VILLE DE
PARIS

PARIS IN THE FACE OF CLIMATE CHANGE

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EDITORIAL

ANNE HIDALGO
MAYOR OF PARIS

In summer 2021, between floods and fires, we were once again confronted with the reality of climate change. The clock is ticking: we must act, and act quickly! Which is why Paris launched its race for the climate fifteen years ago. In 2018, we adopted an action plan to reach carbon neutrality. We were one of the first cities in the world to do so, and over 300 cities have since joined us.

The IPCC's 6th Report makes the urgency clear enough: we must reduce our greenhouse gas emissions on a massive scale and prepare our cities for climate change if we are to avoid suffering its dramatic effects. But there is still hope if we stick to our commitments.

And that is exactly what we are doing in Paris. Over the last fifteen years, the transport sector has reduced its carbon footprint by over 35%. We are renovating our buildings: more than 100 schools have benefited from thermal rehabilitation, as have some 50,000 social housing units. We are opening new green spaces, bringing nature back into the city wherever possible, in our streets and on our squares, by planting thousands of trees. We have established over 30 hectares of urban agriculture and it is once again possible to bathe in living waters, including in the Ourcq Canal, and soon in the Seine.

But although much has been done, there is still so much more to do. And the next few years will be decisive if we are to make radical changes in our lifestyles.

It is time for science-driven policy choices. And it is in order to present Parisians with the data we possess that we have updated this diagnoses of vulnerabilities, so as to inform them on how the situation is evolving and how our city is adapting to it.

Adapting means preparing the future for our young people. It is our responsibility as much as it is a question of solidarity to protect the most vulnerable among us, those particularly sensitive to the effects of climate disruption and pollution.

You can count on my determination to carry the fight forward.

WHAT EXACTLY ARE WE TALKING ABOUT?

Heavy floods, heatwaves, storms... Like all of the world's great metropolises, Paris is entering a new phase in its history. The new risks generated by climate change are leaving their mark on cities' daily lives with ever increasing regularity. The various scenarios published by the Intergovernmental Panel on Climate Change (IPCC) foreshadow major disruptions to our ways of life.

THE DIAGNOSIS OF VULNERABILITIES AND STRENGTHS EXPLAINED

In 2012, Paris carried out one of the first studies of a territory's vulnerabilities and strengths in the face of climate change, highlighting the significant environmental, social and economic risks that it might have to deal with. The study encouraged implementation of the first strategy for adaptation to climate change in 2015.

Ten years later, the study needed to be updated to bring it into line with the knowledge and tools published by the IPCC. Three scenarios were therefore applied to Paris' future by 2100:

- The **proactive** scenario: international goals for reduction of greenhouse gas emissions have been met, and the average rise in temperature worldwide has stabilised at around +2°C.
- The **intermediate** scenario: current trends continue and result in a trajectory of an average worldwide temperature increase of +3.5°C.
- • The **"worst case"** scenario: the global system remains highly carbonated and, in the absence of climate policy, is set to exceed +4.5 – 5°C.

Six major hazards were studies for each scenario:

- Evolution of average temperatures
- Evolution of average rainfall
- Storms
- Heavy rainfall
- Heatwaves
- Floods
- Extreme cold
- Desertification
- Mass wasting
- Snow and freezing rain events

Global warming
is here. Paris has got
2.3°C
warmer since
the preindustrial era

Similarly, climate disruption is transforming five essential resources that make life possible:

- Energy
- Food
- Water
- Biodiversity
- Air

The impact that the evolution of such hazards is having on resources, as well as their combined consequences on the great "systems" that enable Paris to operate, were also measured, namely:

ENERGY NETWORKS

- Electricity
- Gas
- Heat
- Cold

THE URBAN WATER CYCLE

- Potable water
- Sewerage
- Non-potable water

THE URBAN ENVIRONMENT

- The built environment
- Green spaces
- Transport and mobility
- Telecommunications

ECONOMIC AND SOCIAL ATTRACTIVENESS

- Economic fabric and employment
- Tourism
- Insurance

HEALTH

- Infrastructures
- New diseases

A BRIEF SUMMARY OF VOCABULARY

Climate hazards: How likely is it that a natural phenomenon will occur? How intense will it be? Where will it occur? Is it foreseeable? The diagnosis highlights climate hazard trends, with regard to average rainfall for example, severe climate hazards such as heatwaves, and physical hazards such as floods, in order to assess the impacts that global warming is having and will have.

Vulnerability: Each system is vulnerable to a great or lesser extent to the various hazards and diminishing resources. The concept of vulnerability enables study of a system's direct or indirect sensitivity to a given hazard or resource, as well as its ability or otherwise to address the problem and adapt.

Systems: As a territory, Paris was studied as the sum of complex, interconnected systems: energy networks, water networks, waste management, transport networks, economic sectors, etc., each of them representing a system.

Domino effect: This systemic approach enables measurement of the impact that climate change has on each system, as well as their interdependence with domino effects: each hazard can result in cascading reactions. For example, a large-scale power outage would cause disruptions in all the other systems: public transport, waste management, healthcare, etc.

The IPCC (Intergovernmental Panel on Climate Change): It was created in 1988 by the United Nations and brings together 195 States. It assesses the state of scientific, technical, economic and social knowledge on climate change, its causes and consequences, and the measures required to counter it; its 6th assessment report is set to be published in 2022.

The future of the climate in Paris

The symbolic threshold of a 2°C increase in temperature compared with the preindustrial era has now been crossed as far as the Paris region is concerned. Two little degrees Celsius that are not without their consequences, with new climate hazards that the city will have to cope with. For, unsurprisingly, heatwaves will be increasingly common in the decades to come, and torrential rain will be more frequent, sometimes causing floods. Conversely, other hazards will diminish: snow, freezing rain and extreme cold.

STORMS AND MASS WASTING

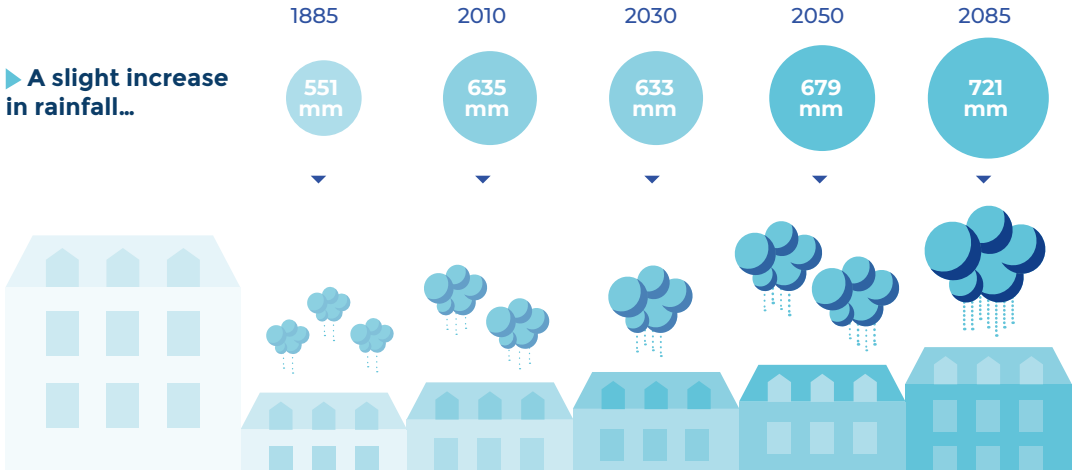
▶ These hazards don't seem to be undergoing any major evolutions due to climate change.

