**Auteurs :**

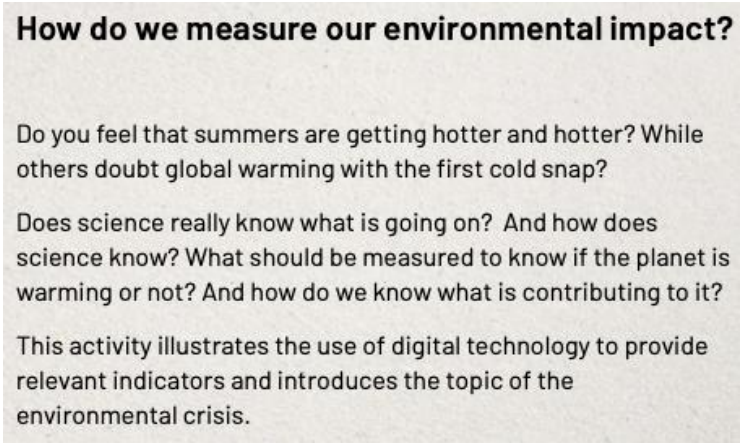
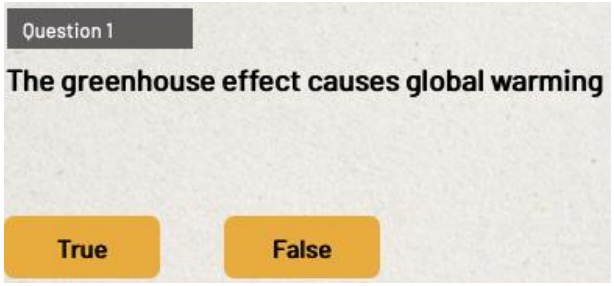
- Françoise Berthoud, CNRS / GRICARD / EcoInfo
- Julie Cornet,animator and trainer, Compagnie du Code
- Martine Olivi, research fellow, Inria

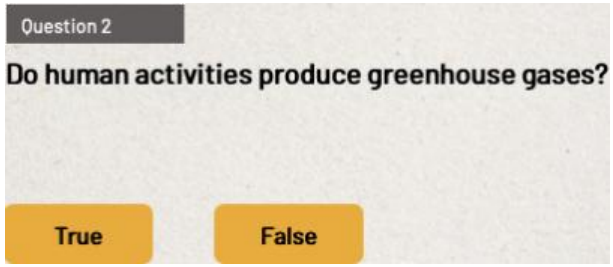
## Activity 01 : How do we measure our environmental impact?

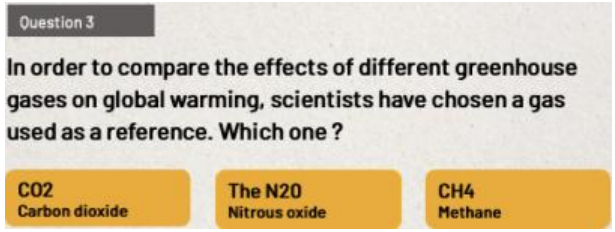
Measuring means moving from the perception that our senses give us to objective information that we can analyse, discuss and compare, which helps us to understand. If we feel cold, knowing our body temperature, the ambient temperature and the humidity helps us to better understand where this sensation comes from.

Today we are in the data age, we have all kinds of data: measurements acquired by high-performance sensors, information collected with or without our consent, etc. Digital technology offers us a tremendous capacity to collect, store and process this data. And this helps us to understand our impact on the environment.

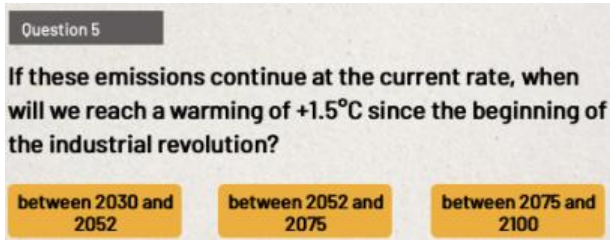
So, what do we know about man's environmental impact on the climate? And what do these indicators tell us about the environmental impact of digital technology?

