



Master of Public Health

Master de Santé Publique

**Exploring the feasibility of a French Regional Lancet Countdown:  
BREIZH Lancet Countdown**

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## List of Acronyms

ADEME: French Agency for Ecological Transition (Agence De l'Environnement et de la Maîtrise de l'Energie)

ARS: Health Regional Agency (Agence Regionale de Santé)

ATMO France: National Network for Air Quality Monitoring Indice multipolluant de la qualité de l'air

BNPE: National Water Withdrawal Database (Banque Nationale des Prélèvements Quantitatifs en Eau)

CNAM: National Health Insurance Fund (Caisse Nationale de l'Assurance Maladie)

CNR-L: National Reference Center for Leishmaniasis

COP21: 21st Conference of the Parties

ECDC: European Centre for Disease Prevention and Control

EPCIs: Public Establishments for Intercommunal Cooperation (Établissements de Coopération Intercommunale)

ERA5: The Fifth Generation Atmospheric Reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF)

G20: Group of 20 – Intergovernmental Forum

GBIF: Global Biodiversity Information Facility

HCBC: High Council for Climate in Brittany (Haut Conseil Breton pour le Climat)

INCA3: Third Individual and National Study on Food Consumption (France) – (Troisième Enquête Individuelle Nationale des Consommations Alimentaires)

INSEE: National Institute of Statistics and Economic Studies (Institut national de la statistique et des études économiques)

Inserm: National Institute of Health and Medical Research (Institut National de la Santé et de la Recherche Médicale)

IPCC: Intergovernmental panel on climate change

NGOs: Non-Governmental Organizations

NHS: National Health Service

ODRE: Open Data Platform for Energy Networks (Open Data Réseaux Énergies)

OEB: Brittany Environmental Observatory (Observatoire de l'Environnement en Bretagne)

PCAET: Territorial Climate-Air-Energy Plan (Plan Climat -Air Énergie Territorial)

PRSE: Regional Health-Environment Plan (Plan Régional Santé Environnement)

SEDAC: Socioeconomic Data and Applications Center

SILAM: System for Integrated modeling of Atmospheric composition

SRADDET: Regional Scheme for Spatial Planning, Sustainable Development, and Territorial Equality

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate

WHO: World Health Organization

## Abstract

The earth temperature has been facing an increase, more felt in the two last decades. Though both natural and anthropogenic activities contribute to the warming of the earth temperatures, from the middle of the 20<sup>th</sup> century man-made activities are considered as the solely cause. The change in the climate is associated with a variety of negative impacts on human health. To address the change and improve the health of the population, the Lancet countdown to 2030 was created following the 2015 Paris Agreement; an international initiative tasked to present and track climate change impact's on health. Due to the geographical, socio-demographic varieties among others from a region to another, there is a need for tailored initiative at a more local level, more relevant to the local politics of transition. Brittany, a region in France, was selected as a study area to explore the feasibility of implementing the Lancet Countdown approach at a local scale (The BREIZH Initiative). After identifying indicators from the Lancet Countdown to serve as starting point, the environmental concerns linked to climate specific to the region were identified through a corpus document constituted through purposely selecting regional framework documents. Crossing of the reference indicators (the 2024 European report) with the concerns specific to Brittany revealed that though the indicators have the potential to help track the evolution of climate change in the region, for more specific concerns of the region such as costal retreat no indicators were found in the reference set, highlighting the need for a regional tailored initiative. The analysis of the availability of the indicators data at the regional level underscored the need for a more data driven approach, data on health worsened by climate change, to have a proper bank of regional data accessible, and ensuring that national values have a regional component.

# 1 Introduction

## 1.1 Global Context: Climate Change and Health

For the past decades, the earth global temperature has known a rapid increase as compared to the last centuries, with the highest records during the last two decades (IPCC, 2021, Chapter 3). Expectations for the temperature are to reach +4°C by 2100, an increase that will not be without consequences (Ministère de la Transition écologique, PNACC 3, 2025). Along the warming of the earth temperature several consequences have been identified: the melting of the ice cap, flooding, high proportion of drought, the acidification of the sea among many others (U.S. Global Change Research Program [USGCRP], 2018). The systemic effect from the climate change has an impact on human health ranging from communicable disease (infectious diseases) to non-communicable diseases (respiratory, cardiovascular, mental), seen through two main pathways: direct and indirect exposures (Haines & Ebi, 2019; Climate Change and Health - PAHO/WHO | Pan American Health Organization, 2025).

With climate change, there is an increase in the temperature leading to extreme events with an increasing frequency and intensity (heatwaves, drought, heavy rainfall). The exposition to those events represents a great health concern as the consequences range from dehydration to even death. Those are considered as direct effect of climate change (Brown, 2020). As record of such direct effect is the 2003 European heatwave, that caused the death of around 70,000 people, with France being the hardest hit, with 14,800 deaths (Maslin et al., 2025). The indirect effect of climate change is through systemic disruption; for example, with global warming a disruption occurs in the precipitation patterns, which in turn affect a system such as water causing water and/or food issues which then will affect the health. Another common occurrence of indirect effect are vector borne diseases; in regions where they are not endemic, they might become as the vector causing the disease adjusts to the environment, leading to an increase in the local burden of the disease (Haines & Ebi, 2019). It can be seen as well in the interaction of climate change with the economy, and social structures. The diagram in Figure1 illustrate both the direct and indirect effect of climate change on human health. As it is a cause-and-effect relationship, with the exacerbation of climate change the consequences on human health will worsen as well. If the prediction of an increase of 4°C in the temperature is reached the frequency and intensity of climate change impacts will be nothing compared to what are faced now.

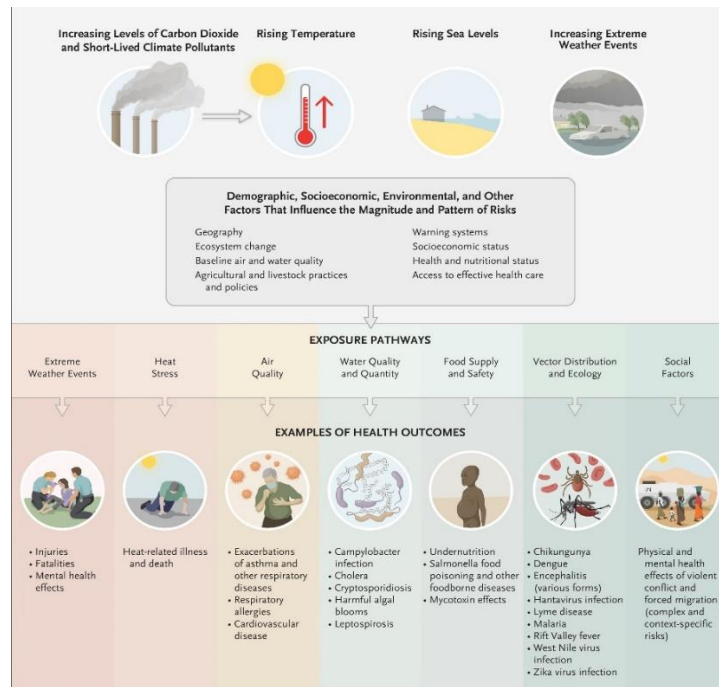


Figure 1: Major Health risks Associated with Climate Change (Haines & Ebi, 2019)

To preserve health, there is a need for actions. Such actions rest on three key themes: vulnerability, adaptation, and mitigation (Lawler et al., 2013). In the context of climate change, vulnerability is how fragile a region is. The Intergovernmental Panel on Climate Change (IPCC) (2023) defined it as the predisposition to be adversely affected. To be able to adequately address the possible effects of climate change, there is a need for an assessment that will provide a picture of the situation. It will show how sensitive and susceptible a concerned region is (two key concepts of vulnerability), does it possess the capacity to cope and adapt. Mitigation is about addressing the actions that participated in the development of the issue - climate change. It is defined by Panepinto et al. (2021) as the actions that will reduce the anthropogenic influence, the human interventions to reduce the emissions or enhance the sink of greenhouse gases. The third pillar of the climate change action is adaptation; it is the process of adjustment to the actual or expected climate and its effects (IPCC, 2023). In dealing with climate change, adaptation can be considered as a cruciality; how its effects are endured by a community is important as those effects are already observable and will keep happening. Following the evolution of the prediction of the increase of temperature, it can be seen the mitigating actions are falling short, with France updating its prediction to a 2100 at +4°C instead of a +3°C globally (Ministère de la Transition écologique, PNACC 3, 2025), emphasizing the need and urgency of adaptation.

Predicting the magnitude and nature of the possible health consequences with precision can be an issue, as there is a real risk the effects will become non-linear, along with the interaction between tail risks (small risks) that can produce larger than expected chances of

catastrophic outcomes (Watts et al., 2015). Those outline the urgent need to have action plans that are thoroughly and meticulously designed.

To tackle the issue of climate health international agreements have been designed, among them is the Paris Agreement signed by 196 parties and adopted at the UN Climate Change Conference (COP21) in Paris, France on December 12<sup>th</sup>, 2015 (United Nations Framework Convention on Climate Change, n.d.). It is an agreement providing the Framework for future international cooperation and national action on climate change. During the agreement design, one of the main goals was to limit the average of the global warming around 2.7°C by 2100, as some modelling incorporating the measures pledged by each signing party showed it as a possibility, along limiting the temperature increase to 1.5°C above pre-industrial levels. To reach these goals was to have the greenhouse gas emissions peak before 2025 at the latest with 43% decrease by 2030 (*The Paris Agreement* | UNFCCC, n.d.). Such initiative required the perception of climate change by national governments to shift from it solely being a threat, to the response to climate change as an opportunity for human, their health and wellbeing. It was to help that transition that was created the Lancet Countdown during the 2015 Lancet commission.

## 1.2 The Lancet countdown initiative

To map out the impact of the climate change and the needed policy responses to achieve the highest attainable standards of health for all population, a commission on health and climate change was established by the Lancet (The Lancet Commission on Climate and Health, 2015). The Commission on health and climate change believed though some actions on climate change are being implemented by international organisations such as the G20, IPCC, UNFCC and the World Health Organization, the health aspect of the crisis that is climate change has been neglected. There was the need for an independent accountability and review process centred on health to achieve this transition. Historically such independent actions have known success, examples are the Countdown to 2015 child survival group and the Global Health 2035 group among others (Watts et al., 2015).

The Lancet Countdown to 2030 was created as a coalition of experts across disciplines (from health to economics) grouped under five interrelated thematics that monitors and report annually a summary of evidence of the health impacts of climate change before the international negotiations of the UN Framework Convention on Climate Change through a set of approximately 40 indicators that ensure comparison over time and or space across sectors, hence tracking progress and possible areas for improvement (Watts et al., 2017). Aside presenting the health impacts, it aims as well to track the speed of the transition to a decarbonized global economy, analyse and show the available health benefits, give a global

picture of successes and obstructions to the shift, and draw out exemplary case studies for shared learning, while engaging with policy makers and the broader health community (Watts et al., 2017). The objective of the commission’s report is to act as an addition instead of a substitute to existing work such as the UN reports and the IPCC’s (Watts et al., 2015).

The initiative made its mission to represent the cycle of climate change with a health perspective. The figure below (Figure 2) was designed to present the existing interaction between the sections of the lancet countdown in such regards. Being aware of the possible health hazards informs what should be the needed adaptation methods to alleviate the climate change impact on health, methods that may require economic and financial support. Such support will often be readily available the more there is a public and political engagement. And to be able to reduce those health hazards there is a dire for mitigation actions. In its reports the initiative quantifies the health impacts, underscores how the delayed or lack of action exacerbates the burden of disease, put a toll on the economy. The initiative successful frames climate change as not only the environmental issue that it is always considered as, but also as the greatest public health challenge that it is in this 21st century (Kastler, 2019).

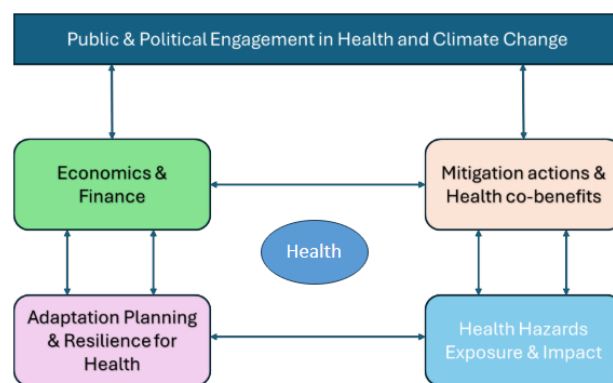


Figure 2: Interaction of the sections’ themes (the five groups) of the Lancet Countdown

The Lancet Countdown on Health and Climate Change has served a variety of purposes since its creation such as being used as guidance in national policies. Its 2020 report served as a guidance in the UK to the NHS’s climate resilience plans and National Adaption Programme (NAP3) though the Health and Care Adaptation Report (NHS England, 2021). It has also contributed to countries’ policies through its policy brief addressed to specific country. The initiative has also helped guiding the allocation of funds, as seen with the Green Climate Fund which has been assigning their financing based on the vulnerabilities (sectoral and regional) identified through the initiative’s reports. Non-Governmental Organisations are counted among the users of the reports as through it they identify where their actions are needed the most and even evaluate themselves in the transition towards a more sustainable system, with the Médecins Sans Frontières for example. The reports themselves have served

as a grid of evaluation for government regarding possible actions where they are falling short as seen by the 2017 Australian report: Australian policy inaction threatens lives (Zhang et al., 2018).

