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## Urban Heat and critical environmental thresholds: new bridges between science and policy?

**Alvaro Artigas \***

alvaro.artigaspereira@sciencespo.fr  
Associate CEE (Sciences Po),  
IES (NUS)

**Charlotte Halpern \***

charlotte.halpern@sciencespo.fr  
CEE, LIEPP (Sciences Po)

**Lup Wai Chew \***

lupwai@nus.edu.sg  
NUS Department of the Built  
Environment, NUS  
Environmental Research Institute

**Sanjay Swarup \***

dbsss@nus.edu.sg  
NUS Environmental Research  
Institute, NUS Department of  
Biological Sciences

**Alexandre Gelabert \***

gelabert@cerege.fr  
CEREGE (Aix Marseille  
Université)

**Nathalie Blanc \***

nathali.blanc@wanadoo.fr  
LADYSS, Centre for Earth  
Politics (Université Paris  
Cité)

### ABSTRACT

Urban warming is expected to increase in the context of climate change, with dramatic effects on urban social and natural ecosystems. Supporting business-as-usual approaches has become increasingly challenging in the face of enhanced scientific knowledge and tangible critical thresholds of climate change. Focusing on two large metropolitan areas, Singapore and the Paris Ile-de-France Region, this policy brief provides a timely opportunity to take stock, identify remaining blind spots and examine how to address them through interdisciplinary research and targeted efforts to bridge the gap between scientific knowledge, governance arrangements and policy processes.

### RÉSUMÉ

Le réchauffement urbain s'accroît dans le contexte du changement climatique, avec des effets dramatiques sur les écosystèmes sociaux et naturels. Le soutien au *statu quo* est une stratégie difficilement tenable, face à l'amélioration des connaissances scientifiques sur les seuils critiques tangibles du changement climatique. À partir des regards croisés sur deux grandes métropoles, Singapour et Paris Ile-de-France, ce Policy brief présente les acquis de la recherche, identifie les angles morts à l'interface de différents champs disciplinaires, et montre l'intérêt d'un agenda de recherches interdisciplinaires pour combler le fossé entre connaissances scientifiques, dispositifs de gouvernance et processus de politiques publiques.

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*Corresponding author: charlotte.halpern@sciencespo.fr*

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## Introduction

The increasing exposure to climate change transformational dynamics by human societies and ecosystems has never been more acutely visible than by the increasing heat waves that have challenged the current anthropogenic uses of urban space. The understanding of the complex entangled causes and consequences of Urban Heat Island (hereafter UHI) and its current development dynamics has increasingly moved under the spotlight, due to recurrent events in almost every urban region. UHI is the phenomenon where an urban area is warmer than the surrounding rural areas. UHI intensity is often around 1 to 3 °C (i.e., the urban area is 1 to 3 °C warmer than the surrounding rural areas) (WMO 2023; Iodice et al., 2024). The causes of UHI have been widely researched, for example anthropogenic heat, release of heat stored in buildings and roads during nighttime, and weaker winds in urban areas to disperse heat. Urban warming is expected to increase in the context of climate change, with dramatic effects on urban social and natural ecosystems. UHI increases the energy demand for cooling, which can further increase UHI intensity, forming a vicious cycle of rising temperature and energy demand in urban areas (Cheshmehzangi 2023, Ademe 2021).

UHI mitigation strategies have been the focus of major research worldwide, especially in the tropics. Findings repeatedly highlighted that supporting business-as-usual approaches or initial environmental responses formulated in the 2000s has become increasingly challenging in the face of enhanced scientific knowledge and tangible breach of critical thresholds of climate change. Yet looking into the transformation of cities today, UHI related mitigation and adaptation programs are confronted with a formidable task: can sustainable city development strategies be developed in the face of upwards trend of energy consumption (e.g., housing, transportation and food production), increasing release of pollutants and the exacerbation of urban warming? In addition, how does UHI contribute to exacerbating socioeconomic inequalities in cities? Indeed, important related questions pertaining to principles of the just transition include demands for better livability are now increasingly tied to UHI exposure, thus redefining the very terms of material affluence (Amorim-maia 2024). Can rapidly developing cities aspire to quick, higher livability standards without clashing with the new imperatives of UHI mitigation and ultimately a set limited amount of “climate related goods”? To what extent have UHI related mitigation and adaptation programs contributed to generating new socioeconomic inequalities in cities and their wider metropolitan regions?