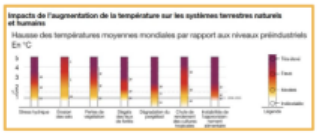
| Capsule slide | Related text |
| --- | --- |
|  | **How do we measure our environmental impact?**<br><br>Do you feel that summers are getting hotter and hotter? While others doubt global warming with the first cold snap?<br><br>Does science really know what is going on? And how does science know? What should be measured to know if the planet is warming or not? And how do we know what is contributing to it?<br><br>This activity illustrates the use of digital technology to provide relevant indicators and introduces the topic of the environmental crisis. |
|  | **Question 1**<br>**The greenhouse effect causes global warming**<br><br>• **True (right answer)**<br>• False |

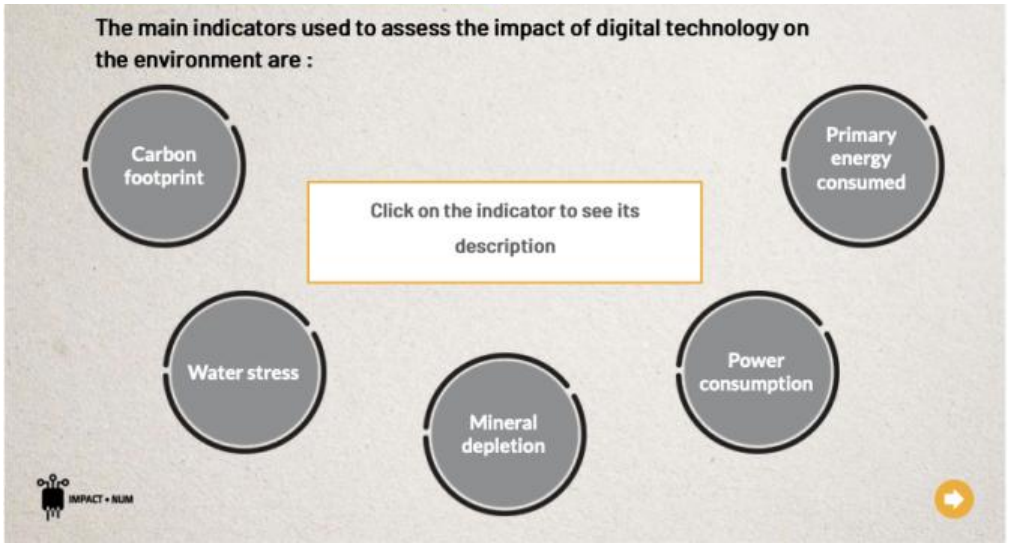
| Capsule slide | Related text |
| --- | --- |
| *Click on the image to zoom in*<br>  <br><br>Source: Credits: Principle of the greenhouse effect ©Ziablik / Shutterstock / Endangered Species<br><br>In 1824, Joseph Fourier (1768 - 1830) described the phenomenon nowadays known as the "greenhouse effect" : sunlight heats the planet and the planet re-radiates infrared radiation.<br><br>This radiation is absorbed by some gases in the atmosphere (GHGs or Greenhouse Gases) and re-radiated in all directions, thus partly towards the earth.<br><br>The greenhouse effect is therefore a proven physical phenomenon. Without this natural greenhouse effect, Earth's average temperature would be -18°C while it is around 15°C today.<br><br>Source : Faut-il croire au réchauffement climatique ? David Louapre, Science étonnante, 2015<br>[ accessed on: 16/12/2021 ] | **Feedback :**<br>**The greenhouse effect causes global warming**<br><br>In 1824, Joseph Fourier (1768 - 1830) described the phenomenon nowadays known as the "greenhouse effect" : sunlight heats the planet and the planet re-radiates infrared radiation.<br><br>This radiation is absorbed by some gases in the atmosphere (GHGs or Greenhouse Gases) and re-radiated in all directions, thus partly towards the earth.<br><br>The greenhouse effect is therefore a proven physical phenomenon. Without this natural greenhouse effect, Earth's average temperature would be -18°C while it is around 15°C today.<br><br>Source : Faut-il croire au réchauffement climatique ? David Louapre, Science étonnante, 2015<br>[ accessed on: 16/12/2021 ]<br>Image : Credits: Principle of the greenhouse effect. ©Ziablik / Shutterstock / Endangered Species |
|  <br> | **Question 2**<br>**Do human activities produce greenhouse gases?**<br><br>• **True (right answer)**<br>• False |