RAINFALL

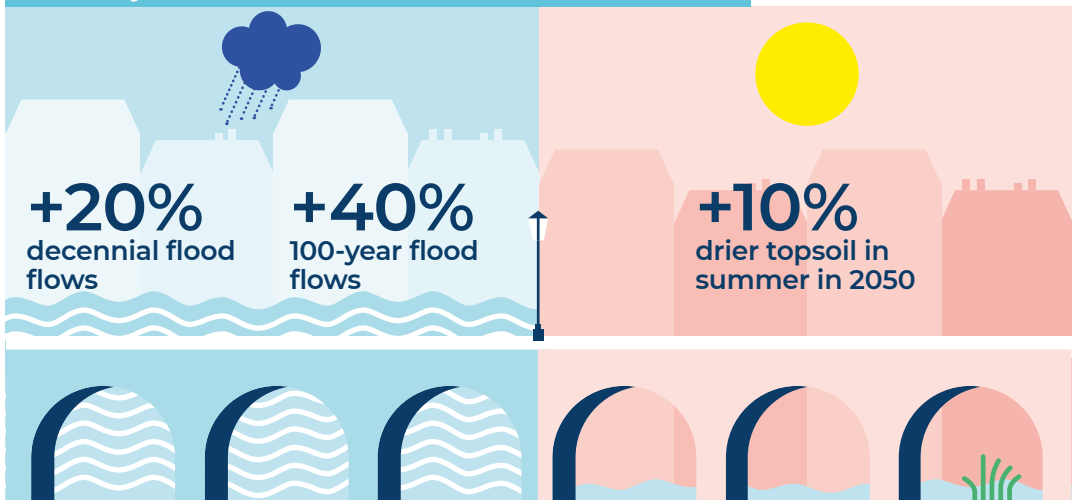
Unlike temperatures, indicators for rainfall are more variable and uncertain. There should be a slight increase in volumes of rainfall, while numbers of rainy days should decrease. With a tendency towards greater intensity of rainfall and consequent greater risks of flooding due to overflowing rivers and stormwater runoff during torrential downpours.

FEWER, MORE INTENSE & MORE SEASONAL RAINFALL EVENTS

There should be no major evolution in cumulative rainfall.
It should rain a little more, with more marked seasonality.



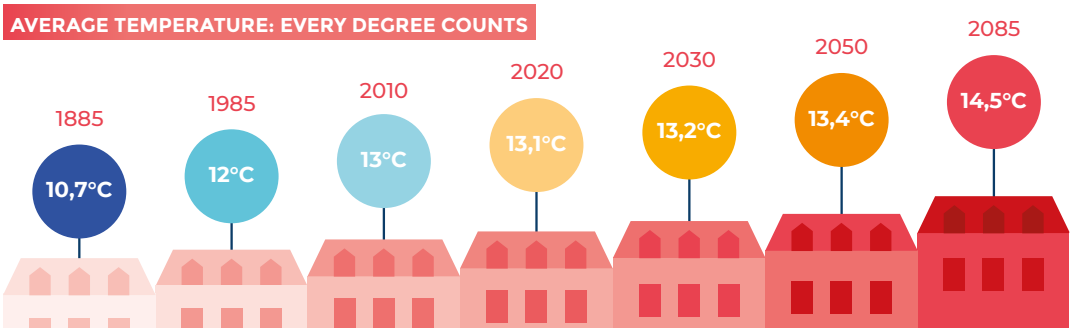
MORE FREQUENT FLOODS IN WINTER AND DRIER TOPSOIL IN SUMMER



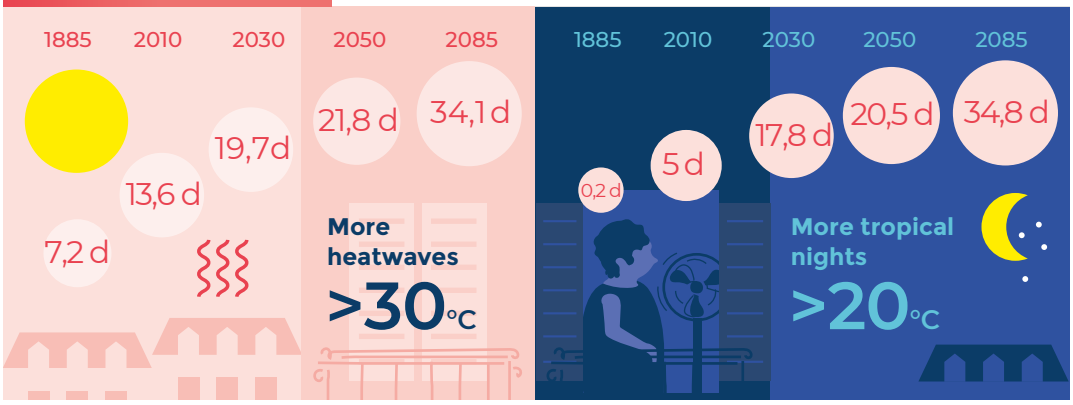
TEMPERATURES

A corollary to the increase in temperatures, the future will see greater frequency and intensity of extreme heat events and heatwaves, becoming a major 21st-century issue, as the heat island effect has also been underestimated by climate models.

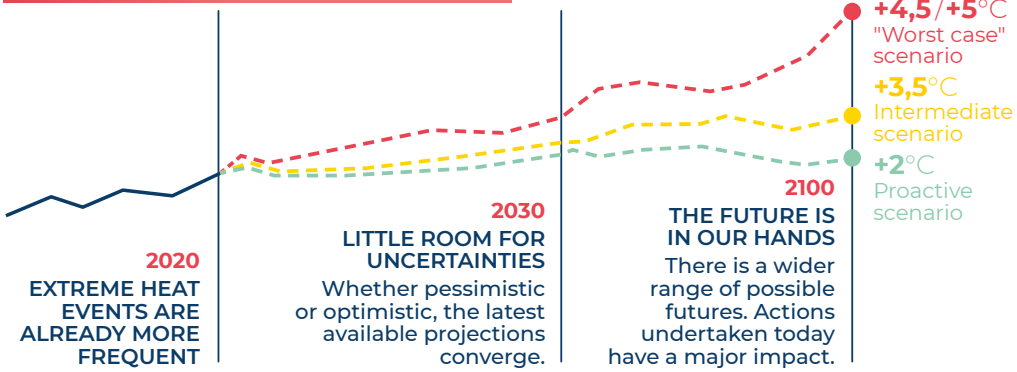
AVERAGE TEMPERATURE: EVERY DEGREE COUNTS



INCREASINGLY HOT SUMMERS



ROOM FOR MANOEUVRE OVER THE LONG TERM



2020
EXTREME HEAT EVENTS ARE ALREADY MORE FREQUENT

2030
LITTLE ROOM FOR UNCERTAINTIES
Whether pessimistic or optimistic, the latest available projections converge.

2100
THE FUTURE IS IN OUR HANDS
There is a wider range of possible futures. Actions undertaken today have a major impact.

MILDER WINTERS

▶ A direct consequence of global warming, winters will be milder and cold periods less intense and less frequent. Between 2010 and 2085, the average number of days of frost should fall from 19.3 to 14.3.

-5 fewer days of frost by 2085

CLIMATE SCENARIOS

▶ The average temperature increases in these 3 scenarios are at global rather than Parisian level.

▶ All the forward-looking data provided on these pages are from the intermediate scenario, with continuation of current trends.

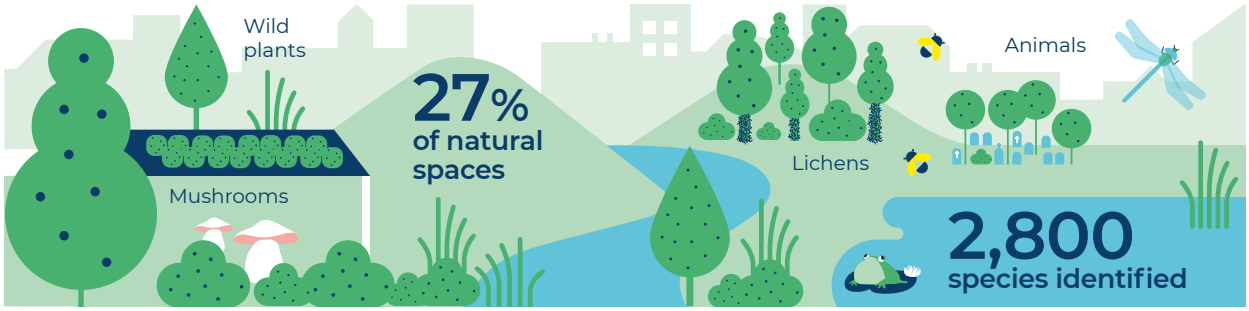
The future of resources for Paris

In Paris, certain resources such as air quality and energy are increasingly better preserved, thanks in particular to public action. Other resources are becoming increasingly threatened. Hence, the rapidity with which biodiversity is declining makes it a major issue for the years to come. The same is true of water, which risks becoming scarcer due to increasingly hot summers and ever greater needs. Yet these two resources are powerful levers of action for adaptation to global warming.

