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Co-benefits as a rationale and co-benefits as a factor for urban climate action: linking air quality and emission reductions in Moscow, Paris, and Montreal

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Abstract

If local governments reduce greenhouse gas emissions, they will not see effects unless a very large number of other actors do the same. However, reducing greenhouse gas emissions can have multiple local "co-benefits" (improved air quality, energy savings, even energy security), creating incentives for local governments to reduce emissions—if just for the local side-effects of doing so. Available empirical research yet shows a large gap between co-benefits as a rationale and an explanatory factor for climate mitigation by local governments: co-benefits are seemingly very large, but do not seem to drive local mitigation efforts. Relying on policy documents, available research, and other written sources, the present paper consists of a multiple case study addressing the link between co-benefits and climate mitigation in Moscow, Paris, and Montreal. Air quality plays a very different role in each case, ranging from a key driver of mitigation to a liability for local climate action. This heterogeneity of mechanisms in place emerges as a likely explanation for the lack of a clear empirical link between co-benefits and local mitigation in the literature. We finally discuss implications for urban climate action policy and research.

Keywords Urban climate governance · Climate mitigation · Climate adaptation · Cities

1 Introduction

The importance of cities for achieving climate mitigation targets is increasingly recognized, and many cities all over the world are committed to climate action. This goes beyond official commitments: cities are actually delivering on emission reductions (Hsu et al. 2020; Khan and Sovacool 2016; Kona et al. 2018). Decreasing emissions in one city does not make a big difference for the global climate. However, that does not seem to halt local governments from taking action on climate change. Much to the contrary, Chapter 8 of the last Assessment Report of the Intergovernmental Panel on Climate Change reports that local governments which reduce emissions and adapt to climate impacts also experience a

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broader range of further local benefits (Dodman et al. 2022): local benefits might thus be more evident for them than global ones. Policy and academic circles have multiple names for those benefits, synergies, or trade-offs related to climate action (including both mitigation and adaptation). The most popular one is arguably the "co-benefits" concept (Floater et al. 2016; Mayrhofer and Gupta 2016; Ürge-Vorsatz et al. 2014). Research has shown how co-benefits of climate policy go way beyond "cost and carbon," covering issues as diverse as national pride, industry innovation, improved international relations, rural development, domestic comfort, noise reduction, greater mobility, and many more (Sovacool et al. 2020). More importantly, some of these co-benefits are substantial, out-weighting the costs of climate action policies. This is the case for the health benefits from improved air quality through mitigation action (Karlsson et al. 2020; Ürge-Vorsatz et al. 2014).

The interest in co-benefits is linked to their "advocacy potential" (Mayrhofer and Gupta 2016; Workman et al. 2018): co-benefits represent a strong rationale for climate action, providing a compelling argument for local governments to make climate action more acceptable to local constituencies. If so, those cities with the greatest potential to reap co-benefits should be among the cities with more advanced climate action. Surprisingly, empirical research on local climate action (Castán-Broto and Westman 2020; van der Heijden 2019) does not list co-benefits among the factors explaining climate action. Climate action by local governments is typically explained in terms of national policies (Andonova et al. 2017; Domorenok 2019; Heidrich et al. 2016), local capacities (Homsy 2018; Krause et al. 2021), and the role of transnational municipal networks (Bansard et al. 2017; Michaelowa and Michaelowa 2017). Co-benefits, instead, do not seem to drive local climate action (Krause 2011; Pablo-Romero et al. 2015; Pitt 2010; Rashidi and Patt 2018). There is, in other words, a large gap between 1) co-benefits as an argumentative *rationale* for climate action and 2) co-benefits as an empirical, explanatory *factor* for climate action.

If research has so far struggled to establish a clear empirical link between co-benefits and actual climate action, we probably know too little about the role of co-benefits in climate action processes. With that in mind, the present paper focuses on the largest and most studied co-benefit of climate action: public health benefits through improved air quality from mitigation policies (Karlsson et al. 2020; Ürge-Vorsatz et al. 2014). We explore the link between air quality and climate mitigation in Moscow, Paris, and Montreal, three large cities with a capable local government, a substantial degree of autonomy, an affinity to the technology sector, an explicit green growth agenda, and membership in multiple transnational municipal networks addressing urban climate action. All experienced air quality problems in the 1990s, and all achieved significant greenhouse gas ("GHG") emission reductions since. Relying on policy documents and available research in the frame of a multiple case study research design, the present paper provides a qualitative account of the processes through which climate action unfolded in the three cities from the 1990s to the present, tracking the role of air quality therein. The goal is to answer the following, overarching research question: how do air quality considerations affect climate mitigation processes?