| Capsule slide | Related text |
| --- | --- |
| All human activities produce more or less GHG. In particular energy generated from fossil fuels (coal, oil, natural gas, etc.) releases a lot of CO2 into the atmosphere.<br><br>**The main GHGs are :**<br>• water vapour (H20),<br>• carbon dioxide (CO2),<br>• methane (CH4),<br>• nitrous oxide (N20),<br>• ozone (03)<br><br>and some gases produced exclusively by industrial activities such as fluorinated gases found in air conditioning, refrigerators, insulating foams,... | **Feedback :**<br><br>**All human activities produce more or less GHG.**<br><br>In particular, energy generated from fossil fuels (coal, oil, natural gas, etc.) releases a lot of CO2 into the atmosphere.<br><br>**The main GHGs are :**<br>• water vapour (H20),<br>• carbon dioxide (CO2),<br>• methane (CH4),<br>• nitrous oxide (N20),<br>• ozone (03)<br><br>and some gases produced exclusively by industrial activities such as fluorinated gases found in air conditioning, refrigerators, insulating foams,... |
|  | **Question 3**<br>In order to compare the effects of different greenhouse gases on global warming, scientists have chosen a gas used as a reference. Which one ?<br><br>• **CO2**, Carbon dioxide **(right answer)**<br>• **N20**, Nitrous oxide<br>• **CH4,** Methane |

| Capsule slide | Related text |
| --- | --- |
| **Why do we measure in CO2 equivalent?**<br><br>The different greenhouse gases do not have the same capacity to absorb the infrared radiation emitted by the earth, nor do they have the same life span in the atmosphere (for the same quantity).<br><br>In order to compare them, we measure their **global warming potential (GWP)** over a given period of time, usually 20 or 100 years. CO2 is the gas being used as a reference because of its **greatest quantitative effect on global warming**. This is why we can talk about CO2-equivalent.<br><br>**The calculation :**<br>1 kg of methane has the same warming potential over 100 years as 28 kg of CO2. We therefore speak of 28 Kg CO2 equivalent.<br><br>1kg of methane = 28 Kg CO2 eq (or Kg CO2e)<br><br>1kg of nitrous oxide = 265 Kg CO2 eq (or Kg CO2e)<br><br>Source : Global warming potential, Wikipedia<br>[ accessed on: 16/12/2021 ] | **Feedback :**<br>**Why do we measure in CO2 equivalent?**<br><br>The different greenhouse gases do not have the same capacity to absorb the infrared radiation emitted by the earth, nor do they have the same life span in the atmosphere (for the same quantity).<br><br>In order to compare them, we measure their **global warming potential (GWP)** over a given period of time, usually 20 or 100 years. CO2 is the gas being used as a reference because of its **greatest quantitative effect on global warming.** This is why we can talk about CO2-equivalent.<br><br>**The calculation :**<br>1 kg of methane has the same warming potential over 100 years as 28 kg of CO2. We therefore speak of 28 Kg CO2 equivalent.<br>• 1kg of methane = 28 Kg CO2 eq (or Kg CO2e)<br>• 1kg of nitrous oxide = 265 Kg CO2 eq (or Kg CO2e)<br><br>Source : Global warming potential, Wikipédia [ accessed on: 16/12/2021 ] |
|  | **Question 4**<br>**To date, what is the approximate global warming generated by human activities since the industrial revolution [1850-1900]?**<br><br>• +0,1 °C<br>• +0,5 °C<br>• **+1 °C (right answer)** |