BIODIVERSITY

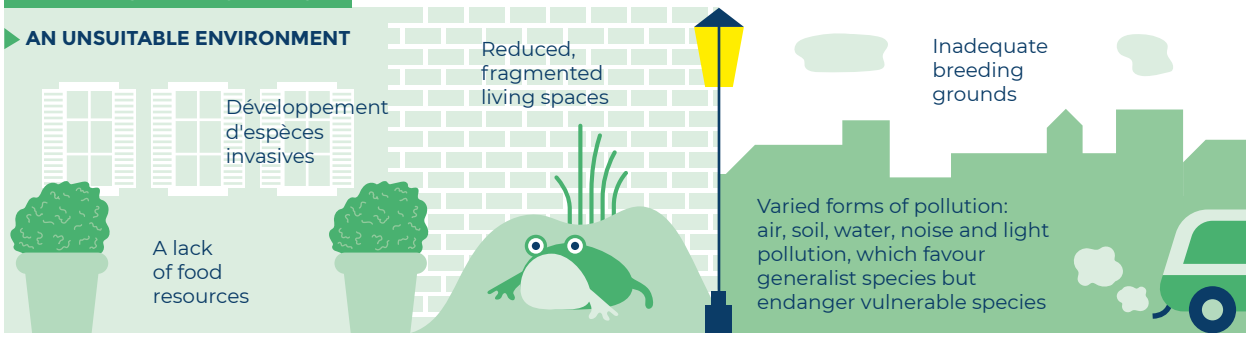
Plant and animal species are disappearing at a frenetic pace across the world; we are currently witnessing a 6th mass extinction. To blame: human activities and global warming, which accelerate the process. In Paris, the decline of biodiversity, shared by the whole Île-de-France region, is unlikely to be curbed by 2050 or by the end of the century, despite all efforts to restore nature. An alarming situation that is still underestimated.

IN PARIS, NATURE TOO HAS HER RIGHTS

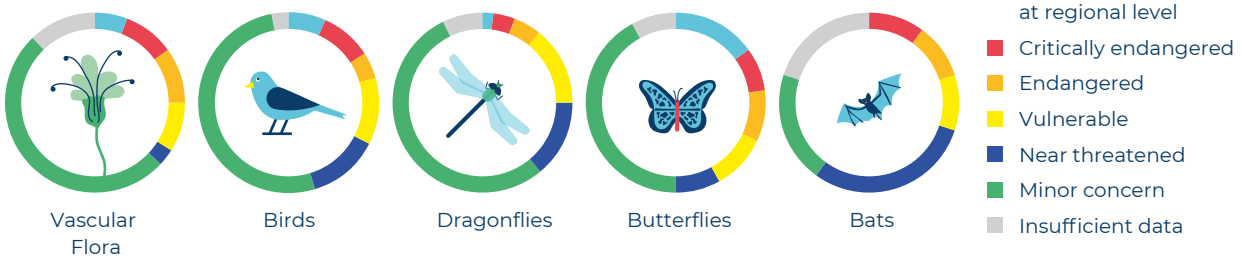


AN ENDANGERED BIODIVERSITY

AN UNSUITABLE ENVIRONMENT



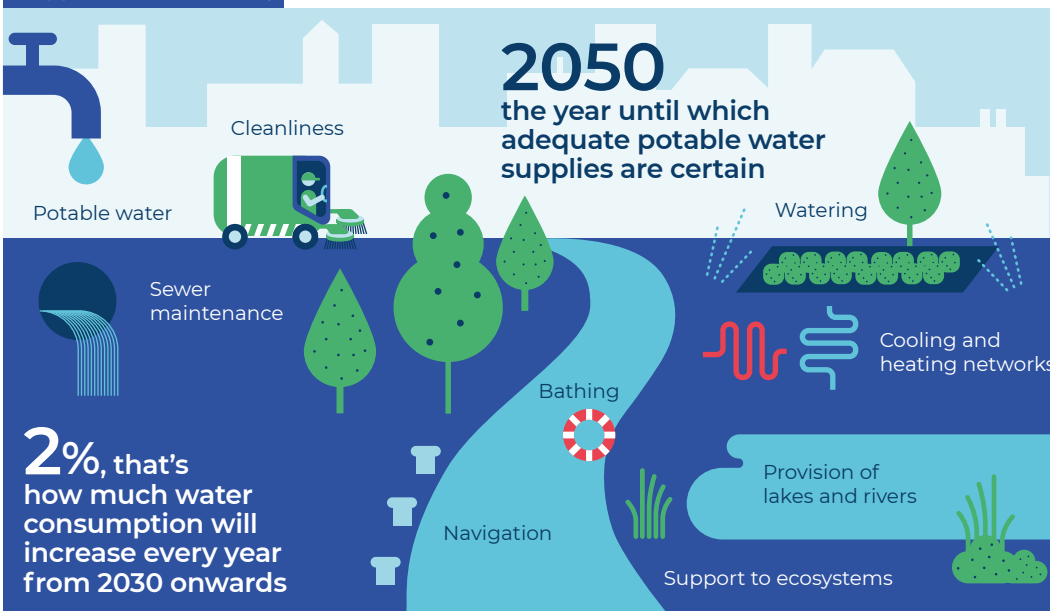
ENDANGERED SPECIES



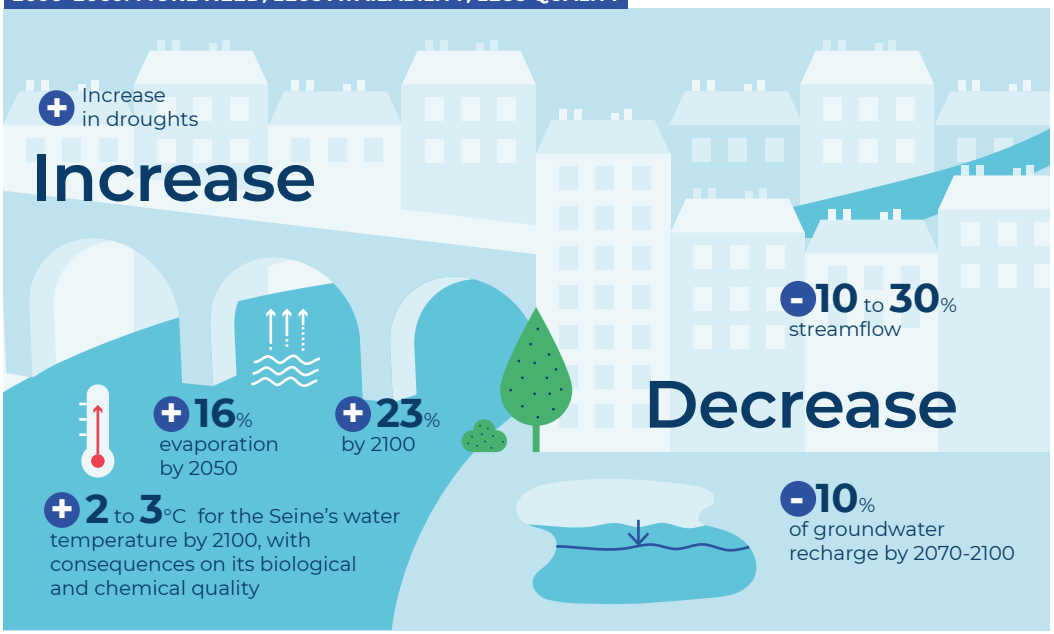
WATER

A strategic resource, water risks being subjected to major tensions by the end of the century. At the moment, stable potable water consumption and a variety of supply sources ensure that Paris enjoys adequate quantities of quality water. But the effects of global warming, with increased dry spells and greater needs, for cooling down the city or for regional agriculture, for example, raise fears of shortages post-2050.

MAJOR EVERYDAY NEEDS



2050-2085: MORE NEED, LESS AVAILABILITY, LESS QUALITY



FOOD

TOWARDS A MORE REGIONALISED MODEL

- Towards diversification of sources of supply, land preservation and resilience of agricultural resources
- Focus on shorter supply chains

ENERGY

TOWARDS A NEW MODEL

- In 2050, energy consumption will have decreased by 50% compared with 2004
- Towards 100% renewable energies, including 20% produced locally

AIR

DEFINITE LOCAL IMPROVEMENT, BUT UNCERTAINTIES ON A LARGER SCALE

- Regulatory factors will be of paramount importance in global reduction of air pollution. In Paris, the disappearance of combustion vehicles (diesel and petrol) in 2030 will contribute and result in marked improvement of air quality.