### 1.3 Rationale for a Regional Adaptation of the Lancet Countdown

Although the entire planet suffers from climate change, the local effects differ both in nature and severity according to where it is occurring. As diverse the social, economic, political and environmental characteristics are, they in themselves create inequalities and vulnerabilities across the regions. These inequalities are then exacerbated by climate change as it acts as a threat multiplier; a low-income community with limited irrigation system may suffer more from food security and debt as droughts become more frequent and severe due to climate change. The effect of geography on climate vulnerability goes beyond climate zones, while communities may share comparable risks being in the same climate zones, the actual risks can significantly vary according to other factors such as infrastructures in the case of flooding. (Solomon et al., 2025) Those variations can be between two regions from different continents, but as well as in the same country. This was outlined in the French context by the Réseau Action Climat (2024) stating: the impact of this climate change is as diverse as are the French landscapes, and the consequences are not the same from a territory to another. Though works or reports at higher level may be useful to some extent, they tend to aggregate regional variation and the underlying conditions of vulnerability (Windfeld et al., 2019). This is case of the Global and European Lancet Countdown, as they try to represent as much as possible the situation of climate change; but having a large geographic coverage fewer heterogeneity is observed.

To address climate change, governments develop and have been developing policies, action plans, an example in France is the “National Climate Change Adaptation Plan” (Plan National d’Adaptation au Changement Climatique - PNACC). Some of those actions have been passed down to local governments for implementation, as a successful action for climate change necessitates a coordination at multiple levels (Dany & Lebel, 2020), the Regional Health-Environment Plan (Plan Regional Santé Environnement [PRSE]) is an example of local translation of a national policy in France. A decentralized tool is expected to lead to measures that are more appropriate for the local context when it comes to adaptation, planning and resilience as they consider local factors (Amundsen et al., 2018). Mandating the local governments a role when some resources might be missing can result in the policy failure. Aguiar et al. (2018) reported in their work some barriers faced by local implementation of adaption such as limited capacity in research communities, lack of data, lack of knowledge generation, lack of knowledge exchange, lack of scientific knowledge in the vulnerability. In

France a dynamic in the climate action is seen as well through the setting of instances such as the Haut Conseil Breton pour le Climat (HCBC) and even the Observatoire de l'Environnement en Bretagne (OEB) which generate environmental related climate change indicators. But such action appears as wobbling as no places seemed to be found for health in the transition, a need for a wholistic intervention.

Having an initiative like the Global Lancet Countdown that answers such needs at a corresponding level, there is the question of its presence at a more local level that will be used to guide local adaption, planning and resilience action, improving the population's health. The European Lancet Countdown was designed with such thought, motivated and encouraged by one of the IPCC reports (2023 Synthesis Report) stating more regional works were needed to properly address the growing issue that is climate change and health. Regional assessments can complement the global and national actions as they may produce a faster and more targeted action at the local level. The importance of the engagement of all levels of government in addressing climate change was outlined in the Paris Agreement (*The Paris Agreement* | UNFCCC, n.d.), highlighting the importance of the possibility as well of the countdown initiative at a regional level.

## 1.4 Objectives

The objective of the project is to evaluate the feasibility of adapting the Lancet Countdown indicators at the regional feasibility; for this project the geographical coverage will be the region of Brittany, France. For the development of a Breizh Lancet Countdown, a local variation of the initiative, our study objectives are:

- To identify the relevant climate health indicators by reviewing the Lancet Countdown indicators (2.1)
- To identify the environmental concerns specific to Brittany (2.2)
- To evaluate the local data availability of the relevant indicators by assess existing regional datasets for completeness and accessibility. (2.3)
- To compute and analyse a subset of indicators illustrating a potential dashboard of a Breizh Lancet Countdown. (2.4)

## 1.5 Brittany – The experimental territory

Brittany is one of the 18 regions of France; it is found in the northwest part of the country. The region consists of four departments Côtes d'Armor, Finistère, Ille-et-Villaine and the Morbihan for a total surface of 27200 km<sup>2</sup> with Rennes as its capital. Its climate is one qualified as oceanic with an average annual temperature of 12 °C with rainfall varying from 700 to

800mm. According to the Institute National d'Etudes Démographiques, its population is of 3475895 habitants. Aside from Rennes Metropole found inland, the population is quite dense along its coastline in cities as Quimper, Lorient, and Vannes in the south, Brest in the west and Saint-Brieuc in the north. The region has the longest coastline in the country, with 2730 km that consists of around one third of the national coastline. It is a region that relies heavily on the agricultural sector with 1.7Mha (62%) of its lands devoted to agriculture, while providing a working activity to 7% of its population (Djomo et al., 2023). Among the region, Brittany is the first region in terms of agricultural product and agri-food, its production accounting for 58% of the country's pork production, 42% of the eggs, 32% of the poultry meat. Its important coastline is also source of revenues employing 74 500 people, which is three times the national proportion. The coastline contributes as well to the region economy due to its link to tourism, another sectoral activity that is considerable in Brittany.

## 2 Methods

This study will start by identifying a suitable set of indicators to assess the adaptability at the regional level, Brittany. Climate concerns specific to the region will be identified, then cross referenced with the Lancet Countdown report's indicators. When applicable the local data will be sourced to compute these indicators at the Brittany level, and selected indicators will be calculated.

### 2.1 Review the Lancet Countdown indicators

To monitor and track the impact of climate change on health as well as the policies and actions designed, the Lancet Countdown proposed a set of indicators spread across five themes: (1) climate change impacts, exposures, and vulnerability; (2) adaptation, planning, and resilience for health; (3) mitigation actions and health co-benefits, (4) finance and economics; (5) public and political engagement (Watts et al., 2018). From the creation of the initiative, the commission has been producing a yearly report.

To identify the set of indicators that will serve as the basis for the regional indicators, a spatiotemporal analysis of the available reports of the Lancet Countdown were done. The reports were collected from the initiative website "lancetcountdown.org" under the section "Resources" → "Our Reports", as well as from PubMed with the search key: "Lancet countdown" AND "climate change" AND "report". There were no restrictions applied on the language and time frame. The detail of the search is provided in Table 1.

Platform	# of Reports/Articles
Lancet Countdown initiative Website	26
PubMed	43

Table 1: Documents Search Results for the Lancet Countdown Reports

All the reports from the Lancet Countdown website were included. The 44 found from PubMed were screened to ensure they were reports presenting list of indicators from the Lancet countdown or from work based on the Lancet countdown. To be included they needed to present a format or content like the Lancet Countdown.

## 2.2 Identification of the regional climate-environmental concerns in Brittany: document corpus

Developing a countdown with a set of criteria necessitates to clearly define the concerns of the region of interest, here Brittany, as for the indicators to serve their purposes of tracking over time the evolution of the concerns, they need to be specific, tailored. To identify those concerns specific to Brittany, a document corpus was constructed through a purposeful sampling; this was to ensure only “information-rich” documents on the topic of interest would be selected, rather than trying to exhaustively capture every possible text. A map of possible stakeholders, institutions and policies relevant in the field of environmental and health was established to direct the search of the corpus’ documents and help disentangled the complexity of the interaction between the stakeholders and policies related to climate change (see appendices 1).

### 2.2.1 Selection criteria

To ensure consistency and transparency the following inclusion and exclusion criteria were used:

- Geographic coverage: documents that cover the Brittany region, inter-municipalities
- Type: strategic frameworks, key reports, plans produced by authorities
- Topic of interest: the document should address at least one of the following:
  - Climate hazards
  - Air-energy
  - Environmental stakes
- Timeframe: implemented version or produced since 2010

Non-valid grey literature (without official endorsement), and documents produced at a communal level or below were excluded.

## 2.2.2 Data extraction and synthesis

For the document selected the following information were recorded:

- Title, publication's year
- Geographical coverage
- Timelines
- The identified concerns

## 2.2.3 Indicators – concerns matrix

The Brittany concerns identified through the literature review were tabled with the five groups of the European lancet countdown's indicators. At the intersection, the indicators corresponding were identified. When possible, for themes not having indicators mentioned in reference set, indicators from the bank of indicators made from all reports will be used.

## 2.3 Data availability assessment

To assess the availability of the indicators, the equivalence of all the original datasets at the regional level will be ascertained. The data will be grouped according to their nature (whether demographic, environmental and so on, this will ease the search through the national and regional databases. Indicators for which the equivalent regional data were not obtained are highlighted (bolded).

## 2.4 Indicators Computation

The end goal of the study being to identify possible indicators that will help in the transition, this section presents as the result of the precedent steps (what are the concerns of the region? Are the data available?) a sample of three indicators to be part of the Breizh Lancet Countdown initiative, those indicators were chosen based on computation time convenience. A resumed methodology is presented below and a further detailed in the appendices 6.4 to 6.6. Those indicators are an example of what would the Breizh indicators be:

### 2.4.1 Indicator 1.1.1: Vulnerability to Extremes of Heat

The indicator expresses the geographical vulnerability of a region to heat according as the mean proportion of the population aged 65 years and above, the proportion of the population living in urban settings, and the prevalence of three comorbidities (diabetes, respiratory diseases, cardiovascular diseases) among those aged 65 and above. In the present setting the last component was adjusted to the prevalence of the three comorbidities among the whole Brittany population. (Daalen et al., 2024)

Data required: Population data - INSEE, Comorbidities - CNAM

## 2.4.2 Indicator 2.1.1|2.1.2|2.1.3|2.2.1: Local assessment of climate change impact and vulnerability for health

The indicator expresses the vulnerability assessment and the provision of climate data to the health sector in the region. Originally done using the WHO Health and Climate Change Global Survey not available at the setting level, the existence of assessments of the Public Establishments for Intercommunal Cooperation (Etablissements de Coopération Intercommunale - EPCIs) in Brittany was used. (Daalen et al., 2024)

Data required: Suivi national de l'avancement des PCAET - ADEME

## 2.4.3 Indicator 3.1.1: Carbon intensity of the energy system

The indicator translates the level of fossil fuel use, which is associated with air pollution impacts. It is calculated by dividing the total CO2 emissions from fossil fuel combustion by the total energy supply. (Daalen et al., 2024)

Data required: CO2 Emissions from fuel combustion – OEB, Total energy supply – OEB

The computation and analysis of the data for the above indicators were done using mainly the tools R and QGIS.

# 3 Results

## 3.1 Lancet Countdown indicators

From both the Lancet Countdown website and PubMed after removing the duplicates and those that were not report of indicators, a combined set of 28 reports were obtained since the creation of the initiative in 2015. Those reports were spread across three levels, global, regional and national (figure 3).

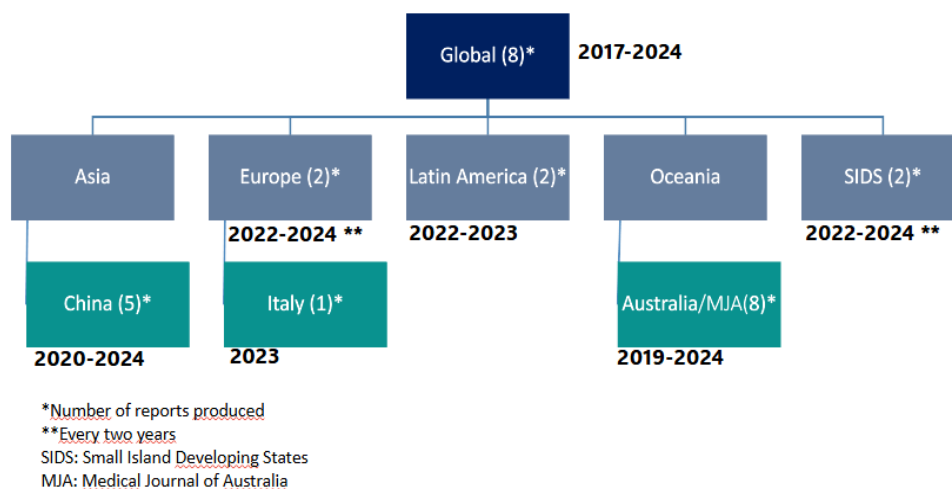


Figure 3: Organigram of the Lancet Countdown and the number of reports produced

Given that Brittany is a region of France and France is within the European Union, this study opted for the Global – Europe lens. The set of indicators of the European Lancet Countdown (Table 2) will be used as basis for the analysis regarding the specificities of Brittany. This was supported as well by the list of indicators of the National Lancet Countdown indicators of Italy, a neighbouring country, which is a subset of the European Lancet Countdown indicators. Indicators of the other regions will be considered as a source of potential indicators to be added to Brittany’s when needed (appendices 6.2). From now on, the mention of region will refer to Brittany as a region of France unless mentioned otherwise.