| Capsule slide | Related text |
| --- | --- |
| **Earth's average temperature has increased by about +1°C since the late 1800s. Since the 1980s**, warming has increased significantly, as shown in this diagram. According to the "Global Warming of 1.5ºC" report (2018) published by IPCC, the current rate of global warming is +0.2°C per decade +/- 0.1°C<br><br>**The global temperature increase index** is an indicator that is used as a reference in international discussions to set a common goal.<br><br>In the Paris agreement (COP 2015), governments agreed to limit global warming to well below 2°C and pursuing efforts to limit it to 1.5°C by 2100<br><br>*Click on the image to zoom in*<br>  <br>*NASA; NOAA; Hadley Center*<br><br>ource : Chiffres Clés du climat 2021, Ministère de la transition écologique [ accessed on: 16/12/2021 ] | **Feedback :**<br>**Earth's average temperature has increased by about +1°C since the late 1800s.** Since the 1980s, warming has increased significantly, as shown in this diagram. According to the "Global Warming of 1.5ºC" report (2018) published by IPCC, the current rate of global warming is +0.2°C per decade +/- 0.1°C<br><br>**The global temperature increase index** is an indicator that is used as a reference in international discussions to set a common goal.<br><br>In the Paris agreement (COP 2015), governments agreed to limit global warming to well below 2°C and pursuing efforts to limit it to 1.5°C by 2100.<br><br>Source : Chiffres Clés du climat 2021, Ministère de la transition écologique [ accessed on: 16/12/2021 ]<br>Image : *NASA ; NOAA ; Hadley Center* |
|  | **Question 5**<br>**If these emissions continue at the current rate, when will we reach a warming of +1.5°C since the beginning of the industrial revolution?**<br><br>• **between 2030 and 2052 (right answer)**<br>• between 2052 and 2075<br>• between 2075 and 2100 |

| Capsule slide | Related text |
| --- | --- |
| **At the current rate, the 1.5°C increase would be reached between 2030 and 2052.** This increase in global warming is directly linked to human activities and the emission of greenhouse gases.<br><br>In this context, the IPCC* report was written on the consequences of a 1.5°C global warming [1].<br><br>In order to assess the impacts of global warming on ecosystems and humans, the IPCC scientists use multiple indicators that measure different risks.<br><br>The conclusion is clear: **a warming of more than 1.5°C would put humanity at much greater risk. In order to avoid exceeding 1.5°C, the IPCC "requires strong and immediate measures" and reminds us that every 10th of a degree counts!**<br><br>*Click on the image to zoom in*<br>  <br>Source : Scénarios et projections climatiques, DataLab, 2019<br>[ accessed 16/12/2021 ]<br><br>Source : [1] Rapport Spécial du GIEC Réchauffement à 1,5°c, 2019 [ accessed on: 16/12/2021 ] | **Feedback :**<br>**At the current rate, the 1.5°C increase would be reached between 2030 and 2052.** This increase in global warming is directly linked to human activities and the emission of greenhouse gases.<br><br>In this context, the IPCC (the Intergovernmental Panel on Climate Change) report was written on the consequences of a 1.5°C global warming [1].<br>In order to assess the impacts of global warming on ecosystems and humans, the IPCC scientists use multiple indicators that measure different risks.<br><br>The conclusion is clear: **a warming of more than 1.5°C would put humanity at much greater risk. In order to avoid exceeding 1.5°C, the IPCC "requires strong and immediate measures" and reminds us that every 10th of a degree counts!**<br><br>*Source : [1] Rapport Spécial du GIEC Réchauffement à 1,5°c, 2019* [ accessed on: 16/12/2021 ]<br>Image : Scénarios et projections climatiques, *Giec, SRCCL, 2019* |
| **What about the impact of digital technology?**<br><br>And what about the environmental impact of digital technology itself? What are the relevant indicators? The quantities that will allow us to consider the evolution of these impacts and to take decisions?<br><br>This is what we are going to see now. | **What about the impact of digital technology?**<br><br>And what about the environmental impact of digital technology itself? What are the relevant indicators? The quantities that will allow us to consider the evolution of these impacts and to take decisions?<br><br>This is what we are going to see now. |