HEATSTROKE ON ENERGY NETWORKS

Energy supply is essential to the entire city's proper operation, its economic activities and the daily lives of Parisians in general. More than 90% of the energy consumed in Paris is imported, so local effects of climate change have little impact on supply. 60% of this energy is electricity, a robust resource in the face of climate hazards, owing to the diversity of the ways it is produced. Although it stands up well overall to climate hazards, certain vulnerabilities to climate change may result in major impacts on energy supply due to the domino effect.

DOMINO EFFECT

A large-scale shutdown of the electricity grid (following a flood, for example), would result in disruption or even shutdown of almost all other systems, including public transport, telecommunications, and waste management.

A ROBUST ELECTRICITY GRID, SENSITIVE TO EXTREME HEAT

With some 10,000 kilometres of electricity networks underground, Paris enjoys major resistance to a number of hazards. However, various surface features, such as source substations and junction boxes, are at high risk in the face of increasing average temperatures, extreme cold events, storms, heatwaves, etc.
For example, over 230,000 Parisian users suffered a brief power outage during the 2003 heatwave, due to junction box failures. Winter cold spells also lead to significant increases in electricity consumption, and are therefore the subject of heightened vigilance on the part of the Réseau de Transport d'Électricité (RTE – Electricity Transmission Network). Flood risks are likely to impact electricity infrastructures located alongside the Seine, in particular due to submersion of such equipment as transformer stations.

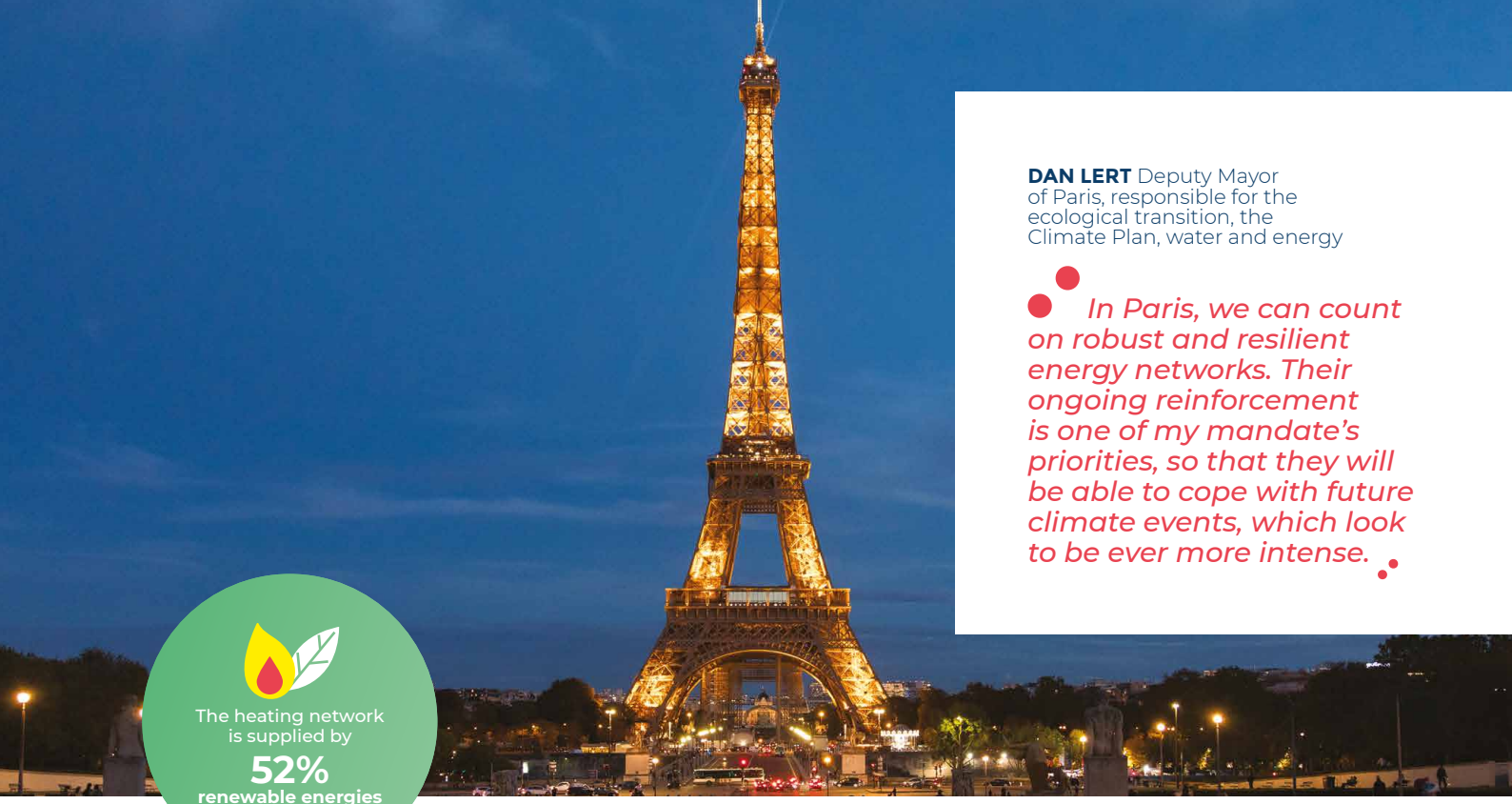
230,000
Parisians deprived of electricity during the 2003 heatwave

PARIS' HEATING AND COOLING NETWORKS, SENSITIVE TO THE SEINE'S EVOLUTION

Real assets for Paris' transition to carbon neutrality, the city's cooling and heating networks are now subject to new risks connected with climate change. The heating network, composed of 510 kilometres of piping and eight production sites, keeps some 1.5 million Parisians warm. The 8 million tonnes of water vapour required are produced using 52% renewable energies. Water vapour production makes the heating network dependent on the Seine, so the whole system may be impacted in the event of flooding. For example, the 2016 flood deprived 10,000 homes of domestic hot water. In the extreme scenario of a hundred-year flood, the break of certain links essential to the network's operation could well lead to the entire Paris network being shut down. Various technical means and targeted investments have helped reduce such risks.
The cooling network, which provides air-conditioning to some 6 million square metres of offices, hotels and museums,

The electricity grid was flooded

It is reckoned that the shutdown of several source substations would be likely to incapacitate the electricity system more widely, even totally. Exercises conducted by the Police Prefecture even envisage 1.5 million users in Île-de-France being deprived of electricity.



DAN LERT Deputy Mayor of Paris, responsible for the ecological transition, the Climate Plan, water and energy

In Paris, we can count on robust and resilient energy networks. Their ongoing reinforcement is one of my mandate's priorities, so that they will be able to cope with future climate events, which look to be ever more intense.

The heating network is supplied by **52%** renewable energies

is also dependent on the Seine. There are risks of shutdown if there is a lack of water or if the river is too warm or too low to discharge hot water from production sites into it. Heatwaves, during which the network is evidently made most use of, are also likely to damage cold generators – although it has to be said that the most recent heatwaves have not yet reached this stage. In order to continue its development, the network will have to ensure expert management of these new risks. Appropriate for cooling various large sites, it must also be thought of as a temporary solution, alongside cooling solutions alternative to air conditioning, to be deployed on a much larger scale, covering the whole city.

Gas, a network with few vulnerabilities

Analysed in the light of climate change, gas networks seem to be among the most resistant in Paris' energy mix. As nearly all of them are underground, they are little impacted by the main climate hazards: storms, heavy rainfall, snow, and increase in average temperatures... Modernisation of infrastructures, along with removal of the most sensitive technical components, will increase the system's resistance in the years to come.
Lesser frequency of extreme cold events also further diminishes risks connected with depletion of the resource, which is made much use of in winter. In comparison, it is potential flooding of the Seine that holds the greatest risk for the gas network. Submersion of the exposed parts of the network alongside the Seine, or of various sensitive technical components, could result in a break in supply for around 3% of gas consumers. A risk lessened by the planned switch to a medium pressure network.

2050 Climate Plan

The Climate Plan is designed to reduce the territory's dependence by halving its energy needs by 2050 and consolidating its autonomy by local production of 20% of its energy needs.