Looking at the same co-benefit in three remarkably similar contexts, we observed remarkably different processes. Air quality considerations clearly drove emission reductions in Moscow. They played only a minor role in Paris, though, where air quality rather relates to climate adaptation. In Montreal, finally, air quality and emission reductions represent completely separate processes, with little interaction. The complexity and heterogeneity of these processes likely explain why local governments seldom exploit co-benefits as a rationale for climate action to make mitigation measures more acceptable to the local constituencies. It is therefore not surprising that previous empirical studies struggle to establish an empirical link between co-benefits and climate action. Furthermore, if process complexity and heterogeneity pose challenges to exploiting the largest and most widespread type of co-benefit, the lesson arguably holds for co-benefits more generally. We then discuss implications for policy and research.

2 Literature review

2.1 Co-benefits as a rationale for climate action by local governments

Co-benefits of climate action (mitigation or adaptation) have attracted a substantial research interest in the last decade (Floater et al. 2016; Mayrhofer and Gupta 2016; Workman et al. 2018). They represent the biophysical and technological interdependencies between climate action measures and other policy areas (health, air quality, housing, transport, waste, etc.): promoting low-emissions vehicles with high fuel efficiency standards reduces energy consumption (a mitigation measure) but also contributes to reducing particulate matter concentrations, lowering the costs connected to respiratory diseases and premature deaths (a public health co-benefit). Co-benefits are not exclusive to mitigation: recent studies highlight adaptation co-benefits as well (Hennessey et al. 2017; Luyten et al. 2023), and address synergies and trade-offs between adaptation and mitigation (Dodman et al. 2022; Sharifi 2021). Recent reviews report a broad range of benefits from climate action (both mitigation and adaptation), including healthier diets and physical activity, soil and water quality improvements, public savings, the reduction of energy poverty, biodiversity, and, most importantly, air quality (Dodman et al. 2022; Karlsson et al. 2020). Air quality co-benefits represent the largest portion of the co-benefits literature, focusing on the public health dimension of climate mitigation (Maibach et al. 2010; Nowak et al. 2018; Sabel et al. 2016).

Early debates brought up the idea of co-benefits as a rationale for local climate mitigation. However simplistic, the reasoning is the following. Climate mitigation constitutes a collective action problem: the costs of reducing GHG emissions stand against benefits (a reduction in future climate impacts) that depend from many other actors also reducing their emissions. Overcoming collective action problems requires "selective incentives" (Brody et al. 2008; Olson 1965; Rübbelke 2002). Co-benefits are good candidates for that. Among those listed above, air quality stands out as a key concern in urban areas (Strosnider 2017), with manufacturing, transport, energy supply, waste, and the residential/commercial sector being both key sources of air pollution (EEA 2020) and key areas of local government regulation. Many have therefore argued that mitigation action is worthwhile for local governments because of the improved air quality, independently of the expected reduction in future climate impacts (Kousky and Schneider 2003; Lee and Koski 2014; Sippel and Jenssen 2009).

Whether co-benefits constitute a rationale for local governments to engage with climate mitigation depends on their size in relation to the costs of mitigation. A substantial amount of research has thus attempted to quantify air quality co-benefits and estimate their magnitude in monetary terms. The World Health Organization reports 6.7 million deaths globally attributed to the joint effects of ambient and household air pollution for 2019—a predominantly (although not exclusively) urban phenomenon (WHO 2023). A study of nine countries (Brazil, China, Germany, India, Indonesia, Nigeria, South Africa, the UK, and the USA) assesses between 1.2 and 1.6 million deaths per year avoided because of the air quality co-benefits of meeting climate mitigation targets (Hamilton et al. 2021). A study of premature mortality in 969 European cities and 47 greater cities assesses preventable deaths between 51,000 and 125,000 yearly (Khomenko et al. 2021). A similar study of 161 Chinese cities estimated 652,000 deaths in 2015 alone (Maji et al. 2018). For 2020, implementing Madrid's integrated air quality and climate action plan should postpone 88 and 519 deaths respectively for $PM_{2.5}$ and NO_2 (Izquierdo et al. 2020).