Table 2: 2024 European Lancet Countdown Indicators

Section	Indicators	
Health hazards, exposures, and impacts	1.1. Heat and health	1.1.1. Vulnerability to heat exposure
		1.1.2. Exposure of at-risk populations to heatwaves
		1.1.3. Physical activity-related heat stress risk
		1.1.4. Heat-related mortality
	1.2: Health and extreme events	1.2.1: Wildfire smoke
		1.2.2: Drought
	1.3: Climate-sensitive infectious diseases	1.3.1: Climate suitability Vibrio
		1.3.2: Climate suitability West Nile Virus
		1.3.3: Climate suitability for dengue (chikungunya and Zika)
		1.3.4: Climate suitability Malaria
		1.3.5 Climatic suitability for Leishmaniasis
1.3.6 Climatic suitability for ticks		
1.4: Allergens	1.4.1: Allergenic trees	
1.5 Food and water	1.5.1 Food security	
Adaptation, planning, and resilience for health	2.1: Adaptation planning and assessment	2.1.1 National assessments of climate change impacts, vulnerability and adaptation for health
		2.1.2 National adaptation plans for health
		2.1.3 City-level climate change risk assessments
	2.2 Adaptation delivery and implementation	2.2.1 Climate information for health
		2.2.2 Exposure to green space
		2.2.3 Air conditioning benefits and harms
Mitigation actions and health co-benefits	3.1 Energy system and health	3.1.1 Carbon intensity of the energy system
		3.1.2 Coal phase-out
		3.1.3 Renewable and zero-carbon-emissions energy
	3.2 Air pollution and health co-benefits	3.2.1 Premature mortality attributable to ambient fine particles

		3.2.2 Production-based and consumption-based attribution of CO2 and PM2.5 emissions (NEW)
	3.3 Sustainable and healthy transport	
	3.4 Food, agriculture, and health	3.4.1 Life cycle emissions from food demand
		3.4.2 Sustainable diets
	3.5 Health sector emissions and harms	
Economics and finance	4.1 Health-linked economic impacts and mitigation of climate change	4.1.1 Economic losses due to climate-related extreme events
		4.1.2 Heat impacts on labour supply
		4.1.3 Impact of heat on economic activity
		4.1.4 Monetised value of unhealthy diets
	4.2 Economics of the transition to zero-carbon economies	4.2.1 Net value of fossil fuel subsidies and carbon prices
		4.2.2 Clean energy investment (NEW)
Public and political engagement	5.1 Scientific engagement with health and climate change (NEW)	5.1.1 Coverage of health and climate change in scientific journals
		5.1.2 Coverage of studies on the health impacts of anthropogenic climate change in scientific articles (NEW)
	5.2 Individual engagement with health and climate change on social media	
	5.3 Political engagement with health and climate change	5.3.1 Engagement with health and climate change in the European
		5.3.2 Political engagement with health and climate change on social media
	5.4 Corporate sector engagement with health and climate change	
5.5 Media engagement with health and climate change (NEW)		

The first set of indicators of the European Lancet Countdown was produced in 2022, with the idea of providing more European related indicators. As the global one, it has known an evolution. The report went from 33 in 2022 to 42 in 2024, 11 indicators to 14 in the first section, seven to nine for the third section, five to six for the fourth section, and four to seven in the fifth and last section, with the only section which remained the same being the second. In comparison the evolution of the global Lancet is more marking, from 31 when considering the first report to be 2017 to 56 indicators in 2024. With the global Lancet having a longer timeline, the dynamic evolution of the indicators is more observable, some being removed and later reincluded.

## 3.2 Regional climate-environmental concerns in Brittany: document corpus

The purposively constructed corpus consisted of 37 authoritative instruments, each covering one or more dimensions of climate health, environmental stakes. Table 3 provides a summary of their key characteristics.

Table 3: Document corpus

Documents	#	Geographical coverage	Date	Scope and Legal Status	Source
SRADDET	1	Region	2021	Regulatory	(Région Bretagne, 2021)
PRSE4	1	Region	2023	Regulatory	(Région Bretagne, 2024)
HCBC reports	3	Region	2023-2025 (Annual)	Non-regulatory (monitoring)	(Haut Conseil Breton pour le Climat [HCBC], 2023, 2024, 2025)
OEB « chiffres clés de l'évolution du climat en Bretagne »	1	Region	2025	Synthesis of regional indicators (monitoring)	(Observatoire de l'environnement en Bretagne, 2025)
Profil environnemental Bretagne	1	Region	2013	Reference document (non-binding)	(Direction Régionale de l'Environnement, de l'Aménagement et du Logement [DREAL], 2013)
PCAETs diagnostic	30	EPCIs	2015-2023	Mandatory	(ADEME, n.d.)

- SRADDET: the Schema Regional d'Aménagement, de Développement Durable et d'Égalité des Territoires produced by the Brittany Region is a document that sets the strategic framework for the region sustainable development.
- PRSE4: the fourth Regional Health and Environment Plan jointly coordinated by the Regional Health Agency (ARS), the Regional Prefecture, and the Regional Environmental Authority (DREAL) outlines the main health risks associated with environmental factors with the needed actions to reduce them
- HCBC Reports: From the Haut Conseil Breton pour le Climat, the reports provide some experts assessments and recommendations to guide the region climate policy and accelerate the transition.

- OEB – "Chiffres clés de l'évolution du climat en Bretagne" : Published by Observatoire de l'Environnement en Bretagne, it presents the environmental region profile in regards to climate change.
- Profil environnemental Bretagne: produced by the Direction Régionale de l'Environnement, de l'Aménagement et du Logement, this document provides an environmental diagnostic of the region along the concerns and strategic plans for an ecologic transition.
- PCAET diagnosis: the diagnosis of the Plan Climat Air Energie Territorial is an imposed assessment to any EPCI with a population of more than 20,000 habitants. It provides all the specificity of the territory along its vulnerability.

The concerns identified through the document corpus were:

### *3.2.1.1 Coastal retreat and marine submersion*

The document corpus analysis revealed coastal retreat and marine submersion as one of the region's major concerns. With its 2730km of coastline, all four departments are no exemption to this concern. This is supported by a combination of data trends and policy developed. According to the Observatoire de l'Environnement en Bretagne, 315km of the region cliffs are in a state of erosion which represents 19.2% of the rocky coasts. Among its departments the Morbihan, located in the south, is the most concerned as it contains around half of the region's rocky coasts. The issue is highlighted as well by coastal PCAETs' diagnosis such as the Quimperlé Communauté's and the Pays d'Iroise's, where a retreat of 0.5 to 2.0 meters per year is observed. The HCBC discusses the concerns while highlighting the role of the ocean. Due to his capacity to rapidly transport vast quantities of sand and heavy granite blocks, it causes a faster retreat of the coastline than the terrestrial process. Aware of the concerns, this led the SRADDET to identify some locations as "zones à enjeux forts" for which a ban on new construction is applied for those at risk in the next 100 years of erosion, a type of adaptation measures.

### *3.2.1.2 High temperature and heatwaves*

The analysis underscored high temperatures and heatwaves as a critical concern of the region. When referring to the timeline 1961 to 1990 as baseline, the annual temperature in Brittany has risen by 1.4 °C. The seven hottest temperatures post the year 2014, with the record of the hottest days being in Bléruais with 41.6 °C and in La Noé-Blanche with 41.2 °C. According to the Observatoire de l'Environnement en Bretagne heatwaves such as 2003's which are expected to occur every 60 years might now have a frequency of every three years. All PCAET's diagnostics have as well presented the increase in the temperature and their frequency as a concern. In some projections a mean increase in the temperature of 1 to 3°C

by the year 2100 was observed with the hot days in the summer doubling while the frost days would know a decrease. A factor underscored by the ensemble of the corpus was the association of the high temperature with the location; urban and peri-urban areas are particularly exposed to the urban heat island which causes the tropical night. The PRSE4 presented the same concerns with a health perspective. When exposed to the high temperatures of heatwaves for long period of time there is a physiological response of the body to maintain its temperature around 37 °C causing heat stress. During those periods of high temperature Brittany observed an association with an increase of the daily number of health concerns ranging from respiratory issues to deaths. Observed as well by the SRADDET, it addresses some of his objectives such as the 22<sup>nd</sup> to the adaptation of the territory to expected heatwaves and increased temperature.

### *3.2.1.3 Drought and water stress*

Brittany is a region whose hydrogeological context is quite different from the rest of the country with its water dependence being 75% on surface water against 36% for the rest of France. The region has known in the summer of 2022 a shortage of drinking water, as it experienced a long and intense drought, a precipitation deficit of 98 and 94% respectively in Rennes and Brest compared to an average year was recorded. The HCBC highlighted this concern in their 2023 bulletin, where the impacts on both ecosystems and humans' activities are discussed. Being dependent on the agricultural sector which in turn is very dependent on water sources, the Brittany region is very vulnerable to this concern. A trend toward harsher dried spells, has been observed by EPCI's diagnostic reports such as Pontivy Communauté, Plöermel communauté and Cornouaille Agglomération. A specific observation regarding the concern that might cause its underestimation was that the annual average precipitation may appear stable but throughout the year a distortion occurs leaving few periods with intense precipitation while the rest of the year undergoes a dry period. The concern is also seen as tension between competing uses of water is emerging. In the summer some small catchments and aquifers started showing signs of stress in summer, as the irregular rain patterns do not allow their recharge. According to the Observatoire de l'Environnement en Bretagne, under the +4 °C scenario by the year 2100, the region will know a drop by 26% in its precipitation while droughts will become 47% harsher and be a month longer.

### *3.2.1.4 Air quality*

Though Brittany is not France most populated region, it is a topic of concern for the region. As the temperature increases the air quality worsens, leading to higher ground level ozone concentrations, recurrent air stagnation episode, and longer seasons of pollen. The PRSE4 acknowledging the concerns has recorded an increase in health issues during those seasons,

among susceptible population such as those with asthma. During season of high temperature some EPCIs diagnostic has showed an increase in certain gases emissions such as nitrogen oxides, particulate matter, ammonia, and non-methane volatile organic compound. The high concentrations are the translation of the great share of the region in the country agricultural sectors; this was observed in the SRADDET diagnostic which presented that 13% of the country ammonia emissions were originating from Brittany.

#### *3.2.1.5 Flooding and storms*

Throughout the corpus, the issue that represents flooding for the Brittany region was highlighted. The Observatoire de l'Environnement en Bretagne identified four types to which the region is susceptible, surface runoff due to heavy rain that is not easily absorbed or drained away for 17% of its population, riverine flooding when streams or rivers overflows for 4% of its population, fluvio-tidal flooding, and marine submersion. From 1995 to 2019, flooding had been associated with 98% of the economic losses due to natural disasters. The same risk of flooding is pointed out by the EPCI in their diagnostic, for Plougonvelin the Pays d'Iroise recorded in the last 30 years an increase rate natural disasters due to flooding. The Quimperlé Communauté identified 44% of its municipalities as being at risk of major flooding. Aware of the risks present on its territory, the SRADDET allocated one of its objectives to its adaptation.

#### *3.2.1.6 Ecosystem and food vulnerability*

As a region whose economy majorly rest on the agricultural, ecosystem and food vulnerability is important to Brittany. The ecosystem plays a crucial role in the production of food from fishing to farming. With irregularities emerging in rain patterns, intensity and frequency of hot days, a disturbance in the ecosystem is occurring. A decrease in the development of insects is observed which in turn affect their lifecycle. In the case of pollinators, this may cause them to live not long enough to pollinate or emerge while the trees are not in season. The climate change causes as well, the flooding of farms, longer period of dryness where the cultures are under stress, causing a precocious development of the cultures, vegetables crops are an example. Crops are difficulty produced which affects the feeding production and the animal production. With the increase in CO<sub>2</sub> the acidification of oceans is observed. The marine life is left to go deeper for appropriate temperature or move towards the northern part, causing fishing to less productive. Mortality rates up to 80% for species such as the abalone between Saint Malo and Saint Brieuc, are the translation of the issues.

#### *3.2.1.7 Vector-borne disease*

With the change in climatic conditions such as temperature, conditions are becoming adequate for the development of certain diseases, such as vector-borne as the disease-carrying organisms start to thrive. This is brushed by some diagnosis though not all, presenting

an awakening awareness of the issues. The Arc Sud Bretagne linked the increase in temperature with a rapid maturation of pathogen in the host. The scope is seen through the PRSE4 as well as it presents the potential link of instable or changing climate with the frequency and prevalence of infectious diseases, included the vector-borne diseases.

### 3.3 Indicators – concerns matrix

The table below, presents the intersection of the Lancet countdown indicators with the key concerns in Brittany obtained from the document corpus analysis. Each group of indicators represents a step at which an intervention is possible. The Group 1, climate change impacts, exposure, and vulnerabilities, presents the possibilities to assess the environmental factors which are impacted by the climate change, and to which we may be vulnerable or exposed to. At the same time, it presents the possible burden of some exposition through certain indicators. The Group 2 adaptation planning and resilience for health contains indicator that help assess how the system adjusts, manages the consequences of climate change with mainly a health perspective, assessing how the human actions can alleviate the burden. The third group mitigation actions and health co-benefits assesses the sustainable transition, how the actions regarding the production of greenhouse gas emissions are being shifted towards the null. Simultaneously it presents the burden of those greenhouse gases to underline the importance of the shift. The fourth group economics and finance, assess the economic feasibility of the intended actions and what would be gained or saved by implementing those actions. In the fifth and last group public and political engagement, the indicators assess the awareness of the community stakeholders which are the public, the government, and companies. It also evaluates the engagement of the scientific community to the cause.

