions. This is a relatively high response rate for a self-completed online questionnaire. The result is all the more satisfying as the respondents were notified that the time required to fill in the questionnaire was fairly long (estimated at 15 to 20 minutes on the homepage). To convince the individuals drawn to respond, in our initial message we stressed how important their participation was to fully reflect the ‘diversity of practices and opinions’ and to ‘find answers to environmental issues by reflecting the multiplicity of viewpoints’, while at the same committing to the anonymity of responses. To fully guarantee future respondents of the serious nature of the survey, we also stressed our institutional affiliations (CNRS, universities), the structure in which the questionnaire was built (Labos 1point5), and the context in which the data would be processed (a CNRS-Inrae research network, GDR).

The response rate, quite low following the initial message (10%), was improved by issuing four reminders to the people having failed to respond to the questionnaire, in July, September, October, and November. In those reminders, we reiterated the interest of the survey and reassured recipients that the message was not spam or a phishing attempt (first reminder). The third reminder proved particularly effective, the number of new responses being two and a half times higher than after the second reminder. This may be explained by the change in tone of the message, with less academic and more natural wording. The subject (‘Survey on research and climate change: your participation counts!’) and content (‘We need you to top the mark of 5,000 respondents, ensure representativeness and reflect the diversity of practices and opinions’) had been adjusted to attract the attention of the recipients, mention being made of a ‘last-chance reminder’ and a questionnaire that would ‘soon be closed’. In addition, the email was no longer sent from an impersonal address associated with the collective (enquete@labos1point5.org), but from the institutional address of the sole woman in the design team. This personalization, and perhaps the female first name, may also have further encouraged the recipients to respond [37]. The last reminder, also more effective than the second, adopted a similar tone. Specific reminders for people having started but not finished the questionnaire were sent at the same frequency, with a supplementary reminder at the end of November.

The relevance of this series of reminders was reflected in the fact that most responses were obtained on the day that each message was sent (nearly 80%), this trend having clearly accentuated over time.

Despite the long response time (median of 28 minutes and average of 40 minutes for those reaching the last page and excluding those having responded over several days), few respondents gave up along the way (15%). The good response rate for a self-completed online questionnaire, along with the low abandon rate, likely reflect both an interest in the topic from research personnel and the successful design of the online questionnaire, which was tested on numerous people before the survey was publicly launched.

Response rate by status and discipline

The information available in the CNRS directory can be used to calculate the response rates, which vary according to status, discipline, and sex. We will focus here on the response to the first page of the questionnaire. Regarding status, researchers, research engineers and research support engineers stood apart with a response rate of 30% to 36%, while just 17% of fully funded PhD students, 15% of technicians, and 17% of other personnel responded (Fig 1; Pearson's chi-squared test, $p < 0.001$). The response rate of non-permanent personnel was probably under-estimated given that the information concerning them in the database is not always up to date.

These differences also applied in terms of discipline (approached by CNRS institutes), the response rate standing at 31% for personnel working in earth sciences, astronomy, and astrophysics, 26% to 28% for physics and ecology personnel, and 20% to 21% for personnel in the human and social sciences, chemistry, biology, and information and engineering sciences (Fig 2; chi-squared test, $p < 0.001$). Women responded slightly more than men (25% and 22%), which could be attributed to their greater sensitivity to ecology [38]. The trends indicated here

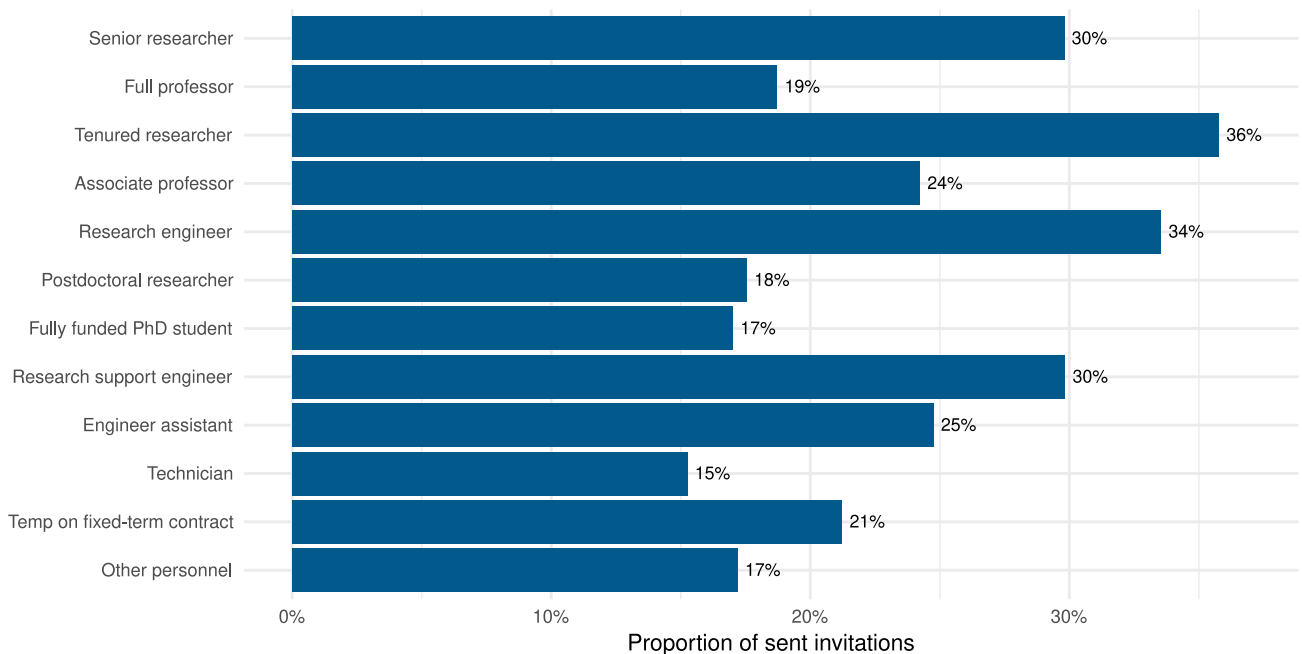


Fig 1. Response rate to the first page of the questionnaire by respondent status.