Once the impacts of air pollution on health are assessed, it becomes possible to quantify the health care expenditures related to such effects. These have been estimated at an order of magnitude similar to or even higher than the costs of mitigation (Pearce 2000; Ščasný et al. 2015; Schucht et al. 2015; West et al. 2013; Zhang et al. 2017). To the best of our knowledge, no other type of co-benefit from either mitigation or adaptation has been shown to out-weight mitigation costs. Air quality co-benefits from mitigation thus represent the ideal case to explore the role of co-benefits as a rationale for climate mitigation by local governments, whether, in particular, local governments exploit the large air quality co-benefits to make climate mitigation efforts more acceptable to local constituencies.

2.2 Co-benefits as a factor for local climate mitigation

Framed in terms of air quality and public health, co-benefits arguably provide a strong argument for local governments to make climate mitigation efforts more acceptable to local constituencies. If so, one would then expect an empirical link between air quality co-benefits and actual mitigation in cities. Empirical research does not confirm that. A large amount of literature is available that tries to link various aspects of urban climate action (mitigation or adaptation; planning rather than measures or actual achievements; the degree of vertical and horizontal integration, etc.) to a plurality of potential explanatory factors (Castán-Broto and Westman 2020; Heidrich et al. 2016; Hsu et al. 2020; Khan and Sovacool 2016; Kona et al. 2018; Reckien et al. 2018; Roggero et al. 2023; van der Heijden 2019). Results rather point at factors such as local government capacity (Araos et al. 2016; Bansard et al. 2017; Heikkinen et al. 2020; Krause et al. 2021; Reckien et al. 2018; Steffen et al. 2019), national policies (Boussalis et al. 2018; Domorenok 2019; Eisenack and Roggero 2022; Krause 2011; Lee and Koski 2014; van der Heijden et al. 2019), and membership in transnational municipal networks (Domorenok 2019; Eisenack and Roggero 2022; Heikkinen et al. 2019; Rashidi and Patt 2018; Steffen et al. 2019).

There is no similarly clear consensus on the role of co-benefits (air quality or otherwise) for local climate mitigation. Pitt (2010) surveys 255 US cities and finds a slightly positive correlation between non-attainment of air quality standards and the number of climate-related policies. For Rashidi and Patt (2018), air pollution is a weakly significant and positive factor for climate policy adoption in 127 cities reporting to the Carbon Disclosure Project (CDP). Pablo-Romero et al. (2015) use data from 7586 Spanish municipalities to show weakly significant, small effects of co-benefits on membership in the Global Covenant of Mayors (GCoM). Zhou et al. (2022) find specific patterns of local, mitigation-related policy instruments in Chinese cities with lower air quality. Other studies do not find a significant relation between air quality and climate mitigation by local governments (Krause 2011). Lack of adequate data is a common issue in the study of urban climate action (Gurney et al. 2021; Parvez et al. 2019) and may account for the above. Qualitative case studies, which are less sensitive to data quality issues, show similar findings. Zimmermann (2018) compares the emergence of climate policy in Munich, Stuttgart, and Frankfurt, Germany, and finds some role for co-benefits (in the form of energy savings) only in

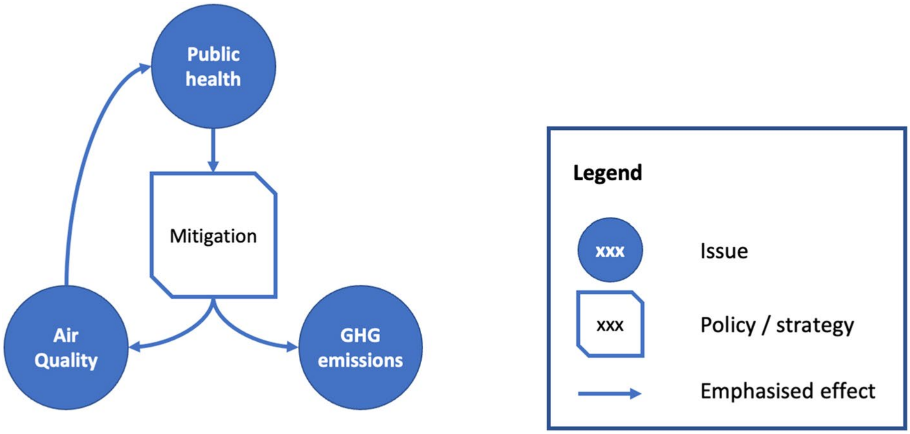

Fig. 1 Link between air quality and greenhouse gas emissions as implied by the co-benefits concept

the case of Frankfurt. Jones (2012, 2013, 2018) provides in-depth comparative accounts of climate action in Stockholm, Copenhagen, Tokyo, New York City, Vancouver, and Melbourne. References to air quality and public health do not feature in any of them.