Table 4: Matrix: Brittany Concerns – Lancet Countdown Indicators (EU 2024)

Brittany's concerns	Group 1 <b>Assessment</b>	Groupe 2 <b>Adaptation</b>	Groupe 3 <b>Mitigation</b>	Groupe 4 <b>Economics</b>	Groupe 5 <b>Engagement</b>
Coastal retreat and marine submersion	1.4* / 1.5**				
High temperature and heatwaves	1.1.1   1.1.2   1.1.3   1.1.4	2.2.2 2.2.3		4.1.2	
Drought and water stress	1.2.2				

Air quality	1.2.1 1.4.1	2.2.2	3.1.1   3.1.2   3.1.3   3.2.1   3.2.2   3.3   3.4.1   3.5	4.2.1 4.2.2	
Flooding and storms				4.1.1	
Ecosystem and food vulnerability	1.5.1				
Vector-borne disease	1.3.1   1.3.2   1.3.3   1.3.4   1.3.5   1.3.6				

\* From the China Lancet Countdown (2022)

\*\* From the MJA lancet Countdown (2022)

Both indicators can be found in the appendices under the bank of indicators (appendices 2)

### 3.4 Data availability

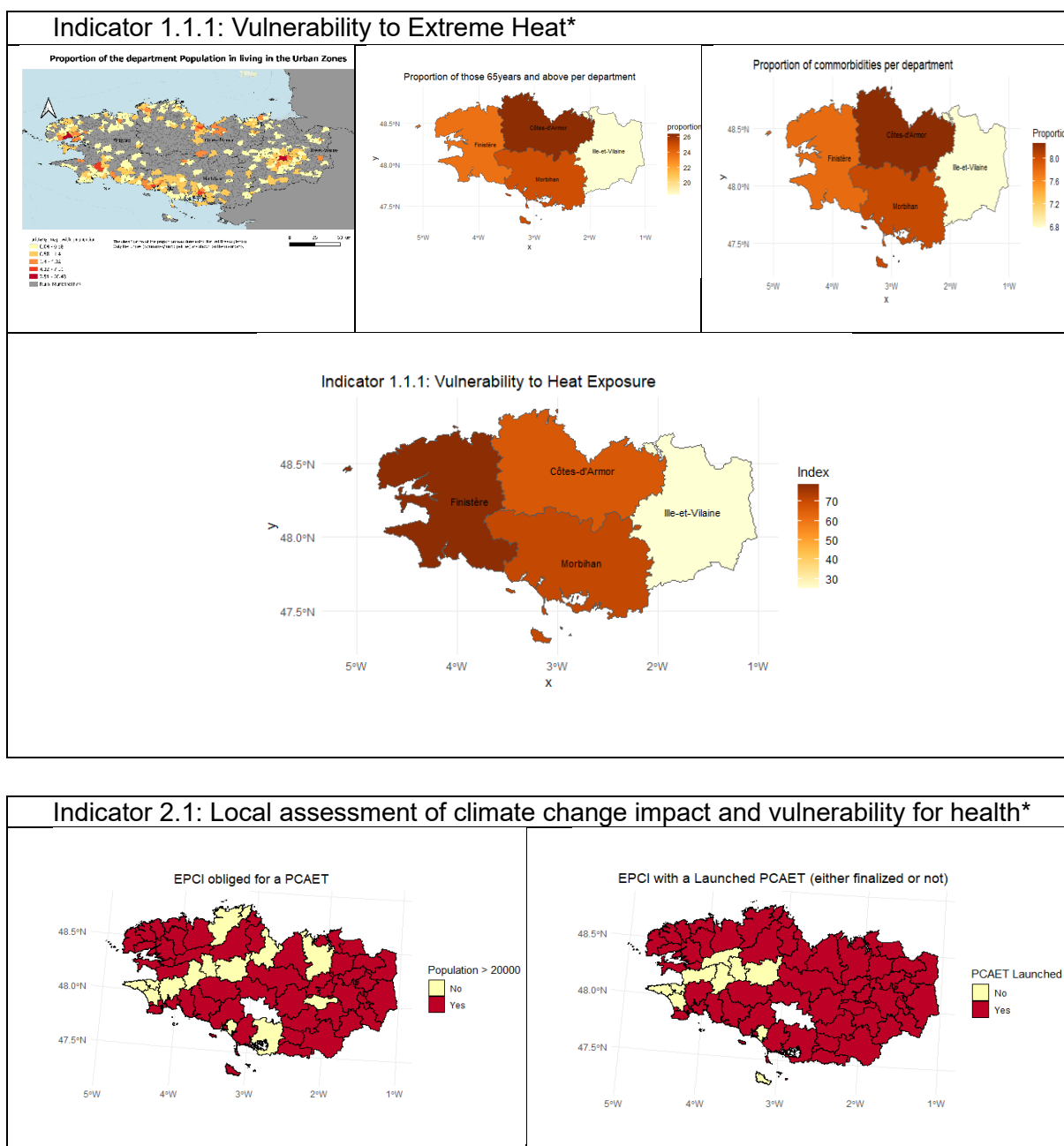
The data needed for the building of the indicator can be grouped into the following socio-demographic, environmental and climate (natural events or occurrence), economic and development, health, agricultural and food, energy and emissions, and the miscellaneous. At the regional level, two major data sources emerge, the Institut National de la Statistique et des Etudes Economiques (INSEE) and the Observatoire de l'Environnement en Bretagne (OEB). The first is France national bureau, a branch of Eurostat, which provides data on the French economy and its people. The second data source is a regional environmental agency in Brittany that has for mission to support the implementation of environmental policies in the region. The datasets can also be divided in groups according to the scale or governmental organisation from the lowest to the highest being municipalities/communes, EPCI, departments, region, country, and global (though they have a regional component of the data).

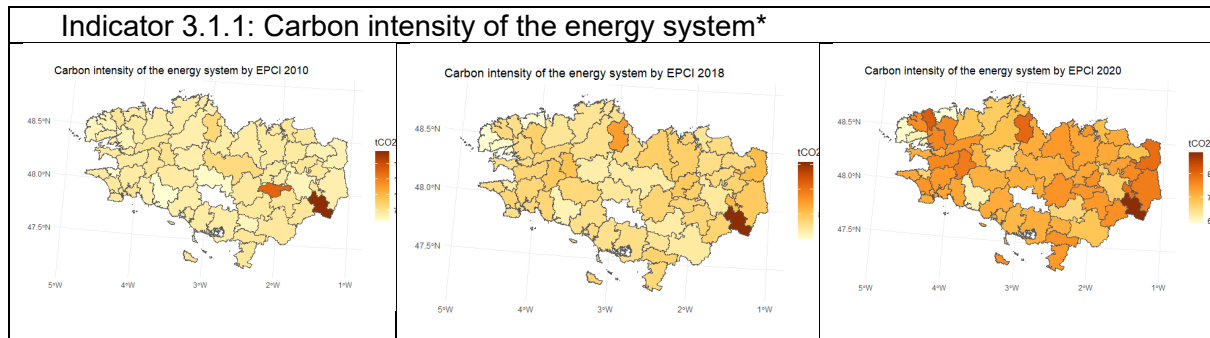
Following the generation of specific themes from the document corpus and the assessment of the data availability, groups of indicators emerged. The first group was those mentioned by the Lancet Countdown that were evoked in the corpus as well and their necessary data for their computation available, such as the indicators 1.1.1 and 3.1.1. The second group were the indicators of adaptation, the response to the awareness of the concerns. There are of an importance as it allows to realise whether or not the community react to the concerns and how so. The methods used to compute such indicators in the European Lancet countdown, are not available in the current settings, hence an adaptation is necessary. The third group contains indicators that would fall under themes highlighted by the corpus but not present in the Lancet

countdown. This would be indicators addressing themes like coastal retreat and marine submersion. A fourth group would englobe indicators of the Lancet that falls under themes presented in the corpus for which if needed to be computed no data were found at the regional level, no adjustment can be made hence imperatively the required data are needed (such as indicators 4.2.1).

### 3.5 Dashboard - Indicators

At the end of the project, indicators specific to the Brittany region will be produced with the goal to help tracking the evolution of climate change in the region. They would be hosted on a dashboard that will continuously be updated. Below, through graphical representation, are a sample of three indicators that will be part of the Brittany set.





\*the map presented for each indicator can be found as well in the appendices under their computation (appendices 6.4.1, 6.5.1, 6.6.1)

## 4 Discussion

The presence of the lancet countdown initiative after its creation at different level highlights the efforts of stakeholders. It expresses a general awakening as well regarding the place of health in the action of climate change (Woodhall et al., 2019). But with this initiative not found everywhere on each scale, it shows there is still a need to pushforward. This was also underscored by Austin et al. (2016) who assessed the place of the public health in the climate change action among the Organization for Economic Cooperation and Development (OECD) countries. The spatiotemporal analysis of the indicators in the pathway world (global) to Europe, revealed though there is an evolution, some indicators are permanently present; and depending on which section they fall under this could indicate: the pervasive characteristic of some of the climate change impact, consistent adaptive measures, or some actions that have proven their mitigating action on climate change. (Abbass et al., 2022)

The assessment of the concerns of our region of interest - Brittany, added to the idea of some well spread climate change impacts. As some of the corpus documents allowed the assessment of the concerns at a level lower than Brittany, the EPCIs, it was seen concerns such as the increasing frequency and intensity of heatwaves, drought, air pollution that were shared among all of them. Those concerns were also well addressed by the Lancet countdown indicators. The sub-regional assessment revealed a concern that started appearing in some but not all EPCI, the vector-borne diseases. In comparison the Lancet countdown extensively addressed it through the presence of significant indicators. This underscores the evolution of the problematic of climate change and its impacts.

Another concern-related specificity which can be considered as a major reason of the present study, was the expression of concerns by the corpus that were in no case addressed by the lancet indicators (the 2024 European's). For Brittany, coastal retreat and marine submersion represent a constant and important concern in the setting of climate change.

Being a region with 2730 km of coastline on which depends a share of its economy depending (Mathew et al., 2020; Harney et al., 2023), it is a concern that need to be addressed or considered. Among the 2024 European Lancet Countdown indicators none were addressing this specific concerns, though it was found addressed in other sets of indicators such as the 2023 China Lancet Countdown, the 2022 MJA lancet countdown, and even the 2023 Global Lancet Countdown.

This identification of the Brittany concerns crossed to the lancet countdown indicator, revealed the need to have a set of indicators that will specifically address the need of the region of interest while providing a support to the intended transition. At a high geographical level, the relevance of a specific community might be overshadowed as it is singular only to that region. there is a need as well to identify, what should be the lowest desirable level, as there is a risk, when going to low, to be faced with a numerous data that may somehow as well blur the singularities.

The assessment of the data's availability highlighted key findings, the specificity, accessibility, and the level of the data. Some indicators required specific data, such as the catastrophic database, but no such data could be openly obtained. For some indicators, the data available were only of a higher level (national level), the decentralized institutions made used of those exact national number without any adaptation, causing them to be less specific to the region hence affecting the indicator computed as well. This underscored the need for an active production of regional data, as they serve as the foundation for the intended shift. Another key finding was the dispersion of the data. Collecting data even under the same categories, necessitated going through diverse depositories. This could harden the design of indicators, as some data might be considered "missing" or "inexistant" due to their inaccessibility instead of a true non-existence. The importance of the data availability is expressed by both the scientific community which can be considered responsible for the generation of the indicators (Faghmous & Kumar, 2014; Schnase et al., 2016), and international key stakeholders in climate change such as the United Nations Environment Programme Finance Initiative (2024).

A continuity of the study is an expert interview. A group of experts according to the main themes of the lancet will be organized. This will serve to gain their insight on the initiative. As actions on climate change are already taken in Brittany with the setting of environmental indicators such as those by the Observatoire de l'Environnement en Bretagne (OEB), there is a need to ensure the place of health. The toll on the society resulting from climate change cannot be address without a consideration of health, as it is core to the community. Having

the region stakeholders involved in the initiative will as well ensure its success, hence reaching the goal of the transition in the best terms possible.

## 5 Limitations

Due to the lack of data on Brittany in peer reviewed journals, the making of the document corpus rested on the purposeful selection of documents considered to represent the Brittany situation. The purposeful selection may have led to the exclusion of some documents that would have presented a perspective of the concerns not caught by the present document corpus. Under the selection of documents for the PCAETs, the list of the available by ADEME was used hence PCAETs of EPCI that may have started or finished without have it presented by ADEME may not have been included.

The concerns identified may not constitute the exhaustive list of the regions. The present project is an on-going project as it will move to an expert consultation for the identification of possible lacking concerns from the present list.

The indicators presented should not be used as criteria of evaluation, but solely as tools to follow the evolution of the transition in the current local context that is Brittany. Care should be taken to not compared the present indicators to another region without considering the methodology used.

## 6 Conclusion

The effects of climate change are becoming more common and intense, occasionally being the same from region to region, or varying due to the regional characteristics. Human activity has been observed to play a crucial role in its evolution, hence making addressing those activities the best answer to the issue. Among the things affected by climate change, the health of the population is no exception, with direct and indirect consequences. As to address the issue that is to public health, actions are taken at different level varying from assessment, adaptation to mitigation. Following the prediction of the issue, the mitigation actions can be considered as falling short making the mitigating crucial.

In Brittany some actions are taken which are perceivable through the effort of the region with the existence of the Haut Conseil Breton pour le Climat, and the Observatoire de l'Environnement en Bretagne which produce some environmental indicators to help the transition. While those actions are made, the place of health a key element to the communities is being overlook. There is a pressing need to help stakeholders recognize and make use of the pillar that is health as a central element of the climate transition.