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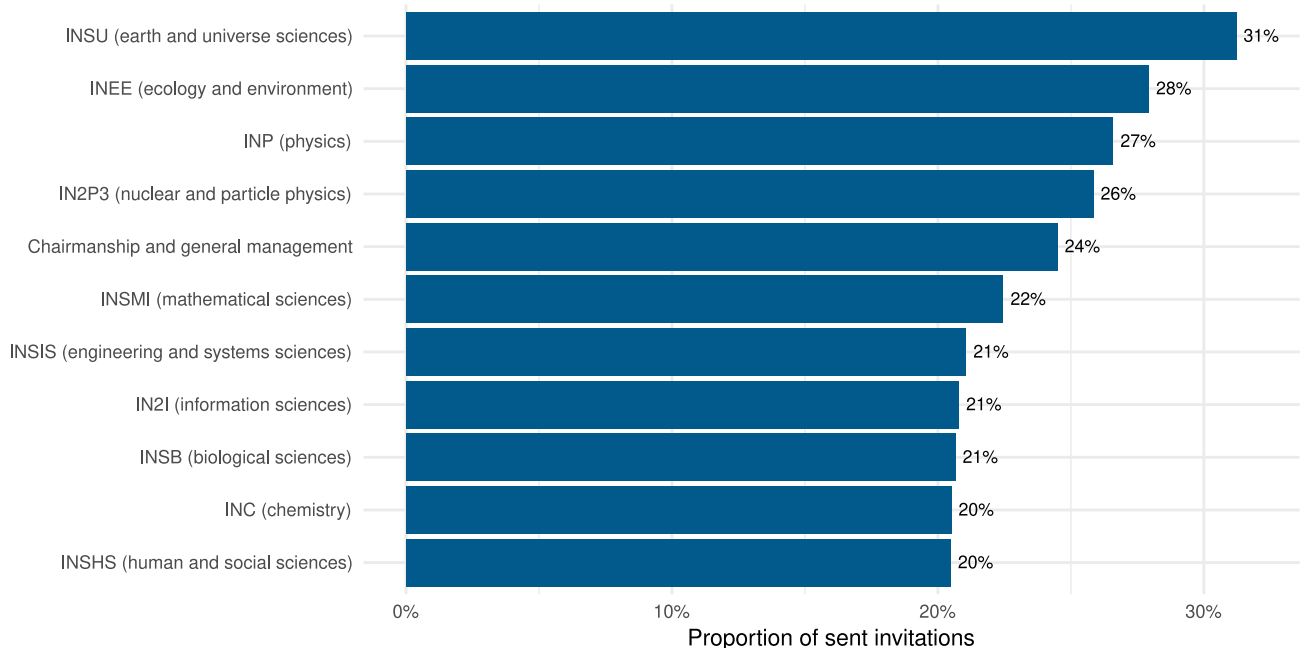


Fig 2. Response rate to the first page of the questionnaire by respondents' disciplinary institute at CNRS.

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using raw percentages are confirmed when estimating a logistic regression controlling for status, discipline, sex and region (see section 1.1 in [S1 Appendix](#)).

One may suspect that respondents more aware of environmental issue were more likely to answer than others. Unfortunately, it is not possible to assess directly the existence of this bias as the CNRS directory obviously does not include information on opinions regarding ecology. The fact that disciplines working on Earth and environment have a higher response rate may be an indication of this phenomenon, though the response rate gap is relatively limited.

Several tenure statuses exist in France for personnel carrying out research at a public education and/or research institution. Researchers perform this activity on a full-time basis, while professors devote half of their working hours to teaching.

See [S4 Appendix](#) for the French version of statuses. The CNRS directory uses a slightly less precise set of statuses than the one used in the survey questionnaire.

Differences between early and late respondents

Another method of analyzing non-response biases consists in examining the trend over time in the characteristics of respondents. This aspect has been analyzed in several studies (for example, [\[39–42\]](#)). By identifying who participated in the survey at a later stage, after several reminders, we can attempt to understand who did not respond. The underlying reasoning is that late respondents would have been non-respondents if reminders had not been sent [\[42\]](#).

By means of a question on how concerned the respondent is about climate change, we can note that more early respondents than late respondents say they are 'Extremely concerned' by climate change (33% of respondents before the first reminder compared with 27% after the last reminder; chi-squared test, $p = 0.003$). More early respondents say they 'strongly agree' that a major ecological catastrophe is going to occur (61% compared with 50% after the last reminder; $p < 0.001$). More early respondents had also carried out a carbon assessment. The

greater concern for the environment on the part of early respondents is also reflected in a greater propensity to fully complete the questionnaire, which appears to suggest that they are more motivated to respond to the survey. The phenomenon of late respondents providing more incomplete data has already been identified in other surveys [43,44].

Overall, early respondents are more in favour than late respondents of introducing regulatory constraints to protect the environment (respectively, 47% and 40% 'strongly agree'; $p < 0.001$). The former are also more inclined to think that we need to protect the environment more than economic growth (58% versus 47%; $p < 0.001$). Concerning research specifically, early respondents think more often that this sector should set an example in terms of reducing GHG emissions (50% vs 42%; $p = 0.003$). Early respondents are more inclined to consider many of the collective solutions proposed in the questionnaire as a priority, such as limiting air travel (56% vs 51%; $p = 0.037$), reducing the weight of international conferences in career assessments (64% vs 56%; $p < 0.001$), and funding train tickets (74% vs 69%; $p = 0.021$).

But the distinction between early and late respondents is not systematic, whether in terms of opinions or ecological commitment. Only a small percentage of both groups think it is pointless to take steps to protect the environment if others fail to do so. They also share the same opinion on taking ecology into account when voting or joining or donating to an environmental protection organization. Members of each of the two groups are divided regarding the ability of more and better technology to solve environmental problems.