ENERGY NETWORKS' VULNERABILITY RELATIVE TO RESOURCES AND HAZARDS

		ELECTRICITY	GAS NETWORK	HEAT	COLD
Hazards	Heatwave	🔴 ↗	🟠 ↗	🟠 ↗	🔴 ↗
	Flood	🔴 ↗	🟠 ↗	🔴 ↗	🟠 ↗
	Desertification*	-	-	-	-
	Average temperature	🟠 ↗	🟠 ↗	🟠 ↗	🟠 ↗
	Heavy rainfall	🟠 ↗	🟠 ↗	🟠 ↗	🟠 ↗
	Mass wasting	🟠 ↗	🟠 ↗	🟠 ↗	🟠 ↗
	Storm	🟠 ↗	🟠 ↘	🟠 ↗	🟠 ↗
	Rainfall*	-	-	-	-
	Extreme cold	🟢 ↘	🟠 ↘	🟠 ↘	🟠 ↘
	Snow and freezing rain	🟢 ↘	🟢 ↘	🟢 ↘	🟢 ↘
Resources	Water (including hydrological droughts)	🟢 ↗	🟢 →	🟠 ↗	🔴 ↗
	Biodiversity	-	-	-	-
	Energy	🟠 ↗	🟠 ↘	🟠 ↘	🟠 ↘
	Air	-	-	-	-
	Food	-	-	-	-

High risk 🔴 Moderate risk 🟠 Low risk 🟢 Evolution of risk by 2050 increased ↗ stable → decreased ↘

* The risk is not zero; it was studied in the context of water resources.

WATER IN ALL ITS FORMS

Essential to life, essential to the city: Water circulates everywhere in Paris, to and from pumping, purification and treatment sites and through hundreds of kilometres of piping, aqueducts, sewers and canals. This powerful, highly strategic network, inherited from our long urban history, has continued to adapt itself over the course of time, and is now having to face up to the major impacts of climate change that have come to characterise our century. Consumed by households, industry and agriculture alike, the resource is coming up against increasing pressure, both with regard to quantity and quality.

DOMINO EFFECT

Certain extreme climate scenarios foreshadow prolonged water supply cuts for 5 million users, whether companies, households or public utilities. For example, the risk may arise due to a major flood in the Paris region. Such an event could well destroy or damage various vulnerable infrastructures: flooding of wells, submersion of electrical equipment, burst pipes, water treatment plants, etc. A scenario of this kind would also have a major impact on water quality, with a risk of pollution for 1.3 million subscribers.

A ROBUST POTABLE WATER NETWORK FOR A RESOURCE UNDER TENSION

Over 2 million Parisians live in an area of around a hundred square kilometres, in one of the world's most heavily populated metropolises. Such remarkable density is only made possible by the existence of a robust network for production of potable water and its transport to consumers' taps.

The future of the cycle, which goes from collection to distribution via treatment, conveyance and storage, is a large-scale issue: Parisians drink water collected within a radius of some 150 kilometres. The issues involved are therefore highly strategic: any interruption in this public utility par excellence would represent an unprecedented risk for the city's entire population, yet climate projections indicate that groundwater and streamflow will have diminished by the end of the century.

Climate projections indicate that water tables and streamflow should diminish by the end of the century

More generally, analyses up to 2050 suggest the emergence of several new stresses on the city's potable water network. Heatwaves in particular are likely to impair its quality by fostering microbial growth. Droughts and global depletion of water resources require close vigilance and need to be taken into full account.

Similarly, any break in electricity grids would impact production and treatment sites, although it would have no effect on conveyance of water, which is dependent on the gravity function of 470 kilometres of aqueducts, or on reservoirs, which, with over a million cubic metres stored, provide Paris with two days of water autonomy. Mostly underground, the network is also resistant to certain types of bad weather, including heavy rainfall. Finally, the diversity of potable water sources – the Seine, the Marne, big lakes and various groundwater tables – limits drought and pollution risks significantly.

SEWERAGE: A FRAGILE SYSTEM IN THE FACE OF HEAVY RAINFALL

One and the same network enables recovery and treatment of the Greater Paris region's wastewater and stormwater: an operational mode known as "unitary". 9 million inhabitants are entirely dependent on extra-muros wastewater treatment plants managed by the Greater Paris Sanitation Authority (SIAAP). Transport, collection and discharge of water is ensured by 2,600 kilometres of sewers and a hundred and thirty-three local management stations (plants, spillways, link sewers and measurement sites) overseen by the Paris Sanitation Section (SAP).

The sewerage system's vulnerabilities are comparable to the potable water network's. Flood risk is the top concern, with 20% of wastewater treatments plants, accounting

DAN LERT Deputy Mayor of Paris, responsible for the ecological transition, the Climate Plan, water and energy

Ensuring that Parisians are supplied with top-quality potable water at all times is Eau de Paris' priority mission. Climate change is our century's greatest challenge, and we work with our public utility's teams on a daily basis in order to be a match for this major concern.

1,200
drinking fountains
and nearly **100 misters**
have already
been installed
across the Paris region

for 85% of capacities, located in floodplain areas. Although the system is scaled to cope with decennial floods, it struggles to overcome constraints connected with heavy rainfall events, which are becoming increasingly frequent and occur at new times of year. Such events, along with hundred-year floods, can result in the system becoming saturated and having to offload directly into the Seine. This raises the question of groundwater pollution due to wastewater being discharged into the natural environment, as well as the local inconveniences that overflows are likely to cause, at drain level for example.
Such risks are all the more prevalent as climate change is weakening the system: topsoil dryness in particular reduces capacities for absorbing stormwater, so leading to greater use of the sewerage system.

And what if? There was a shortage of potable water

Heatwaves, droughts and depletion of the resource are risks that have been fully studied and taken into account by Eau de Paris. Each of them is largely counterbalanced by the system's very nature, the measures implemented and, where required, emergency solutions that can be deployed if an extreme event occurs. For example, the Police Prefecture can activate an ultimate emergency plan in the event of very high stress on supply: it consists of providing for Paris' essential needs by distributing water collected from the Albien water table, a deep reserve totally independent of the present system, but limited in quantity.

COLOMBE BROSSEL Deputy Mayor of Paris responsible for the cleanliness of public space, waste reduction and sorting, recycling and reuse

In the face of climate change and in anticipation of violent rainfall events, we have initiated the ParisPluie Plan, which is designed to make use of rainwater for cooling the city and greening projects, and limiting risks of spillage into the Seine and flooding.

Avoiding overflows

In 2018, Paris provided itself with a "ParisPluie" Plan designed to optimise stormwater management. A document to be taken systematically into account in urban-planning projects, the Plan enables gradual unsealing of Paris's ground surfaces and consequent absorption of water in the natural environment with a view to preventing flood risks caused by heavy rainfall. With the same aim of avoiding overuse of the sewerage system, 150 million euros in investments have been scheduled in the context of the Water Quality and Bathing Plan. Among other things, they will enable creation of a huge stormwater retention basin in the 13th arrondissement. The ultimate aim is to reduce or even eliminate spillage of water in natural environments, with, as a heritage of the 2024 Olympic and Paralympic Games, the possibility of bathing in the Seine.

THE NON-POTABLE WATER NETWORK: AN OPPORTUNITY SENSITIVE TO SEVERAL CLIMATE HAZARDS

A final system, by no means to be underestimated and even to be further developed, is the non-potable water (NPW) network. Pumped in the Ourcq Canal and the Seine, non-potable water is conveyed through 1,700 kilometres of piping duplicating the classical network. Very rare at global level, this fully-fledged network ensures daily cleaning of the city's public spaces and watering of its green spaces, and also provisions the woods and rivers of the Bois de Boulogne and the Bois de Vincennes.
Like the potable water system, sometimes even more so, the NPW system faces growing risks. In the event of drought, it is the first to have its use restricted. If there were a flood, 2 of its 4 pumping sites would be affected along with 90% of its piping, which is easily flooded. Pumping relies almost entirely on electrical solutions: Any eventual failure of the system would inevitably cut off non-potable water supplies.
Nevertheless, the non-potable water network is in itself a lever of resilience for Paris. Experimentally, spraying pavements and roadways during heat peaks substantially reduces the actual temperature and the temperature as felt by pedestrians, while maintaining watering capacities. In order to enable it to continue to diversify while maintaining the essential functions it carries out, Eau de Paris and the City of Paris have adopted a NPW system master plan supplemented by a major investment effort.