The Lancet Countdown launched by the Lancet Commission on health and climate change, represents a suitable tool to the mission. From its creation, it has helped both at the global and international level to direct funds, actions; encourage and initiate research in sectors found lacking or in need of actions. Though their actions are to admire, they may find limitations at a lower geographical and or administrative level. This results from the diversities that make the richness of our planet. As the Lancet countdown has been answering to some extent to expectations at corresponding levels, and with success in its transposition at the international level, a transposition at the intranational level appears legitimate. As going from a set and validated method will insure a more successful regional initiative.

The evaluation of such initiative presented a possibility with however some issues to be addressed, such as the accessibility, specificity and level of the data. Though data are existing at national, the disaggregated data are often hard to find causing a seemingly lack of data. A pressing need underscored by the present work, was the need of collaboration just as it was found needed at higher level. Trying to assess or follow the possible impact and evolution of climate change necessitate a wide range of specialists ranging from the health sector to economics.

Ensuring the existence of such initiative, will present a backbone for the transition at the regional level, arming stakeholders with proper information and tool for the development of policy, their evaluation and how to properly allocate the resources that in some case might be limited. This, with the hope of contributing to the action against climate change, the greatest sanitary threat face in the 20th century, but an opportunity as well to redefine determinants of health.

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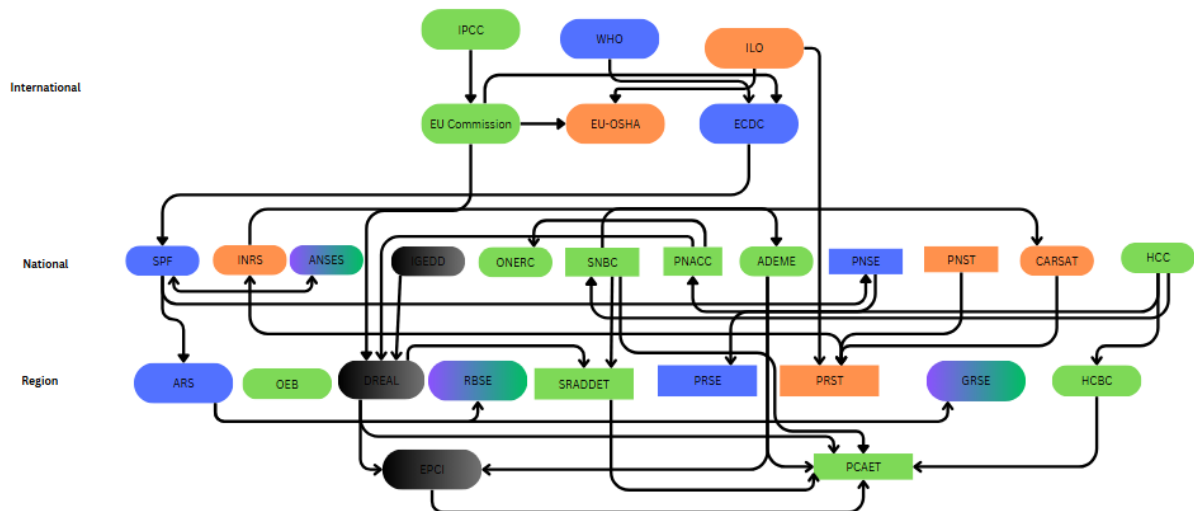
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# APPENDICES

## 6.1 Map of the stakeholders and policies link to climate change



Green: environmental  
 Blue: health  
 Orange: occupational  
 Grey: others  
 Rectangle: plans/strategies/programs  
 rounded rectangle: institutions/organizations

- PNSE – Plan National Santé-Environnement
- PNST – Plan National Santé-Travail
- PRSE – Plan Régional Santé-Environnement
- PRST – Plan Régional Santé-Travail
- PCAET – Plan Climat-Air-Énergie Territorial
- PNACC – Plan National d’Adaptation au Changement Climatique
- SNBC – Stratégie Nationale Bas-Carbone
- SRADDET – Schéma Régional d’Aménagement, de Développement Durable et d’Égalité des Territoires
- SPF – Santé Publique France
- INRS – Institut National de Recherche et de Sécurité
- ANSES – Agence Nationale de Sécurité Sanitaire de l’Alimentation, de l’Environnement et du Travail
- ARS – Agence Régionale de Santé
- CARSAT – Caisse d’Assurance Retraite et de la Santé au Travail
- ADEME – Agence de la Transition Écologique
- IGEDD – Inspection Générale de l’Environnement et du Développement Durable
- DREAL – Direction Régionale de l’Environnement, de l’Aménagement et du Logement
- EPCI – Établissement Public de Coopération Intercommunale
- ONERC – Observatoire National sur les Effets du Réchauffement Climatique
- HCC – Haut Conseil pour le Climat
- RBSE – Réseau Bretagne Santé Environnement
- GRSE – Groupe Régional Santé Environnement
- IPCC – Intergovernmental Panel on Climate Change
- WHO – World Health Organization
- ILO – International Labour Organization
- EU Commission – European Union Commission
- EU-OSHA – European Agency for Safety and Health at Work
- ECDC – European Centre for Disease Prevention and Control

## 6.2 Bank of indicators: Lancet Countdown Indicators not present in the European 2024

World	2024	1.1.4 Rising night-time temperatures and sleep loss
		1.2.3 Extreme precipitation
		1.2.4 Sand and dust storms
		2.2.6 Climate and health education and training
		3.4 Tree cover loss
		4.2.3 Stranded coal assets from the energy transition
		4.2.4 Country preparedness for the transition to net zero
	2023	1.2.3 Extreme weather and sentiment
		1.4 Food security and undernutrition
		2.2.4 Global multilateral funding for health adaptation programs
		2.2.5 Detection, preparedness, and response to health emergencies
		3.1.2 Household energy use
		3.2.2 Household air pollution
		4.1.2 Costs of heat-related mortality
		4.1.4 Costs of the health impacts of air pollution
		4.2.2 Employment in renewable energy and fossil fuel industries
		4.2.3 Funds divested from fossil fuels
		4.2.5 Production-based and consumption-based attribution of CO2 and PM2.5 emissions
		4.2.6 Compatibility of fossil fuel company strategies with the Paris Agreement
		4.2.7 Fossil fuel and green bank lending
	5.3.2 Scientific engagement on the health impacts of climate change	
	5.4.1 Government engagement	
	5.4.2 Engagement by international organisations	
	2022	1.1.4 Change in labour capacity
		2.2.4 Health adaptation-related funding
		2.3 Vulnerabilities, health risk, and resilience to climate change
		2.3.1 Vulnerability to mosquito-borne disease
		2.3.2 Lethality of extreme weather events
		2.3.3 Migration, displacement, and rising sea levels*
		3.2 Clean household energy
3.5.1 Emissions from agricultural production and consumption		
4.1.3 Loss of earnings from heat-related labour capacity loss		
2020	1.4.1: terrestrial food security and undernutrition	
	1.4.2: marine food security and undernutrition	
	2.4: spending on adaptation for health and health-related activities	
	3.6: mitigation in the health-care sector	
China	2022	1.4: population exposure to regional sea level rise*
Latin America	2023	2.2.3 Global multilateral funding for health adaptation programmes
		2.2.3 Global multilateral funding for health adaptation programmes
	2022	3.1.1: Access to clean fuels and technologies
MJA	2024	5.5 Health and climate change litigation in Australia
	2022	1.5 Migration, displacement and rising sea levels*

	2021	1.2 Indigenous health and climate change
		1.3 Health effects of heatwaves
		1.6 Cold- and heat-related mortality
		2.7 Bushfire adaptation
	2019	1.5 Mental health
		4.7 Use of carbon pricing revenues

The bank of indicators presents the list of indicators without any repetitions with the exceptions of those followed by an Asterix (\*) for illustrative purposes.

### 6.3 Regional Adaptability of the indicators' data

Data Source	Data	Indicators
INSEE	Population data Urban population Mortality data Labour data GDP growth data Food security data – Niveau de vie et de pauvreté Deprivation data – SRCV access Health expectancy at birth	1.1.1   1.1.4   1.2.1   1.5.1   2.2.2   3.2.1   3.3   3.4.2   3.5   4.1.1   4.1.2   4.1.3
CNAM	Dalys and deaths	1.1.1
ERA5	Climatic data Temperature data Temperature and SPEI	1.1.2   1.1.3   1.1.4   1.1.2   1.1.3   1.1.4   1.2.2   1.3.2   1.3.3   1.3.4   1.3.5   1.4.6   1.4.1   1.5.1   4.1.2   4.1.3
Eurostat/NASA SEDAC/Zenoob	Population data	1.1.2   1.1.3   1.1.4   1.2.1   1.3.1   1.3.3   3.2.2
Santé Publique France	Daily mortality value WNV infectious data	1.2.1   1.3.2
BNPE EauFrance	Water scarcity	1.2.2
	Corine Land Cover	1.3.4   1.3.5   1.3.6   1.4.1
OEB	CO2 Emission CO2 Emission by sector Total primary coal supply Energy sources	3.1.1   3.1.2   3.1.3   3.2.1   3.4.1   4.2.1

	Energy Consumption Share of electricity from coal Waste	
ODRE	Total Energie Supply	3.1.1   3.2.1
ADEME	Municipality data	3.2.1
Inserm CepiDc	Cause of death	3.4.2
ARS Bretagne	Health expenditure	3.5   4.2.1
France Strategie	Value of statistical life	4.1.4
Agribalyse	Life Cycle Emission	3.4.1
-	Proportion of households with air conditioning	2.2.3
OpenStreetMap		1.3.1
Earth Explorer	Altitude	1.3.4
INCA3	Dietary assessment BMI	3.4.1   3.4.2
Données et études statistiques	Fuel use in energy value Model split of passenger	3.3
Chambre de l'agriculture	Agricultural activity	3.2.1
ATMO-France	Pollen data	1.4.1
France Meteo	ECOCLIMAP	1.4.1
GBIF	Ixodes ricinus presence	1.3.6
ECDC	Vector data	1.3.5
CNR Leishmaniasis	Leishmaniasis data	1.3.5
-	CMIP6 Model	1.3.1
SILAM	Fire smoke dispersion forecasts	1.2.1
-	Fire weather Index	1.2.1
ADEME	PCAET	2.1.1   2.1.2   2.2.1   2.1.3
-	Carbon pricing data	4.2.1
-	Fossil fuel subsidies	4.2.1
-	Catastrophe database	4.1.1
-	Consumer price index	3.5
-	Food availability	3.4.2
-	Food demand	3.4.1

\*Demographic data Health data Environmental/Climate Data Agricultural/Food Data  
Economic Energy/Emissions Data Miscellaneous

\*(-) no regional sources could be identified for those data

## 6.4 Indicator 1.1.1: Vulnerability to Extremes of Heat

```
library(readxl)
library(dplyr)
library(arrow)
library(giscoR)
library(sf)
library(ggplot2)
#####
#proportion of population living in urban area
#####

#uploading the data set, data = base-pop-historiques-1876-2022
#link: https://www.insee.fr/fr/statistiques/3698339#:~:text=Cette%20base%20fournit%20les%20donn%C3%A9es%20de%20populations%20de,%202022%20pour%20les%20communes%20des%20DOM%20%28hors%20Mayotte%29.

munipop <- read_excel(file.choose(), sheet = 1, skip = 1)

#to know the indices of variable which(names(munipop) == "PSDC1999")

#subset the year of year of interest
munipop1 <- munipop[, 1:21]

#subset the municipalities that are in Brittany region = 53
munipop2 <- munipop1[munipop1$REG == 53,]

#re-subsetting the year of interest 2020
munipop3 <- munipop2[, c(1:4, 7)]

#####
##

#uploading the urban composition - which communes is considered urban or not
urban_pop <- read_excel(file.choose(), sheet = 2, skip = 5)
```

```

#subset the variables of interest
urban_pop1 <- urban_pop[, c("LIBGEO", "TYPE_COMMUNE_UU", "STATUT_COM_UU", "DEP",
"REG")]

#subset the region of interest
urban_pop2 <- urban_pop1[urban_pop1$REG == 53,]

#making a new binary variable Urban yes = 1, no = 0
urban_pop2 <- urban_pop2 %>%
  mutate(urban = ifelse(STATUT_COM_UU == "H", 0, 1))

#the urban population dataset that indicated whether a commune is urban or not
#has less observations than the municipalities data 5 to be exact

#checking for extra rows:
extra_communes <- anti_join(munipop3, urban_pop2)

#communes missing in urban_pop: Le Cambout, Coëtlogon, Pléven,
# Pluduno, Saint-Launeuc

#making a dataset that has the population number and whether the place is urban or not
Urban_commune_pop <- munipop3 %>%
  left_join(urban_pop2 %>% select(LIBGEO, DEP, urban), by = c("LIBGEO", "DEP"))

#that one was wrong as it was producing 1218 observations instead of 1206, as
#it duplicated some of them
#Urban_commune_popaa <- munipop3 %>%
#left_join(urban_pop2 %>% select(LIBGEO, urban), by = c("LIBGEO"))

# get the total number of people in urban area per department
urban_pop_dpt <- Urban_commune_pop %>%
  filter(urban == "1" ) %>%
  group_by(DEP) %>%
  summarise(total_pop_urb = sum(PMUN2020))