These observations are valid when controlled for age, sex, discipline, and status (see linear regression results in section 1.2 of [S1 Appendix](#)). Age is one of the characteristics with the greatest impact on response time. The youngest individuals required a half reminder message less than the oldest individuals. Differences between disciplines are slighter and, for the most part, not statistically significant. Differences in status could in part be related to differential variations in the workload over time, as occupations with the fastest response times at the end of the university year were not the same in the back-to-school period.

Lastly, a set of indicators suggests that the individuals most engaged in their work environment or those feeling the happiest about their work are more inclined to respond. The individuals with the fastest response times work less on a part-time basis and have had more work published in the last three years. They also see themselves more as being in a moment in their career in which they are seeking to be promoted, recruited or tenured, and consider that they are paid better. In a further observation, non-French nationals respond later to the questionnaire.

Comparison with other surveys

A final method for assessing non-response biases is to compare our survey with others that have no reason to suffer from the same bias. This is true of the 'Styles de vie et environnement' (lifestyles and environment) survey based on the ELIPSS panel, which is a random sample panel of individuals living in France who have committed to respond to a broad variety of subjects, not limited to ecology. 90% of individuals with higher-level occupations in the civil service said they were somewhat or very concerned by climate change (compared with 93% in our survey, including when considering solely the sub-sample of higher-level occupations). 42% of them strongly agree with the statement, 'If things continue at the current pace, we will soon experience a major ecological catastrophe' (compared with 59% in our survey). These comparisons do not appear to reveal a major bias in our survey, as the latter difference could reflect, at least in part, a real difference between individuals with higher-level occupations in the civil service in general and researchers in particular, who as scientists are potentially more familiar with ecological issues.

Another survey, administered in spring 2020 among European demography researchers [45], may also be used as a reference as ecology was not its main theme. 91% of respondents said they were somewhat, very, or extremely concerned by climate change and 69% very or extremely concerned. These figures are very close to those obtained in our survey (93% and 71%, respectively, and 97% and 82% for researchers in sociology and demography).

Results

Consensus on the gravity of climate issues

A strong consensus exists on the reality, causes, and consequences of climate change among French research personnel. 99% of the respondents think that ‘the climate of the planet is changing’ and 95% think that human activity plays a major role in, or is the only cause of, climate change (Table 1). This result can be compared with the fact that 80% of French people think that ‘global warming is caused by human activity’ and just 66% of them consider that climate change is a certainty for most scientists [46].

Table 1. Opinions regarding climate and ecological issues.

| Do you think the climate of the planet is changing (rise in temperatures in the last century)? | | | | | | | |
|---|------------------------------|-----------------------------|-----------------------------|-----------------------|----------------------|------------|-------|
| | Yes, definitely | Yes, probably | No, probably not | No, definitely not | No opinion | Total | |
| Frequency | 5756 | 535 | 18 | 6 | 31 | 6346 | |
| % | 91 | 8 | 0 | 0 | 0 | 100 | |
| To what degree are you concerned about climate change? | | | | | | | |
| | Extremely concerned | Very concerned | Somewhat concerned | Slightly concerned | Not at all concerned | No opinion | Total |
| Frequency | 1994 | 2534 | 1335 | 367 | 60 | 52 | 6342 |
| % | 31 | 40 | 21 | 6 | 1 | 1 | 100 |
| Are you more or less concerned than 5 years ago? | | | | | | | |
| | Much more | Somewhat more | Neither more nor less | Somewhat less | Much less | No opinion | Total |
| Frequency | 2806 | 2254 | 1069 | 96 | 42 | 20 | 6287 |
| % | 45 | 36 | 17 | 2 | 1 | 0 | 100 |
| In your opinion, are human activities the cause of this climate change? | | | | | | | |
| | Yes, they are the only cause | Yes, they play a major role | Yes, they play a small role | No, they play no role | No opinion | Total | |
| Frequency | 1159 | 4871 | 197 | 9 | 46 | 6282 | |
| % | 18 | 78 | 3 | 0 | 1 | 100 | |
| Do you think that climate urgency calls for profound changes in the practice of our professions? | | | | | | | |
| | Yes, strongly agree | Yes, somewhat agree | No, somewhat disagree | No, strongly disagree | No opinion | Total | |
| Frequency | 2996 | 2594 | 397 | 107 | 247 | 6341 | |
| % | 47 | 41 | 6 | 2 | 4 | 100 | |
| If things continue on their present course, we will soon experience a major ecological catastrophe | | | | | | | |
| | Yes, strongly agree | Yes, somewhat agree | No, somewhat disagree | No, strongly disagree | No opinion | Total | |
| Frequency | 3337 | 1788 | 198 | 97 | 265 | 5685 | |
| % | 59 | 31 | 3 | 2 | 5 | 100 | |
| This type of catastrophe could cause a collapse of our societies: the basic needs (food, energy, health, etc.) will no longer be assured for the majority of the population | | | | | | | |
| | Yes, strongly agree | Yes, somewhat agree | No, somewhat disagree | No, strongly disagree | No opinion | Total | |
| Frequency | 2045 | 2105 | 489 | 361 | 605 | 5605 | |
| % | 36 | 38 | 9 | 6 | 11 | 100 | |
| France has committed to reducing its greenhouse gas emissions by one third by 2030. In this respect, do you think that public research must reduce its emissions by | | | | | | | |
| | More than one-third | Around one-third | Less than one-third | Total | | | |
| Frequency | 2717 | 2423 | 495 | 5635 | | | |
| % | 48 | 43 | 9 | 100 | | | |

<https://doi.org/10.1371/journal.pclm.0000070.t001>

This consensus on the reality of the situation and the underlying reasons is accompanied by an equally unanimous sense of concern. A full 99% of the respondents say they are concerned about climate change, 72% of them very or extremely concerned (including 32% extremely concerned). The concern of research personnel observed in our survey has increased in the last few years, with 80% of respondents saying they are more concerned than five years ago (including 45% much more concerned). And regarding the consequences of global warming, 90% of the respondents agree with the statement, 'If things continue on their present course, we will soon experience a major ecological catastrophe'. 74% of them even think that 'this type of catastrophe could cause a collapse of our societies'.