WATER SYSTEMS' VULNERABILITY RELATIVE TO RESOURCES AND CLIMATE HAZARDS

		POTABLE WATER	STORMWATER	NON-POTABLE WATER
Hazards	Heatwave	🔴 ↗	🟠 ↗	🟠 ↗
	Flood	🔴 ↗	🔴 ↗	🟠 ↗
	Desertification	🟠 ↗	🟠 ↗	🟠 ↗
	Average temperature	🟠 ↗	🟠 ↗	🟠 ↗
	Heavy rainfall	🟠 ↗	🔴 ↗	🟠 ↗
	Mass wasting	🟠 ↗	🟠 ↗	🟠 ↗
	Storm	🟠 ↗	🟠 ↘	🟠 ↗
	Rainfall*	🟠 ↗	-	🟠 ↗
	Extreme cold	🟠 ↘	🟠 ↘	🟠 ↘
	Snow and freezing rain	🟠 →	🟠 ↗	🟢 ↘
Resources	Water (including hydrological droughts)	🟠 ↘	🟠 ↗	🔴 ↗
	Biodiversity	🟠 ↘	🟠 ↗	🟠 ↗
	Energy	🟠 ↗	🟠 ↘	🟠 ↘
	Air	-	-	-
	Food	-	-	-

High risk 🔴 Moderate risk 🟠 Low risk 🟢 Evolution of risk by 2050 increased ↗ stable → decreased ↘

* The risk is not zero; it was studied in the context of water resources.

THE CITY UNDER PRESSURE

In the face of global warming, the entire urban environment must take account of the new climate situation. The expected extreme heat events will make city life increasingly uncomfortable, in homes, public transport and simply in Paris streets. As for urban services and telecommunications, they will have to arm themselves against risks of extreme events, floods above all.

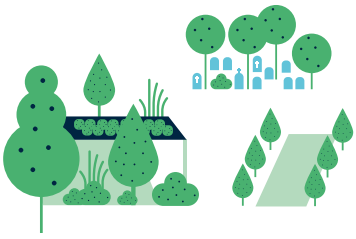
THE BUILT ENVIRONMENT AND PUBLIC SPACES: CATALYSTS OF EXTREME HEAT

Paris has been shaped by centuries of urban development. Buildings, streets and public and private spaces form a highly sophisticated system in which all the city's inhabitants, workers and visitors evolve from day to day. Gradually changing shape as urban projects succeed one another and the city renews itself unprompted, this heterogeneous system is also subject to the new climate hazards.

The issue of temperature variations, extreme cold and extreme heat events, is of particular concern: Above all, post-war buildings up to the early 2000s suffer from too little consideration of thermal comfort. Particularly unpleasant indoors, the negative effects of heatwaves are all the more acute when public spaces are poorly vegetated and asphalt stores the heat: the urban heat island effect. Hence, the study emphasises the need to expand the solutions already deployed and integrated into the City of Paris' major urban planning documents, including vegetation, creation of urban cool islands and solutions for adapting buildings, enabling them to be used as the climate evolves, whatever their purpose.

Recent studies have estimated the possible damage done by floods at several billion euros, and they represent another major risk to the very structure of buildings – including on a number of strategic sites likely to cause domino effects, such as hospitals, town halls and transport hubs. Weakening of soils, network outages and material degradation are therefore to be anticipated: this is the role of the crisis management plan, continuous monitoring of the level of the Seine, and the Flood Risk Prevention Plan (PPRI). Here again, initiatives taken with regard to vegetation help make the city more resilient.

Urban cool islands
Over 1,200 cool spots enable Parisian's to cool off day or night. Urban cool islands are meeting places, stop-offs and/or rest areas, open to the public at large and identified as sources of refreshment in Paris in relation to their immediate surroundings during hot spells and heatwaves. They may be:



Green or wooded spaces such as gardens, parks, woods and walled cemeteries

Establishments open to the public and naturally cool, such as churches, museums and the Heatwave Plan's "cool rooms"

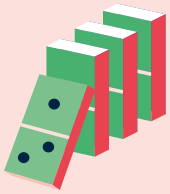
Bathing spots such as swimming pools, aquatic centres and outdoor bathing facilities

Locations equipped with misters and water features, dry fountains, and water mist dispensers

The online map of urban cool islands

CHRISTOPHE NAJDOVSKI Deputy Mayor of Paris responsible for vegetation of the public space, green spaces, biodiversity and animal conditions

Global warming threatens the viability of cities with too much mineral surface, which become nothing less than ovens in periods of extreme heat. Fortunately, we possess natural air-conditioners, trees, in whose shade the temperature drops up to 4 degrees. To keep Paris cool, we plan to plant 170,000 of them.



DOMINO EFFECT

The transport system is one of the systems that best illustrates the domino effect. Upstream, it can be disrupted by all kinds of climate hazards, such as a heatwave that makes walking and cycling arduous, a flood that closes this or that main road to traffic, or a power outage that interrupts metro and RER operation. As a result, a wide variety of other systems is weakened downstream, including the supplying of Paris with goods, foodstuffs in particular, emergency services, hospital services in particular, and waste collection.

And what if? Metros and road traffic at a halt

The EU Sequana exercise, carried out by the Police Prefecture, simulates the interruption of 140 kilometres of metro lines and the closure of most of Paris' bridges to traffic. Such simulations highlight how important it is to anticipate – as it stands, only the Flood Risk Prevention Plan (PPRI) enables implementation of an alert and risk management system. But it does not yet cover the traffic rerouting strategy.

TRANSPORT AND MOBILITY: NETWORKS SENSITIVE TO HEATWAVES AND FLOODS

Paris is a dense transport node, with a great many rail, road and river infrastructures for transporting people and goods. Metro, short- and long-distance rail networks, automobiles, motorised two-wheelers, bicycles and simply walking connect inhabitants to their neighbourhoods, to the metropolis, and to the whole of Europe. Eight million journeys are recorded in Paris every day, 88% of them by Parisians, with a downward trend as regards use of automobiles. There are now over a thousand kilometres of bike lanes, in keeping with Paris' aim of being a 100% cyclable city for the Olympic and Paralympic Games (Plan Vélo, 2015). The rail network is still heavily used for public transport (RER, metro and train).

These networks stand out for their highly systemic character: interrupting flows at a given spot can have an immediate ripple effect on the entire network, including blocking of flows. Once first flood levels have been reached, they can result in the closure of entire sections, with repercussions on the A4 motorway and RER C interchange. Entry of water also threatens a number of underground rail networks. Heatwaves can also cause major travel disruptions, either by the thermal discomfort felt on the surface and underground alike, or by damage to various essential technical components.

Keeping underground Paris operating

Paris also lives and operates underground: in addition to technical systems and works, the quarries and catacombs that weave their way through the city's subsoil also have to deal with climate hazards. These often interconnected underground networks have reinvented themselves several times during their history: as boneyards, groundwater access wells, water reservoirs, stone quarries and military sites among other things... With relatively low vulnerability, such sites are essentially subject to local hazards connected with mass wasting or rises in water tables following heavy rainfall. Such events are liable to weaken structures on the surface. But they can also be an asset and help improve Paris' resilience. Genuine reserves of coolness, they can accommodate such cooling facilities as Canadian wells.

PARKS, GARDENS, WOODS AND CEMETERIES: PRESERVING NATURE IN THE CITY AND BIODIVERSITY

Invaluable in a region as urbanised as Paris, parks, gardens and cemeteries are undoubted assets when it comes to the city's future resilience: They absorb water from light and heavy rainfall, cool the city down naturally during heat peaks, and accommodate high biodiversity… While acting as places where the city's inhabitants can socialise, amuse themselves, or give themselves over to more spiritual pursuits. But the 500 parks and gardens, 1,840 hectares of woodland and 20 cemeteries managed by the City of Paris also have to deal with the profound changes taking place in the climate. A number of solutions that have already been implemented can nonetheless be envisaged as ways to increase the resilience of parks, gardens and cemeteries confronted with climate shocks. Use of the non-potable water (NPW) network, for example, ensures upkeep and watering of parks, as does installation of rainwater storage systems, in compliance with the ParisPluie Plan.