Policy responses have had to meet these contradictory demands in ways that have not up to this day been entirely satisfactory, or that have ultimately sacrificed essential aspects of ecosystemic preservation to the benefit of livability or -more seldom- vice versa (Birkmann et al. 2010). Contradictory demands stemming from city affluence and growth dynamics have not been without consequences in this respect. Framed by the principles of a just transition in the context of more advanced societies, policy responses had to assimilate important principles of equality, evenness, and fairness to the process of adopting mitigating measures advanced by scientific research. These principles, while self-evident (e.g., accessible, well insulated housing for all, affordable non-conventional renewable energy) have not been without complexity at the time of transposing them to reality also in part given their technical complexity. Their disruptive potential has proven every bit as complex as the one brought forth by UHI. The adoption of “cooling city” programs raises inconvenient questions that point to the distributive consequences of these measures -who gets what, when and how and to what extent- which de facto leads to targeting key specific groups that is, the new urban climate precarious. Moreover, in this grand trade-off process, it is also important to ask whether urban ecosystems end up getting the short end of the stick when nature is reintroduced (DU 2024) merely in the form of ecodistricts where the just transition is used for other purposes than strictly climate preserving ones.

## Comparing UHI research and policy responses in Singapore and the Paris Ile-de-France Region

These two large cities are highly urbanized areas, in which high UHI intensities have been observed, with UHI of up to 7 °C recorded in Singapore and 8 °C in Paris. In both cities, important efforts have been made to measure this phenomenon and model its likely evolution in the context of climate change as well as in the light of current urban development objectives. Furthermore, the current and future effects of rising temperatures on ecosystems and urban life is better known. Over the recent years, specific measures have been implemented in Singapore and in the Paris Ile-de-France region, and new, more ambitious, strategies are now being considered to navigate the formidable challenge of rising temperatures and its likely consequences.

In the case of Singapore, the choice of carbon services and trading hub ambitions was studied in concomitance with the government's push towards sustainability under the Singapore Green Plan 2030. Its distinctive feature, as part of the CAPIIn GHG project [1], resided in efforts to include the way in which nature contributes to the

[1] More information about this project available here: <https://www.sciencespo.fr/liepp/en/research/project/capin-ghg/>

reduction of greenhouse gasses. In 2014, an ambitious five-year project was launched to measure the country's carbon footprint, as well as the mitigating effect of the island's greenery. Four key areas have been earmarked in this context, among which are urban solutions and sustainability and including specific themes such as climate science, the development of healthy cities and enhancing the efficiency and productivity of the built environment. Singapore's ambitious goal to achieve net zero emissions by 2050 meets several initiatives included in the CAPIn GHG project in terms of ambitious measures while providing enhanced liveability aimed at curbing the most disruptive consequences of climate change. From setting emissions targets to changing behaviour through procurements in city infrastructure, Singapore's public sector has been resolutely moving towards integrating mitigation and adaptation initiatives within the Singapore Green Plan 2030 as well as through the GreenGov.SG initiative [2].

In the case of Paris Île-de-France, preliminary findings from our own work on the Paris 2020 and 2050 strategy climate action plans [3] show that a diverse pool of environmental objectives and programs partaking of efforts to curb greenhouse gas (GHG) emissions were identified across several scales. An increasingly more complex modelisation has been laid out, where industrial carbon footprint, the accounting of everyday activities and key sectoral areas -like transportation - has been devised and revised upwards by the French Ecological Transition Agency (ADEME). Looking past National Determined Contributions (NDCs), emissions reduction programs in the housing and the waste policy sectors are being developed, there is a growing need for a common GHG inventory at the urban / metropolitan level to enhance policy coherence. A more detailed analysis of urban warming and its impacts is being produced by expert agencies at the regional and the Greater Paris metropolitan levels to inform adaptation strategies and climate mitigation plans (Apur, 2017; Cordeau, Dore, 2024).