```

```

## computing the general population (urban + rural)
dpt_tot_pop <- Urban_commune_pop %>%
  group_by(DEP) %>%
  summarise(dpt_tot = sum(PMUN2020))

#adding the total population per department to the data with the pop
#living in urban area per department
urban_pop_dpt <- urban_pop_dpt %>%
  left_join(dpt_tot_pop, by = "DEP")

#computing the proportion of the urban population
urban_pop_dpt <- urban_pop_dpt %>%
  mutate(across(c(2, 3), as.numeric))

urban_pop_dpt <- urban_pop_dpt %>%
  mutate(urb_prop = (total_pop_urb / dpt_tot)*100)

#####

#Making a map that will present the proportion of the urban pop of a department living in communes

#subset only the urban municipalities
only_urban <- Urban_commune_pop %>%
  filter(urban == 1)

#adding to each of those communes the total population for their departments
only_urban_proportion <- only_urban %>%
  left_join(dpt_tot_pop %>% select(dpt_tot, DEP), by = "DEP")

#Compute the proportion of urban population
only_urban_proportion <- only_urban_proportion %>%
  mutate(proportion = (PMUN2020 / dpt_tot)*100)

# Download French communes (NUTS level LAU2)
fr_communes <- gisco_get_lau(country = "FR", year = "2021")

# Filter to Brittany communes

```

```

brittany <- fr_communes %>%
  filter(LAU_ID %in% only_urban$CODGEO)

#merging the map and the proportion
brittany_map_data <- brittany %>%
  left_join(only_urban_proportion %>% select(CODGEO, proportion), by = c("LAU_ID" =
"CODGEO"))

## the map was made on QGIS

#ggplot(brittany_map_data) +
# geom_sf(aes(fill = proportion)) +
# scale_fill_viridis_c(option = "C", direction = -1, name = "% Urban") +
#theme_minimal() +
#labs(title = "Proportion of Urban Population by Municipality in Brittany",
# caption = "Source: INSEE")

st_write(brittany_map_data, "brittany_map_with_proportion.gpkg")

#####
#Proportion of those 65 years and above data= estim-pop-dep-sexe-aq-1975-2025 (year of interest
2020)
#####

age <- read_excel(file.choose(), sheet = 7)

#making subset of interest, we subset by keeping the row of interest from
#4th to 100, and the variable of interest from the first to the 23rd
all_age_total <- age[4:100,1:23]

#fixing the column names (replace the first row with the 2nd row)
all_age_total <- all_age_total %>%
  `colnames<-` (. [1, ]) %>%
  slice(-1)

#making the necessary variables numeric
all_age_total <- all_age_total %>%

```

```

mutate(across(-c(1, 2), as.numeric))

#making the proportion for the 65 and above
all_age_total <- all_age_total %>%
  mutate(
    total_pop_ab65 = rowSums(select(., 16:22)),
    prop65 = rowSums(((select(., 16:22)) / .[[23]])*100)
  )
#subset for the department of interest -2:15 to remove those below 65
age_brittany <- all_age_total[all_age_total$DEPN %in% c(22, 29, 35, 44, 56), -(3:15)]

#####
####

#making a map for the proportion of the 65 and plu sper department
france_dept <- st_read("https://france-geojson.gregoire david.fr/repo/departements.geojson")

brittany_dept_age65 <- france_dept %>%
  filter(code %in% c("22", "29", "35", "56"))

# Ensure same column type
age_brittany <- age_brittany %>%
  mutate(dept = as.character(DEPN))

# Join to spatial data

brittany_map_age65 <- brittany_dept %>%
  left_join(age_brittany %>%
    select(prop65, DEPN), by = c("code" = "DEPN"))

ggplot(brittany_map_age65) +
  geom_sf(aes(fill = prop65)) +
  scale_fill_distiller(
    palette = "YlOrBr",
    direction = 1, # Low = yellow, high = brown
    name = "proportion",
    na.value = "grey90"
  )

```

```

) +
geom_sf_text(aes(label = nom), size = 3) +
labs(
  title = "Proportion of those 65years and above per department"
) +
theme_minimal()
#####
# making the proportion for the target diseases for the department of Brittany
#####

#following the recommendations of the meeting on 12 May 2025
#We will be considering everybody with comorbidities

#Uploading the data
#link: https://data.ameli.fr/explore/dataset/effectifs/table/?sort=libelle\_classe\_age
disease <- read_parquet(file.choose())
head(disease)

#checking the variables and their type
data.frame(variable = names(disease), type = sapply(disease, class))

#checking values of variable
unique(disease$patho_niv1)

#subset the observation of interest sexe = 9 -> tous
disease_all_gender <- disease %>%
  filter(annee == as.Date("2020-01-01") & sexe == 9)

disease_brittany <- disease_all_gender %>%
  filter(region == "53")

#no longer of use as we are considering all ages
#sub_disease2 <- sub_disease1 %>%
# filter(cla_age_5 %in% c("65-69", "70-74", "75-79", "80-84", "85-89", "90-94", "95et+"))

disease_interest <- disease_brittany %>%

```

```

filter(patho_niv1 %in%
  c("Diabète",
    "Maladies respiratoires chroniques (hors mucoviscidose)",
    "Maladies cardioneurovasculaires"))

#keeping the variables interests
disease_data <- disease_interest %>%
  select(patho_niv1, cla_age_5, dept, ntop, npop, prev)

#grouping the number of cases by disease type and then by department
#there were some NAs that got removed
#this give the total prevalence per disease type per department
disease_prevalence <- disease_data %>%
  group_by(dept, patho_niv1) %>%
  summarise(
    weighted_prev = sum(prev * ntop, na.rm = T) / sum(ntop, na.rm = T),
    total_cases = sum(ntop, na.rm = t),
    total_ref_pop = sum(npop, na.rm = T),
  )

#going with the assumptions of independence of the disease, computing the average burden
#for the department
disease_burden_dpt <- aggregate(weighted_prev ~ dept, data = disease_prevalence, FUN = mean)

###removing the 999 default
disease_burden_dpt <- disease_burden_dpt %>%
  filter(dept != 999)

#####
#making a map for the prevalence of the disease per department

brittany_dept_disease <- france_dept %>%
  filter(code %in% c("22", "29", "35", "56"))

# Ensure same column type
disease_burden_dpt <- disease_burden_dpt %>%

```

```

mutate(dept = as.character(dept))

# Join to spatial data

brittany_map_disease <- brittany_dept %>%
  left_join(disease_burden_dpt %>%
    select(weighted_prev, dept), by = c("code" = "dept"))

ggplot(brittany_map_disease) +
  geom_sf(aes(fill = weighted_prev)) +
  scale_fill_distiller(
    palette = "YlOrBr",
    direction = 1,    # Low = yellow, high = brown
    name = "Proportion",
    na.value = "grey90"
  ) +
  geom_sf_text(aes(label = nom), size = 3) +
  labs(
    title = "Proportion of comorbidities per department"
  ) +
  theme_minimal()
#####
#####

#Combine all dataset, to have all variable of interest

urban_pop_dpt_sl <- urban_pop_dpt %>% select(DEP, urb_prop)
age_brittany_sl <- age_brittany %>% select(DEPN, prop65)
disease_burden_dpt_sl <- disease_burden_dpt %>% select(dept, weighted_prev)

combined_df <- urban_pop_dpt_sl %>%
  left_join(age_brittany_sl, by = c("DEP" = "DEPN")) %>%
  left_join(disease_burden_dpt_sl, by = c("DEP" = "dept"))

# Normalize numeric columns to 0-100 scale
normalize_0_100 <- function(x) {

```

```

(x - min(x, na.rm = TRUE)) / (max(x, na.rm = TRUE) - min(x, na.rm = TRUE)) * 100
}

# Apply normalization only to numeric columns
data_indicator <- combined_df

data_indicator[sapply(combined_df, is.numeric)] <- lapply(combined_df[sapply(combined_df,
is.numeric)], normalize_0_100)

#computer the total index
data_indicator <- data_indicator %>%
  mutate(index = (urb_prop + prop65 + weighted_prev)/3)

#####

#making the map
brittany_dept_ind <- france_dept %>%
  filter(code %in% c("22", "29", "35", "56"))

#Ensure same column type
data_indicator <- data_indicator %>%
  mutate(dept = as.character(DEP))

#Join to spatial data

brittany_map_indicator <- brittany_dept_ind %>%
  left_join(data_indicator, by = c("code" = "DEP"))

ggplot(brittany_map_indicator) +
  geom_sf(aes(fill = index)) +
  scale_fill_distiller(
    palette = "YlOrBr",
    direction = 1, # Low = yellow, high = brown
    name = "Index",
    na.value = "grey90"
  ) +
  geom_sf_text(aes(label = nom), size = 3) +
  labs(

```

title = "Indicator 1.1.1: Vulnerability to Heat Exposure"

) +

theme\_minimal()