COMMUNICATION NETWORK: AVOIDING OVERHEATING

PIf we are to respond to emergencies, we must stay connected. Such is the role played by telecommunication networks. Telephony and Internet, any impact on these networks is likely to isolate at least some of the population temporarily and block various activities, especially if they rely on data processed online. While certain extreme events such as storms may cause local damage (such as the relay tower blown down in 2014, during Storm Qumaira), some large-scale hazards can put the whole system at risk. Heatwaves come top of the list, posing the greatest risk to telecommunications: relay masts, which are highly exposed to sunlight and are usually set on terraces, have an electricity supply system whose electronics are sensitive to high temperatures. Heat also leads to overheating of data centres, making it all the more difficult to carry out maintenance operations.
There are several possible ways of reinforcing telecommunications in the face of new climate hazards. New saturation management modes and replacement of various cables, of example, would be likely to prevent flood risks. Securing underground cable networks has the advantage of securing telecommunication networks along with the electricity networks that keep them operating properly.

Biodiversity, no.1 victim of climate change

Rising temperatures are all too likely to gradually transform existing ecosystems. With chain reactions: certain exotic or undesirable species, such as hornets, wasps, tiger mosquitoes and armyworms for example, may raise public health concerns. The same is true for topsoil dryness, which is also aggravated by depletion of water resources and is likely to impact flora and fauna as well as water body quality. Other hazards impacting surface environments, such as floods, are also likely to damage green spaces.

URBAN SYSTEMS' VULNERABILITY RELATIVE TO RESOURCES AND CLIMATE HAZARDS

		BUILDINGS	PARKS AND GARDENS	TELECOMMUNICATIONS	TRANSPORT
Hazards	Heatwave	🔴 ↗	🟠 ↗	🔴 ↗	🔴 ↗
	Flood	🔴 ↗	🟠 ↗	🟠 ↗	🔴 ↗
	Desertification	🟠 ↗	🔴 ↗	🟠 ↗	🟠 ↗
	Average temperature	🟠 ↗	🔴 ↗	🟠 ↗	🟠 ↗
	Heavy rainfall	🟠 ↗	🟠 ↗	🟠 ↗	🟠 ↗
	Mass wasting	🟠 ↗	🟠 ↗	🟠 ↗	🟠 ↗
	Storm	🟠 ↗	🟠 ↗	🟠 ↗	🟠 ↗
	Rainfall	🟠 ↗	🟠 ↗	- *	🟢 ↗
	Extreme cold	🟠 ↘	🟠 ↘	🟠 ↘	🟠 ↘
	Snow and freezing rain	🟠 ↘	🟢 →	🟠 ↘	🟠 ↘
Resources	Water (including hydrological droughts)	🟠 ↗	🔴 ↗	🟠 ↗	🟠 ↗
	Biodiversity	🟠 ↗	🔴 ↗	-	-
	Energy	🟠 ↘	🟠 ↘	🟠 ↘	🟠 ↘
	Air	🟠 ↘	-	-	🟠 ↘
	Food	-	-	-	-

High risk 🔴 Moderate risk 🟠 Low risk 🟢 Evolution of risk by 2050 increased ↗ stable → decreased ↘

* The risk is not zero; it was studied in the context of water resources.

THE COST OF (CLIMATE) CHANGE

Workers' productivity, Paris' attractiveness, and costs of risks. Climate change also impacts Parisians' wallets and jobs. Costs that may come to tens of millions of euros a year when it's a matter of compensating climate disaster victims.

FRÉDERIC HOCQUARD
Deputy Mayor of Paris responsible for tourism and nightlife

Adapting our city to climate change is essential if Paris is to continue to attract and welcome tourists under the best possible conditions. The Assises du Tourisme Durable (Sustainable Tourism Conference) held in 2021 was an essential step in the collective work required to meet the challenge.

0.2%
of the GDP =
cost of the 2003 heatwave

THE IMPACT OF EXTREME HEAT EVENTS ON ECONOMIC ACTIVITY

Global warming and, a fortiori, extreme heat events represent a risk to the production system due to the potential drop in workers' productivity, in particular but not only in the most exposed sectors (such as building and roadways). According to a study carried out by the International Labour Organisation (ILO) and the World Health Organisation (WHO) in 2016, productivity loss in France is assessed at 0.01% for a temperature increase of 1.5°C, 0.02% for a 2.4°C rise, and 0.29% for a 4°C increase. With specific regard to extreme heat events, the cost of the 2003 heatwave was estimated as being 0.2 GDP points for France over the year, but it could have had greater general and sectoral impact on recovery of economic activity if it had continued after 15 August.

MAINTAINING PARIS' APPEAL TO TOURISTS

Paris is one of the world's three most popular tourist destinations. A popularity that has major economic impact, with 395,000 non-relocatable jobs spread across 80,000 companies and accounting for 7% of the regional GDP. While the capital also attracts French tourists (who account for 42% of visitors), the City of Light, its cultural life and fine dining attract large numbers of foreign tourists. Maintaining rich biodiversity (Seine, parks and gardens focus); Work on air quality, which has major repercussions on heritage (corrosion, discolouration, etc.) and tourists' health (pollution peaks, pollen, etc.) is of key importance in order to maintain the city's tourist appeal.

THE INSURANCE SECTOR IN THE FACE OF CLIMATE CHANGE

According to Lloyd's of London, the world's largest insurance institution, damage and loss due to meteorological conditions across the world increased from an annual average of 50 billion dollars in the 1980s to almost 200 billion in the 2000s. Climate disasters are therefore causing far-reaching changes in the industry. On the French market alone, the cumulative cost of compensable climate events should increase from an average 48 million euros a year in 2015 to an average 92 million euros a year in 2040 (French Insurance Federation). Such costs naturally have an impact on Parisians, through non-life insurance and personal accident insurance, as well as on the public authorities. The natural disaster

entre 3 et 30 milliards d'euros
estimation du coût d'une crue centennale

"For Sustainable Tourism in Paris" Programme
With the "For Sustainable Tourism in Paris" programme, tourism operators are also involved in preservation of the water, energy and food resources in such high demand in the hospitality and catering sectors. Essentially, it is a matter of reducing consumption of these resources in order to reduce dependence on them.

PIERRE RABADAN
Deputy Mayor of Paris responsible for sport and the Olympic and Paralympic Games

National and International sporting events, many of which Paris hosts, must adapt to climate change as well as come up with new modes of organisation. In this regard, the 2024 Paris Olympic and Paralympic Games aim to create a new standard for events in terms of environmental responsibility, reduction of emissions and integration of climate risks.

compensation system (known as CatNat in France) provides insurers and the Central Reinsurance Fund (CCR) with the State's guarantee. The system covers extreme events and has been used nine times in Paris since 1990: seven times for floods and twice for storms. Total cumulative compensation since 1995 is close to 100 million euros released for Paris. Considered to be highly robust, the system may be further strengthened, in particular in order to take account of such major risks as 100-year floods: according to the scenarios, estimated damage could oscillate between 3 and 30 billion euros.

VULNERABILITY OF ECONOMIC, TOURISM AND CULTURAL SYSTEMS RELATIVE TO RESOURCES AND CLIMATE HAZARDS

		ECONOMIC FABRIC	TOURISM AND CULTURE
Hazards	Heatwave	🔴 ↗	🔴 ↗
	Flood	🔴 ↗	🔴 ↗
	Desertification	🟠 ↗	🟠 ↗
	Average temperatures	🟠 ↗	🟠 ↗
	Heavy rainfall	🟠 ↗	🟠 ↗
	Mass wasting	🟠 ↗	🟠 ↗
	Storm	🟠 ↗	🟠 ↗
	Rainfall	🟠 ↗	🟠 ↗
	Extreme cold	🟠 ↘	🟠 ↘
	Snow and freezing rain	🟠 ↘	🟢 ↘
Resources	Water (including hydrological droughts)	🟠 ↗	🟠 ↗
	Biodiversity	🟠 ↗	🟠 ↗
	Energy	🔴 ↘	🔴 ↘
	Air	🔴 ↘	🔴 ↘
	Food	🟠 →	🟠 →

High risk 🔴 Moderate risk 🟠 Low risk 🟢
Evolution of risk by 2050 increased ↗ stable → decreased ↘

And what if?

Decision-making, financial and economic centres were flooded

Paris' entire economic fabric is directly and indirectly exposed to flood risks. First in line are such places as the Elysée Palace, the National Assembly and Bercy, all of which are located in floodplain areas. A flood of the same magnitude as the 1910 event could result in our intuitions being paralysed along with the city's business district in the 8th arrondissement and a great many local companies, which are also located in floodplain areas. According to a study conducted by the OECD, economic activities would be disrupted for one or two months. With problems including travel, communication and destruction of stocks, it could generate direct losses to the tune of 60 million euros. 430,000 jobs could be threatened.