### Main argument

This policy brief adds to existing knowledge by adopting a resolutely interdisciplinary perspective on a well-studied phenomenon. First, it takes stock to examine how heatwaves and UHI related phenomena are altering previous environmental transitions, the role of science in the policy making process and the overall objectives pursued by environmental mitigation and adaptation. Second, it identifies remaining blind spots and explores what solutions could be introduced to address them, either through interdisciplinary research or through targeted efforts to bridge the gap between scientific

knowledge, governance arrangements and policy processes. Overall, this policy brief contributes to better understanding how climate disruptions have been assessed so far and the extent to which these scientific knowledge have shaped policy responses.

## 1. Understanding what urban heat entails for cities and their ecosystems

Being the focus of scientific interest at both national and international settings for the past several decades (as per the World Meteorological Organization (WMO), IPC3 (Integrated Food Security Phase Classification, scale 3) and Global Heat Health Information Network (WMO/World Health Organization)), the responses to this phenomenon, or rather intertwining phenomena, has accelerated in recent years. This has led to a significant array of across-the-board policy responses at the national and local levels, encompassing mitigation and adaptation programs that seek in turn to address, if not all, some of the most salient dimensions of urban heat on livelihoods, the environment and the very fabric of city life. While operating in conjunction, these different dimensions (resource conservation, livelihoods, biodiversity marshaling, housing, services provision) have been driven within policy responses by specific knowledge subsets, increasingly agglomerating interests that convey different interpretations of what urban heat intensification entails for the immediate future of cities and their residents.

These dimensions have been increasingly reconciled under the large umbrella of climate change mitigation by the Intergovernmental Panel on Climate Change (IPCC) internationally, and at the national level like in France the Observatoire National sur les Effets du Réchauffement Climatique (ONERC) or the GREC francilien (groupe régional d'expertise sur le changement climatique et la transition écologique en Île-de-France) at the regional level, or the City of Paris at the local level. Operating along similar lines, whereas stemming from Ministry of Sustainability and the Environment (MSE) or at the local level by Urban Redevelopment Authority (URA) in Singapore, causal mechanisms for UHI and immediate mitigation responses have been deployed. These have contributed to localized as well as aggregated global efforts to curb climate change consequences for human societies.

The exploration of the composition of these aggregated policy responses and their impacts into how urban societies deal with this phenomenon is an important milestone of the workshop as it conveys an important evaluation component.

[2] Among the most salient initiatives, three of them “Expand the Nature Park Network”, “Intensify nature in gardens and parks” and “Strengthen connectivity between Singapore’s green spaces” are landmarks of a holistic approach to the presence of Nature in the City as a powerful vehicle for both mitigation and adaptation.

[3] Research being done by Alvaro Artigas and Charlotte Halpern as part of the CAPIn GHG project (funded under the NUS-Paris programme).

## 2. The aggregation of scientific knowledge on UHI: bridging the gap

An important component of this effort has been the ability to analyse this phenomenon with a diverse range of data. Efforts have thus been deployed in the collection of reliable datasets that not only relate to temperature change per se, but on the multi-faceted dimensions of global warming at the city level. There has been a collective effort of knowledge accumulation and cross-verification operating across several countries and diverse geographical contexts (specific ecosystems, cities located in specific biomes or even, rapidly shifting climate) aiming at enhancing, but also cross-verifying the array of scientific analysis. This research has investigated the specific impacts of heatwaves on materials, populations and overall living organisms, including plants, animals, bacteria, and fungi [4]. Another stream of research has sought to single out the main causes of temperature increase in urban settings, pointing to the extensive use of energy sources for building heating and cooling, transportation and other anthropogenic sources.