| Capsule slide | Related text |
| --- | --- |
|  | **The main indicators used to assess the impact of digital technology on the environment are :**<br><br>*Click on the indicator to see its description*<br><br>• Carbon footprint<br>• Water stress<br>• Mineral depletion<br>• Power consumption<br>• Primary energy consumed |

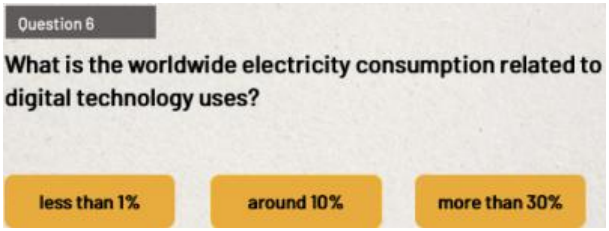


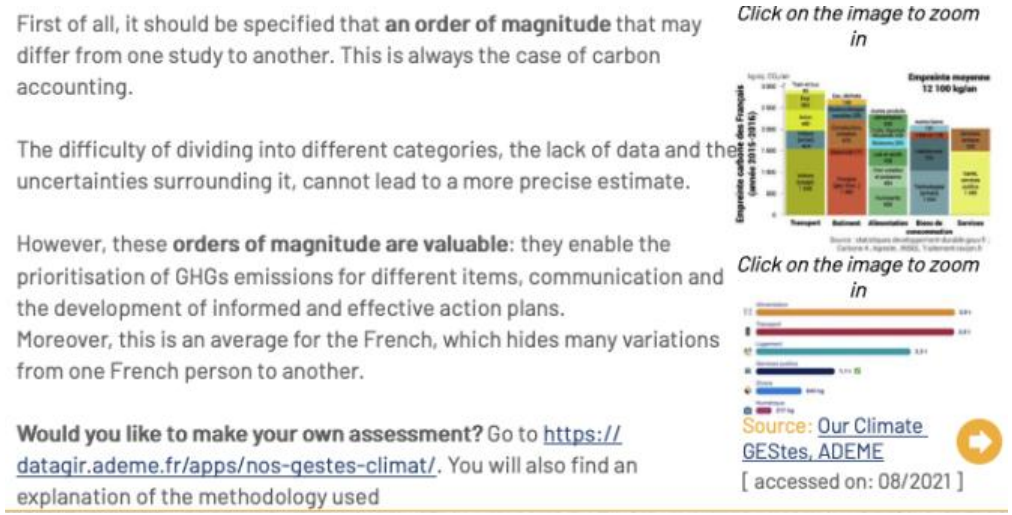
**The description of each indicator :**

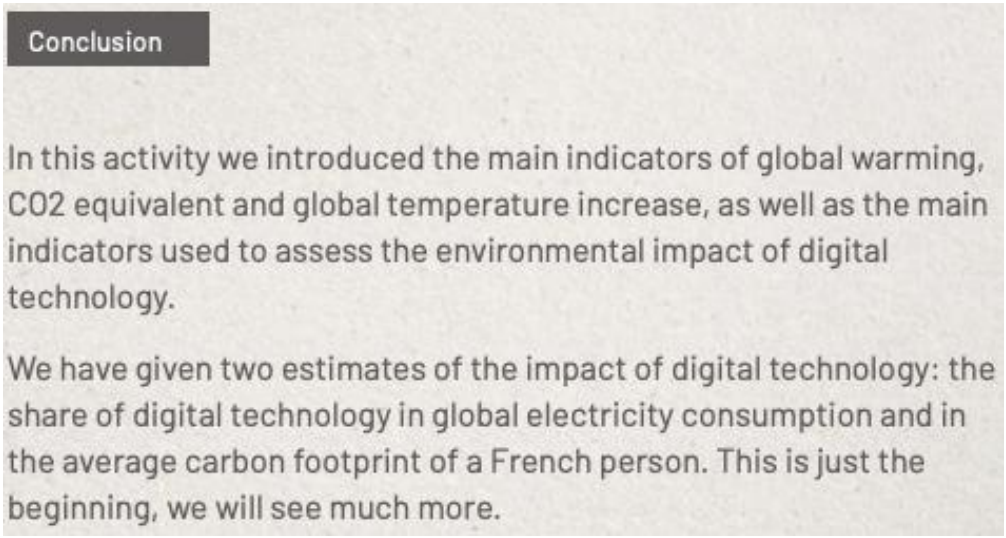
**Carbon footprint**
Quantity of **GHGs** emitted over all life cycle phases of the equipment or service (in kg CO2 eq)