This vision of reality and the concerns of the respondents come hand in hand with a widely held expectation for changes in practices in their occupational activity. A full 88% of the respondents say they agree with the statement, 'Climate urgency calls for profound changes in the practice of our professions' (47% saying they strongly agree). This strong desire for change is confirmed when the question is asked in a more concrete fashion, referring to the objective in France's Low-Carbon Strategy on a one-third reduction in GHG emissions by 2030. A full 91% of respondents agree with the objective of reducing carbon emissions from research by one-third by 2030. And 48% even want to set an example by reducing them by more than one-third.

Opinions on climate change differ little from one discipline to the next. In general, there are no more than five percentage points of variation from the average between disciplines. All disciplines agree on the certainty of climate change, the role played by human activities in that change, and the demand for radical changes in our professions. However, some variations can be noted (chi-squared test, $p < 0.001$). Individuals in some disciplines, such as physics, chemistry, medical research, and biology, are less convinced that research should set an example in the reduction of GHG emissions (around 40% compared with an average for all disciplines of 48%). In contrast, oceanographers, meteorologists, environmental physicists, population biologists, and ecologists are more firmly convinced that the situation is urgent and action needs to be taken.

The status of personnel plays an important role in the responses regarding concern and willingness to change (chi-squared test, $p < 0.001$ for both). Surprisingly, while PhD-level positions (including PhD students) are more concerned about climate change than support staff, the latter are more willing to change research conditions to reduce GHG emissions. Just 62% of research support assistants say they are very or extremely concerned about climate change, compared with 76% of researchers. Conversely, 48% of research support engineers strongly agree with the idea that climate change calls for profound changes in our professions, compared with 40% of senior researchers or full professors.

High-emissions practices: Air travel and IT equipment

The respondents agree on the climate situation and share the same concerns. But the practices and habits of the research sector emit substantial amounts of greenhouse gases, notably through air travel, experimental equipment, buildings and infrastructure, IT equipment and its renewal, and receptions at conferences. To explore how research personnel aim to reduce these emissions, and to understand any reticence on their part, we need to know how much greenhouse gas is emitted and why, as emissions levels and reasons differ according to discipline and status. To that end, we will focus on two sources of emissions: air travel and IT equipment.

Excluding the research sector and at global level, the GHG emissions generated by air travel result from a minority of individuals (11% of the world population took a plane in 2018, 4%

for an international flight), which explains in part why they account for just 2% of worldwide emissions [47]. But air travel is a widespread practice in research, constituting the sector's number-one source of emissions (see above).

Professional travel is part and parcel of today's research work, notably for conferences abroad, fieldwork or observations in distant countries, research stays, teaching, and participation on juries or in international research programmes. As they are faster than trains, sometimes cheaper, and can be used to travel to far-flung destinations, planes are often the preferred means of transport for research personnel. As research support personnel have more modest travel requirements, we are limiting our analysis here to PhD-level positions (including PhD students), who account for 77% of our sample.

58% of PhD-level respondents travelled by plane for professional reasons in 2019. By way of comparison, in France in 2017, one person in five with an occupation of the same level travelled by plane at least once for professional reasons; this was the case for individuals with higher-level occupations in the civil service and similar sectors (teachers and artistic occupations) and for individuals with higher-level occupations in the private sector. Yet these are the professions that fly the most, and by far, as only 7% of the economically active population flying for professional reasons in the same year ('Styles de vie et environnement' survey, ELIPSS 2017, processed by the authors). Research personnel, then, are heavy users of air travel. On average, they flew 9,000 km in the year preceding the survey, emitting approximately 2 tonnes of CO₂e, and those having flown at least once travelled 15,500 km (the method for calculating distances and GHG emissions is detailed in S2 Appendix).

But the use of air travel varies considerably according to academic discipline (one-way ANOVA, $p < 0.001$). In some disciplines, where air travel is common, a researcher flies an average 10,000 km to 15,000 km a year (Fig 3). Researchers in astronomy, geology, anthropology, and mathematics, as well as ecology, fly more than the average (t-test against the grand mean, $p = 0.007, 0.003, 0.006, 0.032, \text{ and } 0.014$), which explains why researchers in the latter