TENSION ON THE PUBLIC HEALTH SYSTEM

The new threats connected with global warming weigh particularly heavily on Parisians: emergence of new health risks, declining quality of life, disruption of public utilities, increasing economic cost of post-crisis repairs, etc. They might to some extent also weaken such vital services as healthcare.

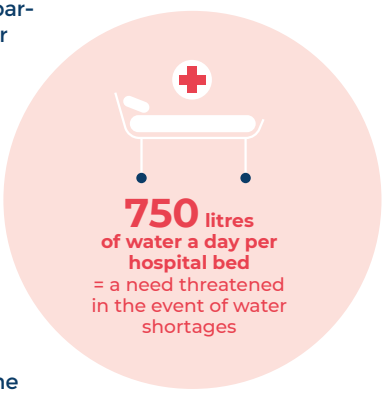
And what if? Hospitals were flooded

The Paris Prefecture's Flood Risk Prevention Plan (PPRI) has identified a total of fifty care facilities located in floodplain areas: eighteen hospitals, including the Georges Pompidou European Hospital, sixteen accommodation facilities for senior citizens and sixteen accommodation facilities for people with disabilities or in difficulty. In addition, a flood may well impact driving conditions (flooded highways, only authorised vehicles allowed on the road, etc.). A great many healthcare facilities will be unable to work at full capacity and some will have to close temporarily. Such a situation will mean increased waiting times in hospital departments.

VULNERABLE, UNDERSIZED INFRASTRUCTURES?

Paris' healthcare services are exposed to numerous climate hazards. As every facility must always stay supplied with potable water, electricity, and heating and cooling systems, the healthcare system is particularly sensitive to climate hazards and domino effects. In 2008, for example, a power outage at Saint-Antoine Hospital required temporary evacuation of patients in intensive care. Nonetheless, such events are still rare, all the more so as they can be prevented by such simple solutions as generators. Similarly, depletion of water resources is a growing concern: each hospital bed "consumes" an average of 750 litres of water a day, roughly the equivalent of the daily quantity consumed by six Parisians. In order to cope with shortages, healthcare facilities will therefore have to reduce their water consumption.

In addition to the risks of partial interruption of healthcare services, other risks are likely to increase the population's needs in their regard. Waves of extreme cold, and waves of extreme heat even more so, may result in peaks in hospitalisations and mortality, in particular among the most vulnerable, including the elderly, young children and the homeless. As for air pollution, it is still the primary factor impacting Parisians' health, equivalent to alcohol and tobacco, even though the situation should eventually improve thanks to the actions undertaken by the City of Paris. Ozone and fine particles in particular contribute to degradation of air quality and impact the healthcare system as they cause more respiratory and cardiovascular diseases and premature deaths.



EMERGENCE OF NEW PATHOLOGIES DUE TO CLIMATE CHANGE

Degradation of biodiversity can also play an indirect role in the appearance and spread of epidemics and pandemics. In this respect, the

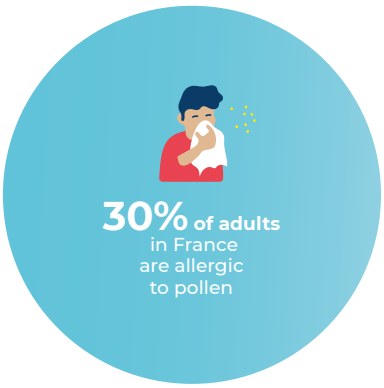
ANNE SOUYRIS Deputy Mayor of Paris responsible for public health and relations with the APHP, environmental health, the fight against pollution, and risk reduction

Paris is taking action on environmental and community health. We are preparing to provide the healthcare required to meet the great challenges posed by the Anthropocene Era, which include climate change.

Covid-19 crisis comes as a reminder of the importance of maintaining a health service robust enough to absorb major shocks. Health issues are bound to arise: infectious diseases transmitted by mosquitoes, mental health problems (in the face of climate changes and extremes), greater risk of water-borne and food-borne infections, respiratory diseases caused by pollen. Creation of a Parisian Environmental Health Service (SPSE) in 2016 led to the drafting of a new Paris Health Environment Plan aiming to better understand health issues connected with the environment. It enables integration of objectives regarding improvement of Parisians' health into the City's operation and its urban projects.

Social support at the service of Parisians' health.

In the same vein, the Paris Urban Planning Agency (APUR), in collaboration with the City of Paris, has also developed a mapping tool to identify environmental, social and territorial health inequalities in Paris. Finally, a Santé Publique France study on the relationship between temperature and mortality in Île-de-France, published in 2020, has reinforced the policy on knowledge of the healthcare system. In Paris, close attention is paid to actions designed to reduce numbers of urban heat islands, which seem promising as far as reduction of the risks involved is concerned, and complement targeted action on behaviours and the most vulnerable sectors of the population – including through the REFLEX file.



THE PUBLIC HEALTH SYSTEM'S VULNERABILITY RELATIVE TO RESOURCES AND CLIMATE HAZARDS

		PUBLIC HEALTH
Hazards	Heatwave	↗ High risk
	Flood	↗
	Desertification*	-
	Average temperatures	↗
	Heavy rainfall*	-
	Mass wasting	↗
	Storm	↗
	Rainfall*	-
	Extreme cold	↘
	Snow and freezing rain	↘
Resources	Water (including hydrological droughts)	↗
	Biodiversity	↗
	Energy	↘
	Air	↘
	Food	→

Moderate risk Low risk

Evolution of risk by 2050 increased ↗ stable → decreased ↘

* The risk is not zero; it was studied in the context of water resources.

CELIA BLAUEL Deputy Mayor of Paris responsible for the Seine, Prospective Paris 2030 and Resilience

Droughts, floods, submersions, and loss of agricultural crops are already making some territories both near and far uninhabitable, resulting in migratory phenomena. Developing policies on adaptation, support and reception of the peoples concerned is a challenge for us all and an issue to be taken account of in creation of a resilient city.

CLIMATE CHANGE IN PARIS

Paris has already been subject to some of the manifestations of climate change, such as the heatwaves in the summers of 2019 and 2020 and floods due to heavy rainfall (June 2016), which caused considerable damage to basements and the Paris metro. Average temperatures will continue to increase, rainfall events will become less frequent and more intense, and the territory will experience more frequent periods of drought. The risk of flooding due to the Seine overflowing is also set to increase throughout the century. The effects of climate change are already being measured today (+2.3°C), and they will accelerate and intensify as the 21st century continues, reaching critical thresholds for which the Paris region is preparing itself.

LIVING WITH THE CLIMATE

Climate change threatens our infrastructures and is also going to impact our ways of life. We are going to have to adapt to the new climate situation throughout this 21st century. It can only be done if we are all committed to building a city which will always be a pleasure to live in.

ADAPTATION SOLUTIONS BASED ON DEVELOPMENT OF NATURE IN THE CITY

Although the natural resources of water, flora and fauna appear to be the best weapons, they will be increasingly threatened as the century continues. Will water be adequate in quantity and quality? Will biodiversity be preserved? Paris' climate policy aims to respond in practical, holistic fashion by adapting its territory sustainably through such actions as vegetation, reinforcement of biodiversity, unsealing of surfaces and stormwater management, as well as via regulatory documents integrating climate risks and resource depletion (Local Bioclimatic Urban Plan).

INCLUSIVE WAYS OF LIFE ADAPTED TO THE CLIMATE CHALLENGE

The whole Paris region is going to have to adapt to present and future manifestations of climate change. The health system, energy networks, the insurance system, transport networks, the built environment and public space will all have to be adapted, when possible, if their sustainability and proper operation is to be ensured. Technical and technological progress may facilitate these necessary modifications. However, changes in our behaviour, our way of life and of consuming depend on our individual and collective willingness to stimulate change and advance towards a sustainable form of organisation. We do not all have the same capacity for adaptation, and, in order to deal with the climate challenge, society must rethink the way its members relate to each other and make solidarity a tool for successful socio-ecological transition. Parisians are already starting to have new aspirations: a need for nature, space, a desire to consume more locally and travel differently. The main concern is how capable we are of changing our lifestyles, of reshaping them in order to create an inclusive Paris adapted to climate change.

VILLE DE
PARIS