More intense, more frequent extreme events, such as heatwaves and storm surges, have been predicted and observed. New records are continuing being set, the most recent record was set by July 2024 being the hottest month since 1880 (NASA, 29/07/2024).

Combined with research on climate change, scientific research has increasingly identified interactions between these different variables where mutually-reinforcing dynamics are at work and can potentially exacerbate, if they have not, the consequences of naturally occurring phenomena. The example of the US National Integrated Heat Health Information System (NIHHIS), in partnership with Climate Adaptation Planning and Analytics (CAPA), the US Centers for Disease Control and Prevention and the US Environmental Protection Agency among others for the mapping of UHI developments at a global level is an example of these aggregated, increasingly collaborative efforts. However, and as per other areas that are vital to climate change prevention, like GHG inventorying, the policy response and overall aggregated means are fragmentary and significantly insufficient in order to tackle the complexities and increasing threat brought by this development. Triggers that would allow for dedicated responses building on experimental sciences (like biophilic markers), could potentially increase the predictability not only of UHI evolution in time,

but also heatwave episodes and precise urban consequences are still in the making and much research needs continuing development. In the same way, the “tipping points” of nature (Eisenhauer 2017), pointing to the metabolic and more broadly eco-systemic limits of city life are still to be fed back into these analytical models.

## 3. Enhancing science and policy making readability: identifying triggers, removing blinds, setting up complex instruments

Scientific knowledge pertaining to UHI causes and possible mitigation and adaptation in cities, while operating with significant blinds, has nonetheless gained significant traction, in part driven by campaigns to map and identify the direct and indirect consequences to human life by a broad coalition of partners. From local governments (Resilience/Adaptation offices, public health departments, etc.), universities, NGOs (environmental justice, museums, etc.), and the private sector, different science streams have been playing a significantly more important role in policy making. Nevertheless, are policy makers willing to make unpopular policies guided by scientific knowledge to mitigate UHI? For example, the science is clear that reducing anthropogenic heat can reduce UHI intensity, but local governments may be constrained to adopt policies to reduce

***"As per other areas that are vital to climate change prevention, the policy response and overall aggregated means [to Urban Heat Islands developments] are significantly insufficient."***

anthropogenic heat by reducing energy consumption. There is today a large ensemble of stakeholders participating in the definition of policy responses that have yet to be properly evaluated as per their real contribution to curbing the most disruptive effects of UHI. Further, are all UHI mitigation strategies effective? For example, many cities have gone “green” by increasing vegetation coverage and planting trees, but does “greening” mitigate UHI and if it does, to what extent and how can this be precisely quantified -if ever? Even though the contribution of vegetation to reducing UHI has been widely highlighted by research, it is still understood in a limited way: it would therefore be relevant to address the place of nature-based solutions and more specifically biodiversity, i.e., the eco-systemic, specific and genetic complexity of living entities in cities. Indeed, transcending a mere sectoral problem, the UHI requires us to take into account the quality of the urban ecosystem and the attainment of critical tipping points as perceived by their human dwellers [5]. Other dimensions, such as the importance of urban geography (location, morphology, etc.) needs to be taken into account, so that intra-urban and inter-urban geographical diversity can be appreciated, while at the same time qualifying the complexity at work. Comparing

[4] For example, exploring the interaction between UHI and energy consumption requires understanding the dynamics of UHI intensity and air pollution indices in different land uses (Aghamohammadi, Santamouris, 2022).

[5] As the community level is where climate change impacts are most experienced, successful adaptation necessarily implies the broad support of affected communities. See Graça et al. (2022).

neighbourhoods and cities also enables us to take into account the links between UHI and social, environmental and climatic inequalities.