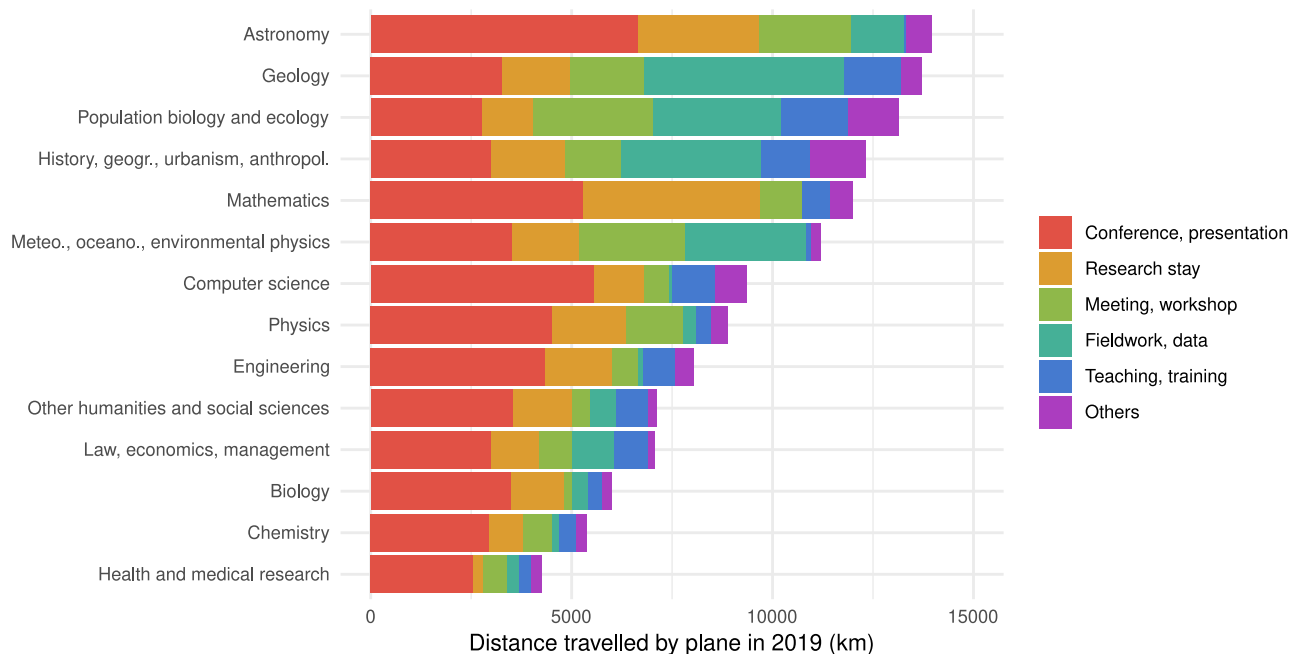


Fig 3. Average distance traveled by plane in 2019 by discipline of respondents.

<https://doi.org/10.1371/journal.pclm.0000070.g003>

field were the first to question themselves on their paradoxical use of air travel [1]. Air travel is less frequent than the average in other disciplines such as medical research, chemistry and biology, the distance traveled being three times lower on average ($p \leq 0.001$ for all three).

These differences in the use of air travel do not simply concern its intensity. Depending on the discipline, professionals do not fly for the same reasons. Geologists travel extensively for field studies, the production and collection of data, or research stays, but not so much to attend conferences. In contrast, astrophysicists, though flying as much as anthropologists, do so half as much for data but twice as much for conferences. That being so, whether the individual belongs to a discipline that makes little or extensive use of air travel or to a discipline in which empirical activity requires them to fly or not to fly, in almost all cases conferences are the main reason for air travel. They account for roughly 40% of the distance travelled by all respondents. Data production and collection (11% of the total distance) and research stays (18%) account for far fewer flights.

Naturally, such variations exist not just between disciplines but between different statuses (one-way ANOVA, $p < 0.001$). Research personnel travel more as their careers advance (Fig 4): while tenured researchers fly an average 10,000 km a year, senior researchers fly 15,000 km (post-hoc Tukey-Kramer test, $p = 0.017$); while associate professors fly 7,000 km, full professors fly 10,000 km ($p < 0.001$). Among young researchers, fully funded PhD students fly less (at 4,000 km) than tenured and senior researchers ($p < 0.001$ for all three), and post-doctoral researchers (at 8,000 km) less than than tenured and senior researchers ($p = 0.08$ and $p < 0.001$). This confirms results in the literature and generalizes them to multiple disciplines and institutions [7,12,28,30]. We can also note that for a given seniority level, researchers travel more than professors, the latter devoting half of their work time to teaching ($p = 0.016$ for senior vs full, and $p < 0.001$ for tenured vs associate).

The reasons for air travel are fundamentally similar across statuses. While air travel distances differ, the reasons for flying vary relatively little. 40% to 50% of the air travel of the

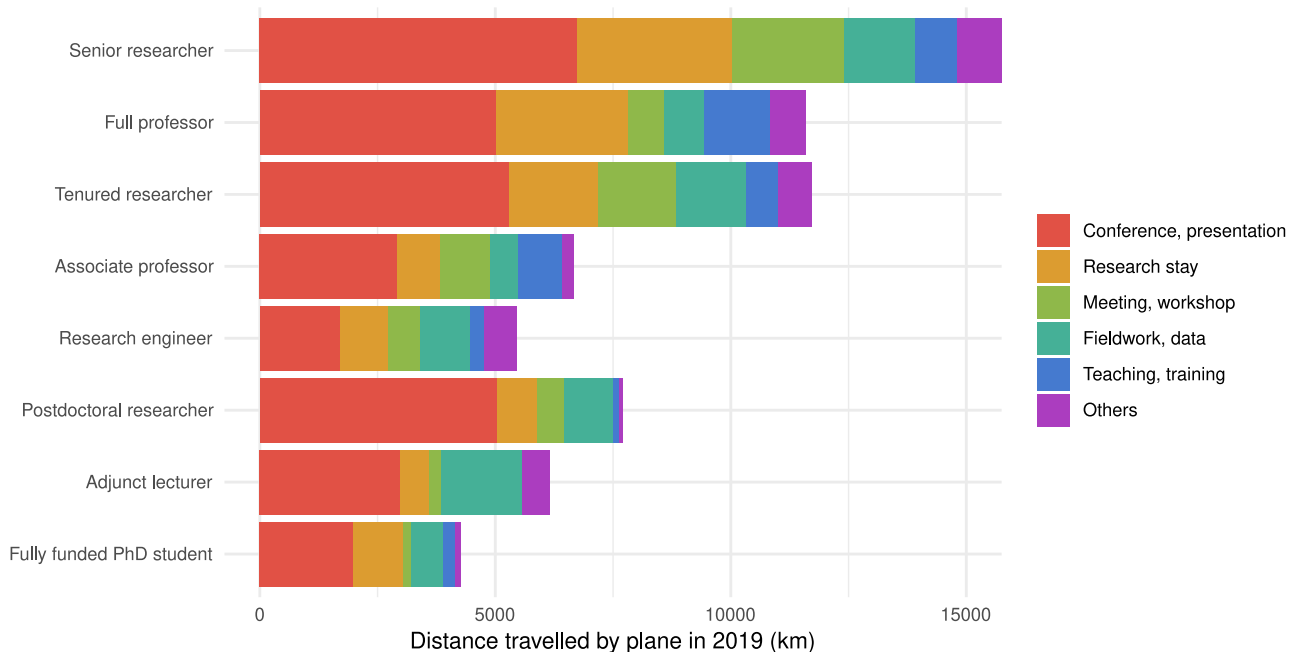


Fig 4. Average distance traveled by plane in 2019 by status of respondents.