**Water stress**
**Water resource depletion,** expressed in $m^3$ equivalent, corresponding to the direct and indirect use of water by the consumer or producer.

**Mineral depletion**
**The scarcity of mineral resources** (especially metals) several dozen minerals are considered in this indicator. The method takes into account the rate of extraction and the available stock and the unit is kg antimony equivalent (kg Sb).

| Capsule slide | Related text |
|---|---|
| **Power consumption**<br>**The amount of primary energy** needed to produce the final energy used throughout the life cycle of an equipment (in kWh)<br><br>**Primary energy consumed**<br>The amount of **electricity** consumed in the use of an equipment, a service (in kWh). | |
|  | **Question 6**<br>**What is the worldwide electricity consumption related to digital technology uses?**<br><br>• less than 1%<br>• **around 10% (right answer)**<br>• more than 30% |
| The new technologies sector accounts for between 6 and 10% of global electricity consumption, depending on estimates.<br><br>If we now take a look at all the energy (and not just electricity) needed for the entire life cycle of digital equipment, we are closer to 4%. This energy footprint **increases by 6% each year** meaning that it **doubles every 12 years** (Rule of 72, Wikipedia to understand the doubling time). At this rate it will overtake the car's carbon footprint shortly.<br><br>Source : Impact environnemental du numérique : tendances à 5 ans et gouvernance de 5G, TheShiftProject, 2021 [ accessed on: 16/12/2021 ] | **Feedback :**<br>**The new technologies sector accounts for between 6 and 10% of global electricity consumption, depending on estimates.**<br><br>If we now take a look at all the energy (and not just electricity) needed for the entire life cycle of digital equipment, we are closer to 4%. This energy footprint **increases by 6% each year** meaning that it **doubles every 12 years** (Rule of 72, Wikipedia to understand the doubling time). At this rate it will overtake the car's carbon footprint shortly.<br><br>Source : Impact environnemental du numérique : tendances à 5 ans et gouvernance de 5G, TheShiftProject, 2021 [ accessed on: 16/12/2021 ] |

| Capsule slide | Related text |
| --- | --- |
|  | **Question 7**<br>**How much is the average French person's carbon footprint accounted for, by digital technology?**<br><br>• **less than 10% of the total (right answer)**<br>• between 10% and 20%<br>• more than 20 |
|  | **Feedback :**<br>**The share of the digital sector in the average French person's carbon footprint is between 3 and 10%, depending on the study.**<br><br>First of all, it should be specified that **an order of magnitude** that may differ from one study to another. This is always the case of carbon accounting.<br><br>The difficulty of dividing into different categories, the lack of data and the uncertainties surrounding it, cannot lead to a more precise estimate.<br><br>However, **these orders of magnitude are valuable:** they enable the prioritisation of GHGs emissions for different items, communication and the development of informed and effective action plans.<br><br>Moreover, this is an average for the French, which hides many variations from one French person to another.<br>**Would you like to make your own assessment?** Go to https://datagir.ademe.fr/apps/nos-gestes-climat/. You will also find an explanation of the methodology used<br><br>Images : |