Much remains to be researched about how cities conduct this data collection process (whereas through mapping, open data, review reports from previous campaigns, civil society involvement) and how more subjective dimensions of liveability (such as well-being perceptions, climate stress) are objectively assessed and fed into pluriannual planning programs. As UHI is but one dimension of the overall impacts of global warming and climate change in cities among other (cycle of water related events for instance, biodiversity to name another), other dimensions have been postponed or partially addressed, as a result of long entrenched path dependent dynamics and the muddling through overall (Lindblom 1959, Mercer 2021). In this process of institutionalisation of responses to UHI, public authorities have inevitably privileged specific dimensions over others, in accord with their specific agendas of economic growth, social development and justice, and even environmental preservation. They have also been met with resistances and long entrenched sectoral interests (energy, housing) and their own specific agendas.

More significantly in the case of the EU and other multi-level governance setups, there has been a process of increasing convergence of different initiatives aimed at mitigating UHI with standardised procedures, processes and mechanisms through which international forces such as legal harmonisation, institutionalised information flows have steered domestic environmental policy change. Climate adaptation is at the heart of the European Climate Law (article 5), and as part of the EU Adaptation Strategy overarching data-collecting and policy evaluating entities such as the European Climate and Health Observatory have been launched in 2021. The EU's wide-reaching support – over 300 EU regions, cities and local authorities in their efforts to build resilience against the impacts of climate change – has included relevant initiatives such as the 3 billion Trees Pledge, aimed to increase tree coverage across Europe by 2030. Also, a large array of smaller local projects making use of the natural cooling effect provided by vegetation to protect European city dwellers from extreme temperatures, such as the LIFE@Urban Roofs project in Rotterdam, Netherlands or The LIFE PACT project – launched in Leuven, Belgium, and to be replicated in other parts of Europe – is developing digital tools aimed at reporting biophilic solutions and feeding them into policy decisions aimed at cooling cities. In Singapore, similar efforts to mitigate UHI have been initiated, such as the Singapore Green Plan 2030 and the Cooling Singapore Project.

## Conclusion: Towards a future agenda for research and practice: key dedicated triggers

This policy brief points to the formidable challenge of UHI mitigation and seeks to bring under the spotlight most of the issues currently grappled by related environmental programs. This provides readability and avenues for future research and scientific collaborations. It also contributes to setting up actionable research objectives that will potentially assist policy makers in developing more encompassing, environmentally sound programmes. The research objectives are broken down in four dedicated triggers:

1. **To assess** the disconnect between ambitious UHI mitigation and adaptation policy objectives and their enactments through UHI related plans and the selection of scientific triggers and thresholds;
2. **To explore** the disruptive impact of new science, technologies and stakeholders and the extent to which the issue of UHI has changed in relation to these;
3. **To examine** evolving environmental policy capacities in both the Paris Ile-de-France Region and Singapore (whereas relating to national or local governance) in relation to setting local climate action plans that address urban heat;
4. **To carry out** this research in a highly interdisciplinary environment, to lay the foundations for a joint exploration of UHI and its impacts by bringing together Earth sciences, Engineering and Social sciences and Humanities.

More specifically, two lines of interdisciplinary research could be developed. To begin with, to produce an assessment of the design and implementation strategies of policy makers in relation to a complex science-based instrument that has far reaching consequences in terms of accelerating vital city processes such as energy transitions, transport modernisation and real-estate development. The variations observed and commonalities found over time and across policy areas and in the two regions should, notably, point to the limitations of these policy transfers and the embedded nature of these instruments. Furthermore, this comparative analysis between the two urban areas contributes to current academic debates about persisting regional policy styles in designing UHI programs and emissions and addressing the climate emergency, while at the same time assessing standardizing dynamics resulting from the circulation of policy instruments and solutions through global policy communities and networks.

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**Directrice de publication :**  
Anne Revillard

**Edition et maquette :**  
Andreana Khristova  
Ariane Lacaze

Sciences Po - LIEPP  
27 rue Saint Guillaume  
75007 Paris - France  
+33(0)1.45.49.83.61