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respondents is for conferences, apart from research engineers, who travel much less for this reason, and postdoctoral researchers, who travel much more for it. Research engineers, PhD students and adjunct lecturers devote a larger proportion of their flying distances to fieldwork and data. Conversely, the distance travelled for research stays increases as individuals advance in their careers, with the exception of PhD students who are the status with the highest proportion of distances flown for this motive. Logically, air travel for teaching concerns professors (both associated and full) more than other statuses.

See [S4 Appendix](#) for the correspondence with French statuses.

IT equipment is another major source of the GHG emissions and, more broadly, the pollution of the research sector. This equipment emits less pollution than air travel, the functioning of buildings, and heavy scientific equipment used in some disciplines, but it is interesting because it concerns all disciplines and may be measured relatively reliably through an individual questionnaire. It is also a field in which emissions reduction initiatives may potentially be implemented as regards the frequency of equipment replacements, without necessarily impacting core research activities.

To estimate the environmental cost, and notably the GHG emissions of IT, the focus is often placed exclusively on the energy consumed by equipment use. Yet the lifecycle ('cradle to grave') of the equipment also needs to be considered. The production of IT equipment accounts for over half of the total GHG emissions [48] and consumes extensive resources, notably rare-earth metals. In addition, IT equipment produces a substantial quantity of hazardous waste at end of life (waste electrical and electronic equipment, or WEEE), which is complex and costly to recycle.

To give an idea of scale, over its life cycle, a laptop emits approximately 150 kg of CO₂e, a desktop computer 200 kg, a high-performance computer 400 kg, and a 21.5-inch screen 250 kg [48]. Lengthening the lifespan of equipment would sharply reduce the corresponding emissions.

Our survey shows that most research personnel are equipped with IT devices (a computer or tablet purchased with professional financing) under five years old (62% of respondents). More importantly, 42% of the respondents have several devices, and among the latter 40% (or 17% of the total sample) consider that some of those devices are not indispensable. This suggests that there is some scope for reducing the emissions generated by IT equipment, through the more frugal management of devices.

Major differences are observed between disciplines and statuses. The share of respondents with a device aged under five years old is higher in the natural sciences, mathematics, and computer science (between 60% and 73%) than in humanities and social sciences (47% to 55%; chi-squared test, $p < 0.001$). The same trend is observed regarding the proportion of respondents with several devices ($p < 0.001$). The share of respondents considering that all these devices are not indispensable does not vary significantly from one discipline to the next ($p = 0.5672$). Lastly, and unsurprisingly, the number and recentness of devices increases in step with professional status (30% of adjunct lecturers have a device aged under five years old compared with 69% of senior researchers; $p < 0.001$). The same trend can thus be observed as with air travel.

The fact that personnel possess devices that they do not consider as indispensable can be attributed in part to project-based research funding, which may lead to expenditure of questionable usefulness to use up any credits that have not been spent before the end of the contract. 60% of the respondents say they have already had some leftover money to spend. Of this 60%, 35% say they had already used leftover money to buy IT equipment that was not indispensable.

However, only 6% of the respondents concerned report having used leftover budget money to buy plane tickets considered as non-essential. Air transport emissions being particularly high, the GHG emissions of this expenditure, seen as non-essential, may nevertheless be substantial. These results underscore some of the perverse effects of funding research on a project-by-project basis or via non-extendable annualized credits. They call at the very least for new mechanisms enabling personnel to use the funds granted in a manner that they see as more productive for their research.

Scientific community willing to change practices

So what needs to be done? How is this strong ecological sensibility reflected in the perceptions research personnel have of their profession? What do they see as the necessary changes required for reducing the GHG emissions of their research activity?

Several questions serve to identify the fields (air travels, experiments, etc.) in which respondents are willing to make the effort to reduce their emissions by 2030 and those in which they are less inclined to do so. Since the time horizon calls for medium-term planning, questions concerning individual efforts were asked only to permanent personnel. However, more general questions, with no specified time frame, and regarding the solutions to be rolled out and the risks involved, were asked to all the respondents.

Regardless of the field, most respondents say they are willing to reduce their emissions by at least one-third by 2030 (Fig 5). This is particularly true concerning air travel for conferences and IT equipment, with just 2% and 7%, respectively, of the respondents saying they are opposed to reducing the related emissions. And while a few variations were observed depending on status and discipline, the percentage remains under 10% in almost all cases (results detailed in S1 Appendix).

The proportion of respondents concerned varies according to the question.

Opposition is stronger for changes regarding core research activities. 14% of concerned respondents are opposed to reducing emissions stemming from travel for fieldwork, observation, and data collection. Similarly, nearly one-quarter are against reducing the emissions