### 6.4.1 Maps Indicator 1.1.1: Vulnerability to Heat Exposure

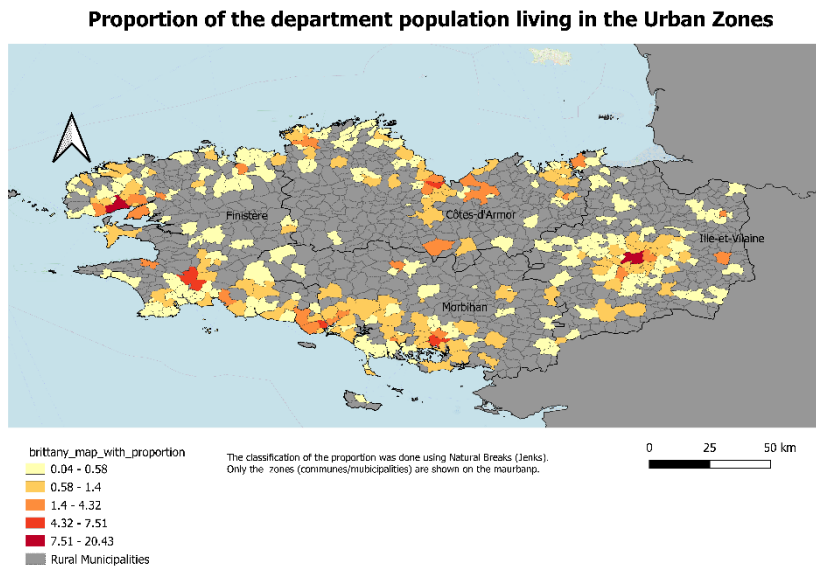


Figure 4: Proportion of the department Population living in Urban Zones

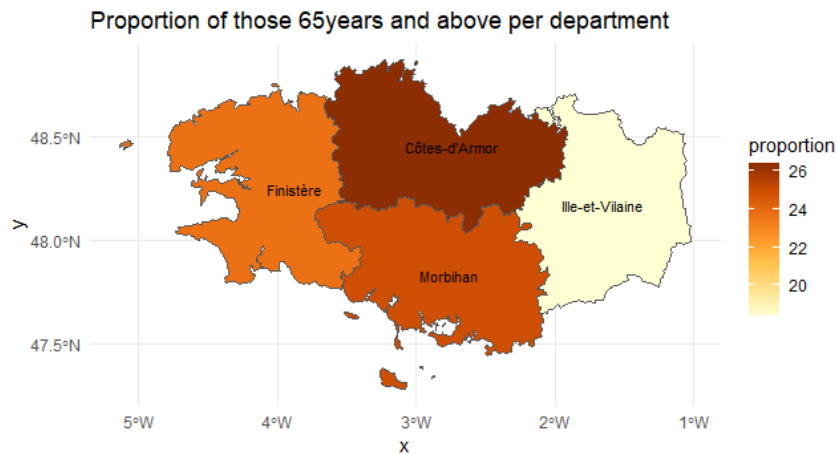


Figure 5: Proportion of those 65 years and above per department

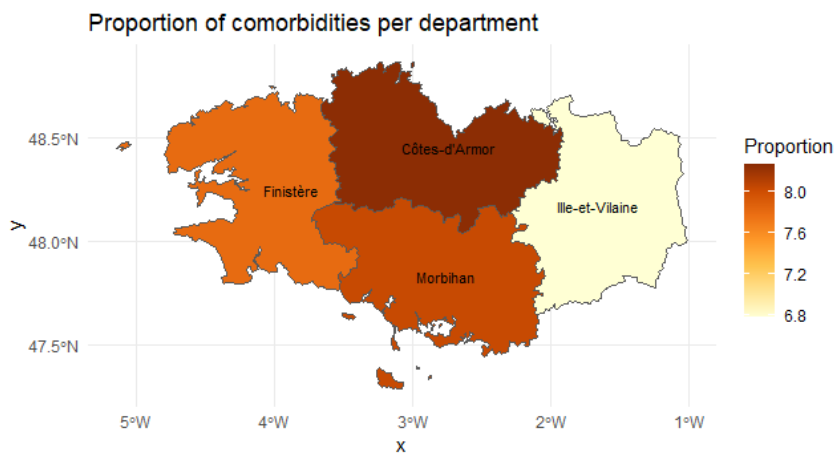


Figure 6: Proportion of comorbidities per department

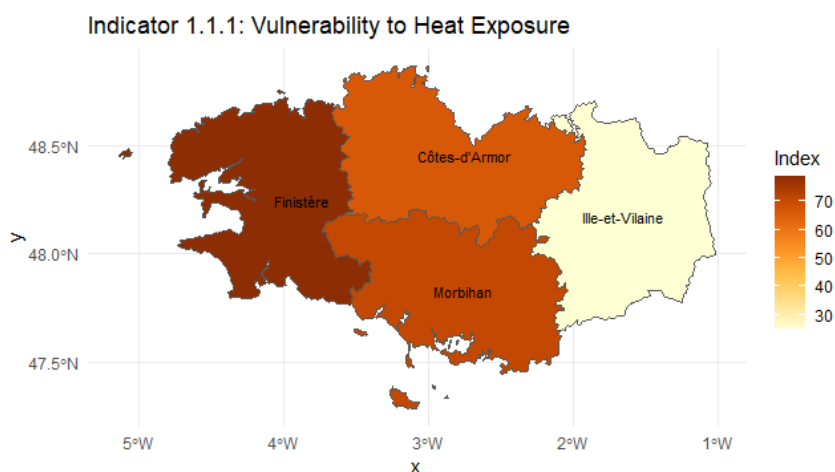


Figure 7: Indicator 1.1.1 Vulnerability to heat exposure

## 6.5 indicator 2.1: Local assessment of climate change impact and vulnerability for health

```
library(readxl)
library(dplyr)
#install.packages("janitor") #it help replace space with underscore and remove all accents
#install.packages("openxlsx")
library(openxlsx)
```

```

library(janitor)

#from the website of ADEME (https://www.territoires-climat.ademe.fr/ressource/652-232)
#collecting the list of the PCAET

PCAET <- read_excel(file.choose(), col_types = "text")

#removing the accents and spaces in the variables names

PCAET <- janitor::clean_names(PCAET)

#colnames(df) <- stri_trans_general(colnames(df), "Latin-ASCII") # Remove accents
#colnames(df) <- gsub(" ", "_", colnames(df)) # Replace spaces with underscores
#colnames(df) <- tolower(colnames(df))

#subset the region of interest

PCAET <- PCAET %>%
  filter(region_siege == "53 - Bretagne")

#sub-setting the variables of interest
#also shows which ones among the EPCI have or do not have a pcaet
PCAET1 <- PCAET %>%
  select(c("n_siren", "departement_siege", "nom_du_groupement", "population",
"lancement_demarche_0_1"))

# the following part will be in word
#making a word for each of the EPCI and upload their doc

#making a dataset for each of the categories

#white group = no PCAET
no_pcaet<- PCAET %>%
  select(c("n_siren", "departement_siege", "nom_du_groupement", "population",
"lancement_demarche_0_1", "date_lancement",
"date_avis_ae", "date_avis_etat", "date_approbation")) %>%
  filter(lancement_demarche_0_1 == 0 & is.na(date_approbation))

```

```

in_process_pacet <- PCAET %>%
  select(c("n_siren",      "departement_siege",      "nom_du_groupement",      "population",
"lancement_demarche_0_1", "date_lancement",
          "date_avis_ae", "date_avis_etat", "date_approbation")) %>%
  filter(lancement_demarche_0_1 != 0 & !is.na(date_lancement) & is.na(date_avis_ae) &
is.na(date_approbation) & is.na(date_avis_etat))

consul_regl_pacet <- PCAET %>%
  select(c("n_siren",      "departement_siege",      "nom_du_groupement",      "population",
"lancement_demarche_0_1", "date_lancement",
          "date_avis_ae", "date_avis_etat", "date_approbation")) %>%
  filter(!is.na(date_avis_etat) & is.na(date_approbation))

pacet <- PCAET %>%
  select(c("n_siren",      "departement_siege",      "nom_du_groupement",      "population",
"lancement_demarche_0_1", "date_lancement",
          "date_avis_ae", "date_avis_etat", "date_approbation")) %>%
  filter(!is.na(date_approbation))

volunteer_pcaet <- PCAET %>%
  select(c("n_siren",      "departement_siege",      "nom_du_groupement",      "population",
"lancement_demarche_0_1", "date_lancement",
          "date_avis_ae", "date_avis_etat", "date_approbation")) %>%
  filter(lancement_demarche_0_1 != 0 & is.na(date_lancement))

#using the 2023 data of the

#checking the EPCI for a PCAET is mandatory
must_EPCI<- PCAET %>%
  filter(population > 20000)

must_EPCI_compared <- PCAET %>%
  select("n_siren", "departement_siege", "nom_du_groupement", "population") %>%
  mutate(have_to = if_else(population > 20000, "yes", "no"))

did_EPCI <- must_EPCI %>%
  filter(!is.na(date_approbation))

```

```

#exporting the list of the EPCI that need to have a PCAET and did it
write.xlsx(did_EPCI, file = "did_pcaet.xlsx")

#making a new dataset that will serve as base to randomly select for the metho the PCAET that
will be analyzed
coastal_epci <- c(
  "CA Lorient Agglomération",
  "CC Auray Quiberon Terre Atlantique",
  "CA Guingamp-Paimpol Agglomération de l'Armor à l'Argoat",
  "CC Leff Armor Communauté",
  "CC du Pays d'Iroise",
  "Brest Métropole",
  "CA Concarneau Cornouaille Agglomération",
  "CC Communauté Lesneven Côte des Légendes",
  "CA du Pays de Saint Malo Agglomération",
  "CC Arc Sud Bretagne"
)

dat1 = did_EPCI

dat1$coastal <- ifelse(dat1$nom_du_groupement %in% coastal_epci, "yes", "no")

dat1 <- dat1 %>%
  mutate(stratum = paste(departement_siege, coastal, sep = "_"))

set.seed(123) # For reproducibility

sampled_epci <- dat1 %>%
  group_by(stratum) %>%
  sample_n(size = 1, replace = FALSE) %>%
  ungroup()

name_li = sampled_epci %>% select(nom_du_groupement)

#####

```

```
#MAKING THE MAP
```

```
france_shapefile <- st_read(file.choose())
```

```
#remove the duplicate in the france shapefile
```

```
france_shapefile_agg <- france_shapefile %>%  
  group_by(CODE_EPCI) %>%  
  summarize(  
    NOM_EPCI = first(NOM_EPCI),  
    cat = first(cat),  
    TYPE_EPCI = first(TYPE_EPCI),  
    ID_list = first(ID),  
    geometry = st_union(geometry),  
    .groups = "drop" # Ungroup after summarizing  
  )
```

```
#subset the EPCI of interest
```

```
brittany_EPCI <- france_shapefile_agg %>%  
  filter( CODE_EPCI %in% PCAET1$n_siren)
```

```
#MAKING THE MAP FOR THE EPCI THAT HAVE LAUNCHED A PCAET
```

```
# Join to spatial data
```

```
EPCI_PCACET <- brittany_EPCI %>%
```

```
  left_join(PCAET1 %>%  
    select(lancement_demarche_0_1, n_siren), by = c("CODE_EPCI" = "n_siren"))
```

```
ggplot(EPCI_PCACET) +
```

```
  geom_sf(aes(fill = as.factor(lancement_demarche_0_1), color = "black", size = 0.3) +
```

```
  scale_fill_manual(  
    values = c("0" = "#ffffb2", "1" = "#bd0026"), # YlOrRd: light yellow to dark red
```

```
    name = "PCAET Launched",
```

```
    labels = c("No", "Yes")  
  ) +
```

```
  labs(title = "EPCI with a Launched PCAET (either finalized or not)") +
```

```
  theme_minimal() +
```

```
theme(plot.title = element_text(hjust = 0.5))
```

```
#Map of the EPCI that have to do a PCAET
```

```
EPCI_PCACET_obl <- brittany_EPCI %>%
```

```
left_join(must_EPCI_compared %>%
```

```
select(have_to, n_siren), by = c("CODE_EPCI" = "n_siren"))
```

```
ggplot(EPCI_PCACET_obl) +
```

```
geom_sf(aes(fill = as.factor(have_to)), color = "black", size = 0.3) +
```

```
scale_fill_manual(
```

```
values = c("no" = "#ffffb2", "yes" = "#bd0026"), # YlOrRd: light yellow to dark red
```

```
name = "Population > 20000",
```

```
labels = c("No", "Yes")
```

```
) +
```

```
labs(title = "EPCI obliged for a PCAET") +
```

```
theme_minimal() +
```

```
theme(plot.title = element_text(hjust = 0.5))
```

### 6.5.1 maps Indicator 2.1: Local assessment of climate change impact and vulnerability for health

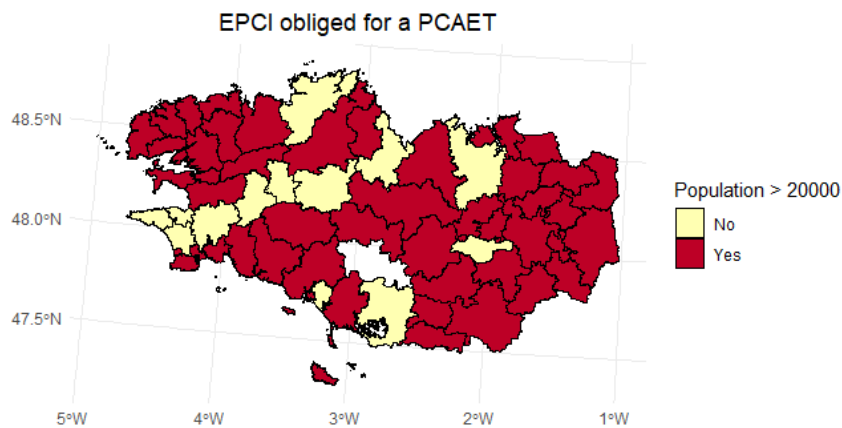


Figure 8: EPCI obliged for a PCAET

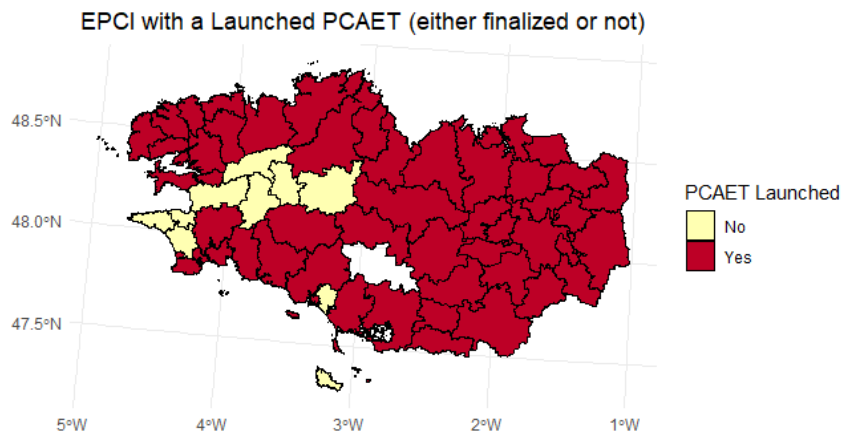


Figure 9: EPCI with a launched PCAET (either finalized or not)

## 6.6 Indicator 3.1.1: Carbon intensity of the energy system

```

library(dplyr)
library(readxl)
library(giscoR)
library(sf)

#upload the dataset of interest
#data = emissions de gaz a effet de serre ges en bretagne
#link: https://data.bretagne-environnement.fr/datasets/emissions-de-gaz-a-effet-de-serre-ges-en-bretagne
carbon_dat <- read.csv(file.choose(), header = T, sep = ",")

#check the summary of the dataset
glimpse(carbon_dat)

#subsetting the secteur, polluant (CO2), and energies of interest
carbon_dat1 <- carbon_dat %>%
  filter(energie %in% c("Gaz naturel", "Produits pétroliers", "Autres"))

carbon_dat2 <- carbon_dat1 %>%
  filter(secteur %in% c("Autres transports", "Agricole", "Industrie hors énergie", "Résidentiel", "Routier", "Tertiaire")) %>%
  filter(polluant == "CO2") %>%

```

```

select(c("nom_epci", "code_epci", "emission", "unite", "annee_ref"))

#making year dataset
carbon_dat_2010 <- carbon_dat2 %>%
  filter(annee_ref == 2010)

carbon_dat_2018 <- carbon_dat2 %>%
  filter(annee_ref == 2018)

carbon_dat_2020 <- carbon_dat2 %>%
  filter(annee_ref == 2020)

#As per EPCI there a row for each sector and energy type will group them
carbon_data_2010 <- carbon_dat_2010 %>%
  group_by(code_epci, nom_epci, unite, annee_ref) %>%
  summarise( Total_emission = sum(emission, na.rm = T))

carbon_data_2018 <- carbon_dat_2018 %>%
  group_by(code_epci, nom_epci, unite, annee_ref) %>%
  summarise( Total_emission = sum(emission, na.rm = T))

carbon_data_2020 <- carbon_dat_2020 %>%
  group_by(code_epci, nom_epci, unite, annee_ref) %>%
  summarise( Total_emission = sum(emission, na.rm = T))

##COMPUTING THE DENOMINATOR *TOTAL ENERGY SUPPLY

#MAJOR INDICATOR ASSUMPTION: there is no loss of energy in the system

#####
#####

#uploading the consommation d'énergie par EPCI en bretagne
#link: https://data.bretagne-environnement.fr/datasets/consommation-denergie-en-bretagne

conso_energy <- read.csv(file.choose(), header = T, sep = ",")