| Capsule slide | Related text |
| --- | --- |
| | • Empreinte carbone moyenne des français en 2016, statistiques.develeppement-durable.fr; Carbone 4 ; Agreste, INSEE, Traitement ravijen.fr<br>• Nos GEStes Climat, ADEME |
|  | **Conclusion**<br><br>In this activity we introduced the main indicators of global warming, CO2 equivalent and global temperature increase, as well as the main indicators used to assess the environmental impact of digital technology.<br><br>We have given two estimates of the impact of digital technology: the share of digital technology in global electricity consumption and in the average carbon footprint of a French person. This is just the beginning, we will see much more. |

## If you wish to go deeper into certain concepts

The **Indicators: from definition to construction** explains what an indicator is, how it is constructed and what the main environmental indicators are.
The **Digital technology and environment in a few figures** gives you some international and French figures on digital equipment, and some illustrations of equipment and digitisation rates in France.
The **Digital technology and electricity: measurements, proportionality and energy efficiency** explains the metrics used to analyse the electricity consumption of digital equipment in use and how to measure the consumption of digital equipment.
The **Quantified results: how reliable are they?** suggests that you reflect on the reliability of the figures and the degree of confidence that can be placed in them. Alert to figures, alert to greenwashing! Based on 3 examples: an article, an application and a study.

## Conclusion

Global warming is real and measurable! The influence of human activities on the climate, suspected since the 1970s, was established indirectly in the second IPCC report in 1995. The conclusions of this report, questioned by some scientists (whose research was financed by industrial lobbies, see [1]), finally reached a consensus in the community of climatologists. It was only in 2021 that the human origin of warming was directly proven in a scientific paper [2]. The global temperature increase indicator is used as a reference in international discussions to set a common target. In the Paris agreements (COP 2015), the objective of not exceeding 2 degrees of warming and getting as close as possible to 1.5 degrees was adopted. To achieve this objective, GHG emissions would have to be limited to 2 tonnes of CO2 eq. per year and per person by 2050, compared with 11 tonnes currently in France! A study by Carbon 4 [3] highlights the importance of individual actions, whose impact is far from negligible, but also the fact that they cannot do everything. A French person cannot hope to reduce his or her ecological footprint by more than 2.8 tonnes per year. The rest is the responsibility of other actors (industries, politicians) and requires going beyond the individual level to a collective level of action. Moreover, all sectors are concerned, from housing to food and transport. The digital part is not negligible, but above all it is not limited to our uses. Moreover, digital technology is set to grow disproportionately if nothing is done to curb its expansion. These subjects will be addressed in the rest of the Mooc.


- [1] The Merchants of Doubt, Erik M. Conway, Naomi Oreskes, Le Pommier. 2014
- [2] For the first time, the human origin of global warming has been directly demonstrated. SciencePost, 25/03/2021 [accessed 15/12/2021]
- [3] Doing your part? Power and responsibility of individuals, companies and the state in the face of the climate emergency. Carbone 4. 06/2019 [accessed 15/12/2021]

# Credits :

| | |
|---|---|
| **Authors :**<br>● Françoise Berthoud, CNRS / GRICARD / EcoInfo<br>● Julie Cornet, animator and trainer, Compagnie du Code<br>● Martine Olivi, research fellow, Inria | **A co-production of Class'Code / Inria** |
| **Pedagogical team :**<br>● Laurence Farhi, Tatiana Khomenko, Inria Learning Lab<br>● Sophie de Quatrebarbes, S24B for Class'Code | With the support of the Minister of National Education, Youth and Sport and UNIT. |
| **Graphismes :**<br>● Illustrations : Mikaël Cixous, 4 minutes 34<br>● Photographies of Guillaume Clémencin : Nicolas Ledu | |
| This resource was produced as part of the Mooc Environmental impacts of digital technologies under licence CC BY 4.0 FR 2021 www.fun-mooc.fr | |