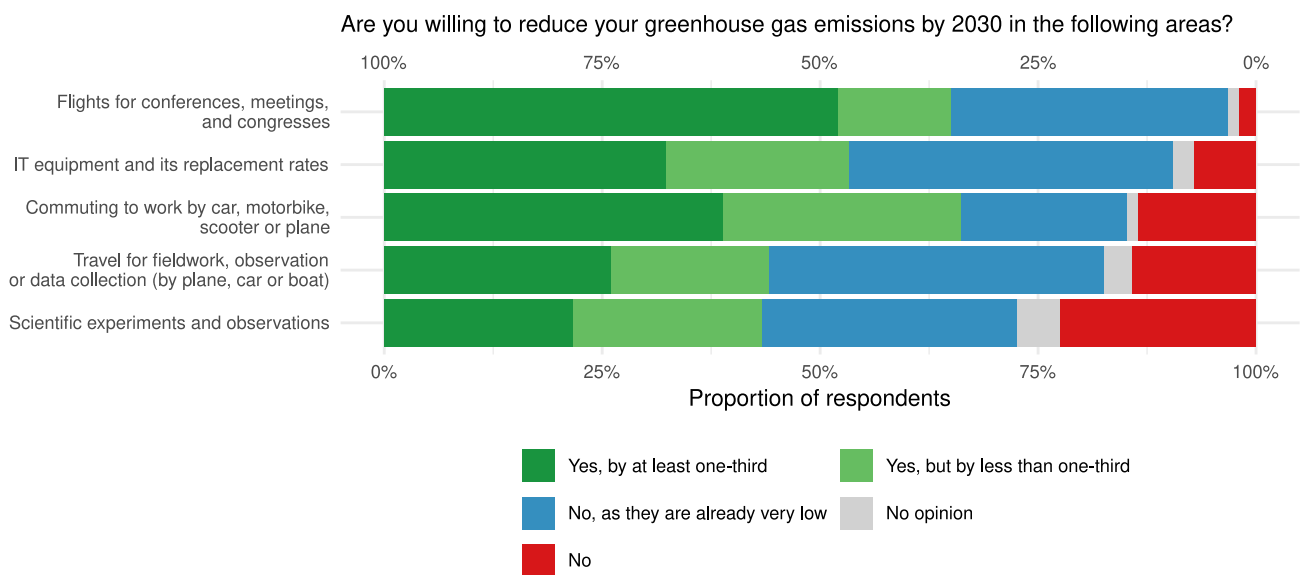


Fig 5. Willingness to reduce GHG emissions by 2030 in various areas.

<https://doi.org/10.1371/journal.pclm.0000070.g005>

generated by scientific experiments and observations. This reluctance is even stronger concerning the concrete means for achieving these reductions, as 42% of the sample are opposed to a reduction in their use of equipment for experiments and observations.

A willingness to limit emissions does not imply that one believes it is without consequences or without danger. We asked the respondents to assess the risks that could be involved in the reduction of professional air travel (regardless of the reason) and the reduction of emissions generated by experimental equipment in the next ten years.

While the respondents are globally in favour of a reduction in professional air travel, many of them say it could engender some of the risks we presented to them and that these risks are problematic. For example, many of the respondents (54%) are afraid that it poses a risk to the professional integration of young researchers. In something of a paradox, this fear is expressed slightly more by people further along in their careers than the young researchers themselves. Many of the respondents (44%) are also afraid that this could increase bureaucracy. Further concerns among the respondents are that initiatives to reduce emissions could harm the dissemination of their work (36%) and isolate French research from the rest of the world (43%), the latter being more of an issue for researchers and professors than for PhD students, post-doctoral researchers, adjunct lecturers, and support staff (chi-squared test, $p < 0.001$). Fears that these actions could hinder access to funding (16%) and eliminate some of the advantages of the profession (like travelling and discovering other countries. . .) (11%) are less frequent. Regarding this last point, most respondents think that cutting down on air travel will eat away at what they see as the innate advantages of the profession, but that this does not pose a problem. This result can be interpreted as a sign of willingness consistent with the strong convictions in favour of the climate expressed in response to the other questions.

These risks affect the functioning of research as currently organized (career paths, administrative and financial framework, etc.). But what about when the measures suggested in the questionnaire affect the scientific approach in itself (data production, experiments, etc.)?

Surprisingly, very few respondents (18%) are worried about the harmful impact of the reduction of professional air travel on the quality of scientific work. The level of concern in this respect varies substantially according to the discipline (chi-squared test, $p < 0.001$), with no relation to the distance traveled. However, of the half of the respondents who use air travel to access some field sites or to collect/produce some data, many (47%) think that implementing a policy on the reduction of air travel would hinder them in this regard and that it is a problem. This risk is seen as greater in disciplines where it is common to travel long distances by plane to produce or collect data ($p < 0.001$): this is the case for 72% of historians, geographers, urbanists and anthropologists, 73% of geologists and 61% of population biologists and ecologists.

Generally speaking, respondents are more concerned about the risks associated with a decrease in emissions related to empirical work, data and experiments, which is consistent with their being less willing to reduce their emissions in these areas. When we suggested to respondents using experimental and observation equipment (60% of the sample) that they reduce the emissions generated by this equipment, half of them said it would probably impact the quality of their work. Much mention is also made of the risks stemming from competition-based research, with 44% of respondents fearing that it would set them back relative to rival teams, 33% that it would reduce their access to funding, and 29% that it would lead to a decline in their number of publications.

These fears being so, what type of collective solutions should be implemented? A large majority of the respondents agree with the solutions suggested in the questionnaire (Fig 6). Almost all the respondents agree with the measures providing simply for a review (carbon assessment) or those coming at no cost for institutions, such as financing train travel where