```

```

#susbetting the consommation to keep only the sectors of interest and the energie
conso_energy1 <- conso_energy %>%
  filter(secteur != "Déchets") %>%
  filter(energie %in% c("Gaz naturel", "Produits pétroliers")) %>%
  select(c("nom_epci", "code_epci", "conso_gwh", "annee_ref"))

#making year dataset
conso_energy_2010 <- conso_energy1 %>%
  filter(annee_ref == 2010)

conso_energy_2018 <- conso_energy1 %>%
  filter(annee_ref == 2018)

conso_energy_2020 <- conso_energy1 %>%
  filter(annee_ref == 2020)

#As per EPCI there a row for each sector and energy type will group them
consom_energy_2010 <- conso_energy_2010 %>%
  group_by(code_epci, nom_epci, annee_ref) %>%
  summarise( Total_conso_gwh = sum(conso_gwh, na.rm = T))

consom_energy_2018 <- conso_energy_2018 %>%
  group_by(code_epci, nom_epci, annee_ref) %>%
  summarise( Total_conso_gwh = sum(conso_gwh, na.rm = T))

consom_energy_2020 <- conso_energy_2020 %>%
  group_by(code_epci, nom_epci, annee_ref) %>%
  summarise( Total_conso_gwh = sum(conso_gwh, na.rm = T))

#there is a discrepancy in the name of 3 EPCI, in consom data they have upper
#case in the middle
consom_energy_2010 <- consom_energy_2010 %>%
  mutate(nom_epci = ifelse(nom_epci == "Ouessant (Commune)", "Ouessant (commune)",
nom_epci)) %>%
  mutate(nom_epci = ifelse(nom_epci == "Île-de-Bréhat (Commune)", "Île-de-Bréhat (commune)",
nom_epci)) %>%

```

```
mutate(nom_epci = ifelse(nom_epci == "Île-de-Sein (Commune)", "Île-de-Sein (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "CA de la Presqu'île de Guérande Atlantique (CAP
ATLANTIQUE)",
```

```
"CA de la Presqu'île de Guérande Atlantique (Cap Atlantique)", nom_epci))
```

```
consom_energy_2018 <- consom_energy_2018 %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "Ouessant (Commune)", "Ouessant (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "Île-de-Bréhat (Commune)", "Île-de-Bréhat (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "Île-de-Sein (Commune)", "Île-de-Sein (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "CA de la Presqu'île de Guérande Atlantique (CAP
ATLANTIQUE)",
```

```
"CA de la Presqu'île de Guérande Atlantique (Cap Atlantique)", nom_epci))
```

```
consom_energy_2020 <- consom_energy_2020 %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "Ouessant (Commune)", "Ouessant (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "Île-de-Bréhat (Commune)", "Île-de-Bréhat (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "Île-de-Sein (Commune)", "Île-de-Sein (commune)",
nom_epci)) %>%
```

```
mutate(nom_epci = ifelse(nom_epci == "CA de la Presqu'île de Guérande Atlantique (CAP
ATLANTIQUE)",
```

```
"CA de la Presqu'île de Guérande Atlantique (Cap Atlantique)", nom_epci))
```

```
#combining the carbon_data and the consom_energy
```

```
data_2010 <- consom_energy_2010 %>%
```

```
left_join(carbon_data_2010 %>%
```

```
select(code_epci, nom_epci, annee_ref, Total_emission),
```

```
by = c("code_epci", "nom_epci", "annee_ref"))
```

```
data_2018 <- consom_energy_2018 %>%
```

```
left_join(carbon_data_2018 %>%
```

```
select(code_epci, nom_epci, annee_ref, Total_emission),
```

```
by = c("code_epci", "nom_epci", "annee_ref"))
```

```
data_2020 <- consom_energy_2020 %>%
```

```

left_join(carbon_data_2020 %>%
  select(code_epci, nom_epci, annee_ref, Total_emission),
  by = c("code_epci", "nom_epci", "annee_ref"))

#converting GWH to TJ
data_2010$Total_conso_TJ <- data_2010$Total_conso_gwh * 3.6
data_2018$Total_conso_TJ <- data_2018$Total_conso_gwh * 3.6
data_2020$Total_conso_TJ <- data_2020$Total_conso_gwh * 3.6

#computing the indicator
data_2010 <- data_2010 %>%
  mutate(Carbon_intensity = Total_emission/Total_conso_TJ)

data_2018 <- data_2018 %>%
  mutate(Carbon_intensity = Total_emission/Total_conso_TJ)

data_2020 <- data_2020 %>%
  mutate(Carbon_intensity = Total_emission/Total_conso_TJ)

#####

#making the map

#2010

#making a map for the prevalence of the disease per department
france_shapefile <- st_read(file.choose())

#remove the duplicate in the france shapefile
france_shapefile_agg <- france_shapefile %>%
  group_by(CODE_EPCI) %>%
  summarize(
    NOM_EPCI = first(NOM_EPCI),
    cat = first(cat),
    TYPE_EPCI = first(TYPE_EPCI),
    ID_list = first(ID),
    geometry = st_union(geometry),

```

```

    .groups = "drop" # Ungroup after summarizing
  )

#subset the EPCI of interest
brittany_EPCI <- france_shapefile_agg %>%
  filter( CODE_EPCI %in% data_2010$code_epci)

# Join to spatial data

EPCI_map_2010 <- brittany_EPCI %>%
  left_join(data_2010 %>%
    select(Carbon_intensity, code_epci), by = c("CODE_EPCI" = "code_epci"))

ggplot(EPCI_map_2010) +
  geom_sf(aes(fill = Carbon_intensity)) +
  scale_fill_distiller(
    palette = "YlOrBr",
    direction = 1, # Low = yellow, high = brown
    name = "tCO2/TJ",
    na.value = "grey90"
  ) +
  labs(
    title = "Carbon intensity of the energy system by EPCI 2010"
  ) +
  theme_minimal()

#2018

# Join to spatial data

EPCI_map_2018 <- brittany_EPCI %>%
  left_join(data_2018 %>%
    select(Carbon_intensity, code_epci), by = c("CODE_EPCI" = "code_epci"))

ggplot(EPCI_map_2018) +
  geom_sf(aes(fill = Carbon_intensity)) +

```

```

scale_fill_distiller(
  palette = "YlOrBr",
  direction = 1,    # Low = yellow, high = brown
  name = "tCO2/TJ",
  na.value = "grey90"
) +
labs(
  title = "Carbon intensity of the energy system by EPCI 2018"
) +
theme_minimal()

#2020

# Join to spatial data

EPCI_map_2020 <- brittany_EPCI %>%
  left_join(data_2020 %>%
    select(Carbon_intensity, code_epci), by = c("CODE_EPCI" = "code_epci"))

ggplot(EPCI_map_2020) +
  geom_sf(aes(fill = Carbon_intensity)) +
  scale_fill_distiller(
    palette = "YlOrBr",
    direction = 1,    # Low = yellow, high = brown
    name = "tCO2/TJ",
    na.value = "grey90"
  ) +
  labs(
    title = "Carbon intensity of the energy system by EPCI 2020"
  ) +
  theme_minimal()

```

### 6.6.1 Maps for Indicator 3.1.1: Carbon intensity of the energy system

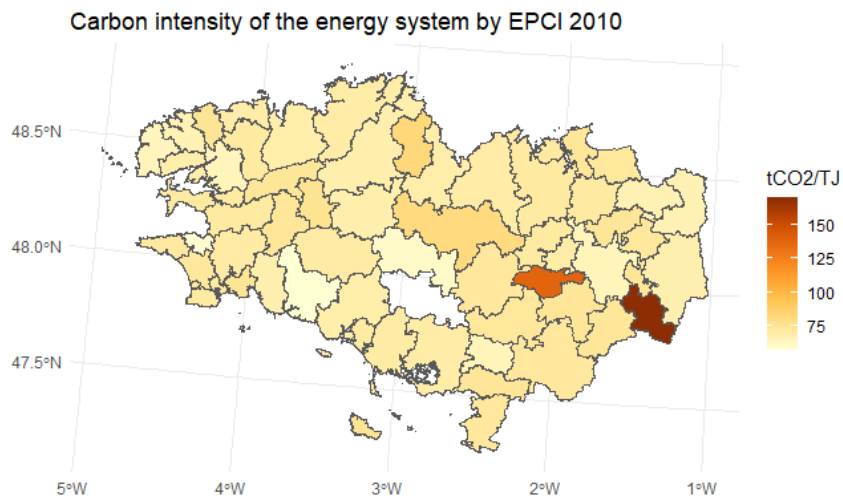


Figure 10: Carbon intensity of the energy system by EPCI in 2010

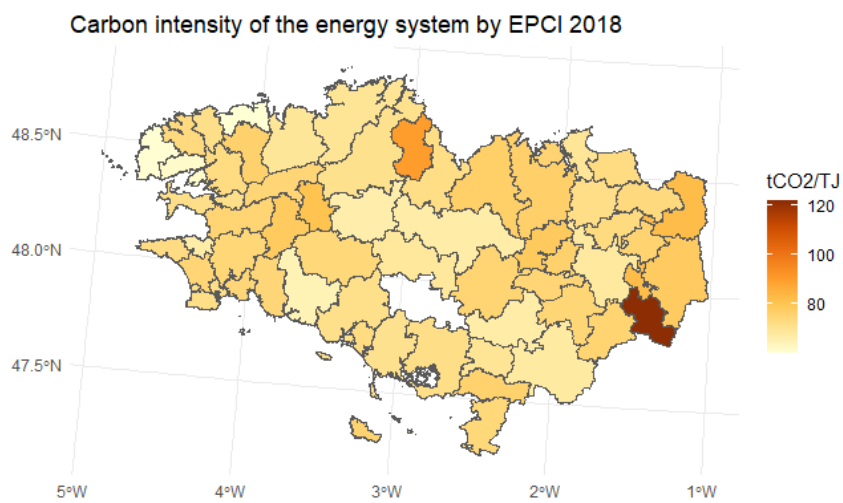


Figure 11: Carbon intensity of the energy system by EPCI in 2018

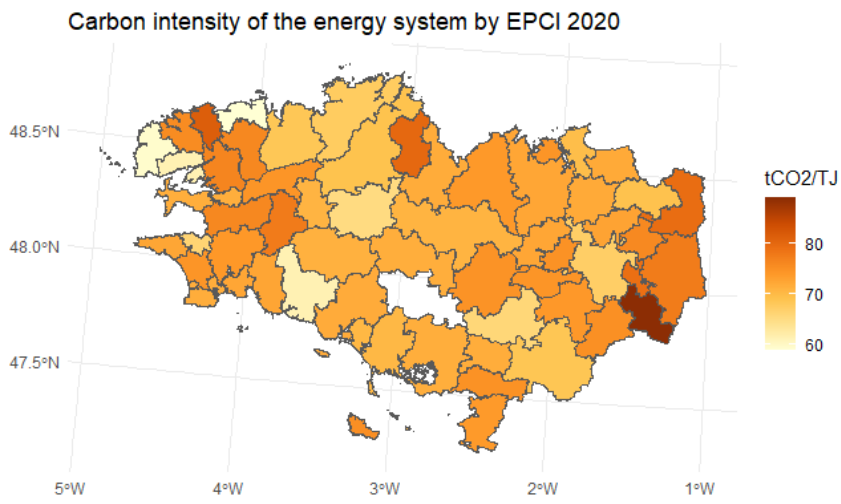


Figure 12: Carbon intensity of the energy system by EPCI in 2020

## Résumé

Les températures terrestres ont connu une augmentation rapide, qui fut plus ressentie durant les deux dernières décennies. Bien que le réchauffement des températures est dû à des causes naturelles et humaines, depuis la moitié du 20<sup>ème</sup> siècle la cause humaine apparait majoritaire. A ce changement climatique sont malheureusement associées des causes néfastes sur la santé humaine, de manière directe et ou indirecte. Pour pallier le changement climatique et atténuer les impacts sur la santé humaine fut créée, une initiative internationale visant à suivre les impacts du changement climatique sur la santé et accompagner les décideurs dans la mise en place de politiques favorisant l'amélioration de la santé humaine. Compte tenu des variétés d'une région à une autre, il se voit nécessaire d'avoir une initiative localement adaptée pour une meilleure relevance local au niveau des politiques de transition. Pour évaluer cette déclinaison régionale, la Bretagne une région française fut sélectionnée. Après avoir identifié un ensemble d'indicateurs du Lancet Countdown qui servira de point de départ, les enjeux environnementaux spécifiques à la Bretagne liés au changement climatique furent identifiés à travers une analyse thématique de documents cadres soigneusement sélectionnés. L'intersection des enjeux spécifiques à la Bretagne et les indicateurs de Lancet Countdown (rapport Européen 2024) souligna deux éléments clés, les indicateurs proposés du Lancet peuvent être utilisés à la transition au niveau régionale, toutefois pour des enjeux spécifiques aucun n'indicateurs dans l'ensemble de départ, ce qui traduit le besoin d'une initiative soigneusement adaptée à la région. Aussi, l'analyse de la disponibilité des données nécessaires pour le calcul des indicateurs révéla le besoin de données, avoir des données facilement accessibles, une banque soignée de données spécifiques à la région, et la déclinaison de données clés et essentielles au niveau local.