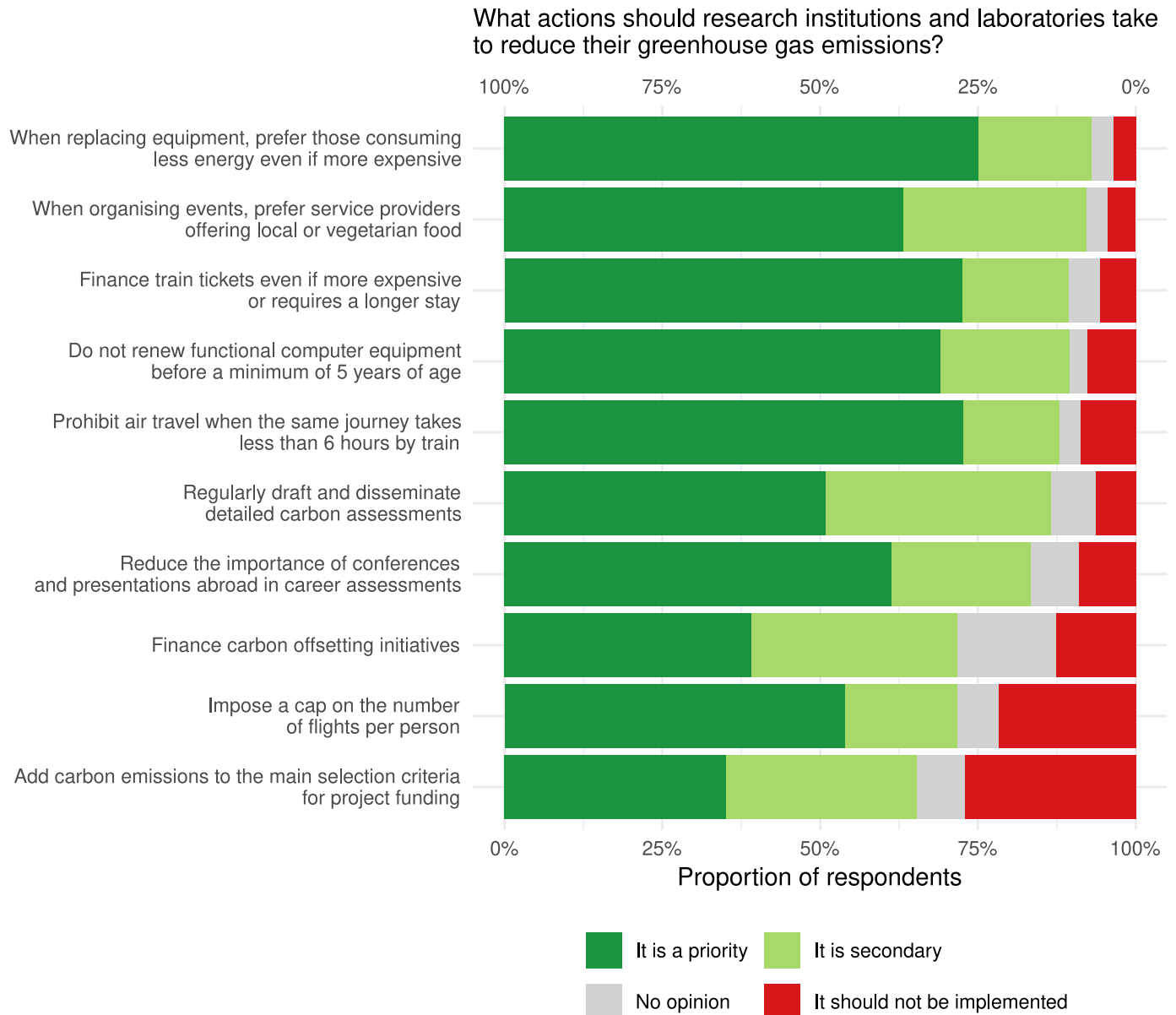


Fig 6. Support to institutional actions to reduce GHG emissions.

<https://doi.org/10.1371/journal.pclm.0000070.g006>

more expensive than plane travel, preferring to buy energy-efficient equipment even where more expensive, and funding carbon offsetting initiatives. Even measures that transform some career organization aspects are accepted by most respondents, as are others having a greater impact on the daily lives of the respondents. These include favouring local or vegetarian food stands, not replacing IT equipment before five years, and prohibiting air travel for journeys that take under six hours by train. Ultimately, the respondents express relatively strong opposition to just two measures: capping the number of flights per person (22%) and integrating carbon emissions into the selection criteria when financing projects (28%). These two initiatives, among the most radical, may for some disciplines impact the core of scientific data production.

Conclusion and discussion

Our survey highlights three results. First, members of the scientific community are acutely aware of environmental issues. Second, they are willing to implement change. And third, there is a substantial divide between these attitudes and practices emitting large quantities of greenhouse gas.

We cannot completely rule out the existence of two biases which would reinforce the first two results, making them appear stronger than the reality of the target population. First, we have noted that the survey is likely affected by some non-response bias, though its extent is impossible to assess precisely. Our analyses of response rates by discipline, of late respondents' answers and the comparison with other surveys seems to indicate that the bias is real but limited, especially when compared with the incredibly strong concern for ecological issues expressed by respondents. Second, some degree of acquiescence bias may affect answers, especially given that the survey is focused on environmental issues. In particular, respondents may be more inclined to support strong actions against climate change because the structure of the questionnaire highlighted the contradiction between their concern about the environmental crisis and their GHG-emitting practices. However, other surveys not focused on climate change found a similar degree of concern about it.

We therefore believe that research personnel's support for measures aiming at reducing GHG emissions would be strong if they were implemented, at least if they were not imposed blindly using a top-down approach. Some experiments have already been implemented locally in French laboratories or research teams without generating opposition, but they have been accompanied by significant awareness-raising and exchange on the part of the personnel behind these initiatives [49].

While one may think that support for concrete measures among research personnel will erode once individuals have to put them into practice, the converse may actually be true. In today's post-health crisis environment, many research personnel have already tried out new working methods, particularly with the unprecedented increase in the use of videoconferencing [50]. A mere 8% of our respondents used videoconferencing several times a week before the lockdowns; 72% of them did so during the lockdowns. Most importantly, 68% of the respondents said they had a more positive image of videoconferencing following their lockdown experience despite the particularly trying situation and a lack of preparation. This result shows that new work organization methods acceptable to personnel may be implemented quickly where collective action is taken. More broadly, the pandemic demonstrated that individuals and organizations alike were able, when faced with a threat, to radically change their way of working. The lessons of the pandemic should inspire us to rethink the way research works [51].

The key now is for institutions to drive and support profound change to fight against climate change. The scientific community is ready to make these changes but, for now, its members are unable to implement them individually without running the risk of being negatively impacted owing to the way the research sector operates (promotion of mobility in career assessments, project-by-project funding, competition, etc.). Failing this institutional action, the necessary changes will not take place [52].

As an occupation with a highly developed awareness of climate issues, and one that generates high levels of greenhouse gas emissions, the research community is currently facing regulatory issues that all sectors will soon have to deal with.

Supporting information

S1 Appendix. Additional tables and plots.

(PDF)

S2 Appendix. Calculation of air travel distances and the corresponding GHG emissions.
(PDF)

S3 Appendix. English translation of the questionnaire.
(PDF)

S4 Appendix. French statuses and their English translations.
(PDF)

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