2.3 Wrap-up: analytical framework and operative research questions

We hereby focus on air quality co-benefits from mitigation. Given the above, two main arguments call for that. First, the widespread character of air quality co-benefits makes them suitable for cross-case analysis. Second, if the largest type of co-benefits can be ignored, all other co-benefits can be ignored too—providing lessons for co-benefits more generally. We thus move from the premise that poor air quality can fuel public health concerns within a local constituency, and that local governments might leverage that to make mitigation efforts more acceptable. Local constituencies, voting mayors in and out of office, may or may not perceive the direct benefits of local climate mitigation measures (that is, a reduced contribution to climate change) as worth the costs. However, they may be more inclined to do so if confronted with the additional public health benefits of mitigation, next to those from a reduced contribution to climate change. We may thus expect local governments to highlight such co-benefits when articulating their mitigation policies—that is, to exploit the "advocacy potential" of co-benefits as illustrated in Fig. 1. Crucially, this should leave traces in the policy documents (plans) and broader narrative (news articles, assessments, reports) characterizing climate action in the three cities at stake.

It is an open question whether Moscow, Paris, and Montreal actually exploit the advocacy potential of air quality co-benefits. Literature has shown that local governments tend to ignore air quality co-benefits while formulating their mitigation strategies: institutional barriers, lack of technical or financial capacity, and lack of political will can hamper the consideration for co-benefits in urban climate action, however large they may be (Boyd et al. 2022; Dale et al. 2020; Gotgelf et al. 2020; Shimamoto and McCormick 2017; Ürge-Vorsatz et al. 2014). With this in mind, we analyze the policy documents articulating climate mitigation in Moscow, Paris, and Montreal; reconstruct the processes through which climate mitigation in the three cities unfolds over the years; and search for references to public health-related air quality considerations. This leads us to a set of operational research questions: First, do local governments exploit the advocacy potential of air quality co-benefits to raise acceptance for local climate mitigation action? Second, do local governments take air quality co-benefits into account in their mitigation policies and strategies? And third, does air quality represent a key factor for local climate mitigation?

3 Materials and methods

Our paper constitutes an in-depth case study of climate action in three cities. The rationale for a case study lies in the need for a better understanding of the processes at play: the possibility that a link between air quality co-benefits and mitigation by local governments does exist, but has so far gone undetected because some important elements of it are yet unknown. The case study method represents the method of choice in such a situation, being designed to address complex, poorly understood phenomena in their natural setting (Yin 1994). A well-designed case study achieves this by choosing cases that are paradigmatic of a particular phenomenon and by relying on a diversity of sources in order to contextualize evidence (*ibid.*). The rationale for a multiple case study rests on two considerations. First, the same phenomenon (here: the link between co-benefits and mitigation by local governments) may play out differently in different contexts. Observing multiple instances of the same phenomenon allows to better disentangle the role of context. Second, there may be qualitatively different (heterogeneous) processes linking co-benefits and mitigation. Multiple cases are a key precondition for observing heterogeneity. As a result, the three cases do not constitute counterfactuals of one another (as in a comparative case study) but rather address the same phenomenon in different contexts.

Case selection proceeded as follows. The case study method is geared towards analytical representativeness, not statistical representativeness (Bhattacherjee 2012; Yin 1994): cases need to be representative of a specific phenomenon (here: air quality co-benefits from local climate mitigation), not of a specific population ("all cities," "all European cities," "all cities with a green mayor"). To this aim, we chose Moscow, Paris, and Montreal in light of (1) their progress in climate mitigation and (2) their well-documented history of poor air quality. Furthermore, we opted for a "most similar" research design (Seawright and Gerring 2008), with the goal of ideally ruling out expected confounders. By design, all the three cities bear those attributes that are well-known factors for urban climate action: all represent the main center of their respective politico-administrative systems, enjoy a wide degree of autonomy and a supportive institutional environment, are members of transnational municipal networks, and can pursue a green growth agenda relying on a local economy that has successfully transitioned from industry to services, with a strong role of research and innovation. All three cities also face challenges linked to a growing population and the resulting congestion problems.

More importantly, the most similar, multiple case study research design also calls for a narrow focus on air quality co-benefits: it requires all case studies to address the same phenomenon in different contexts. Addressing multiple and/or different co-benefits in the three cities implies analyzing different processes: health co-benefits in Paris, energy security in Montreal, or international recognition in Moscow are very unlikely to unfold through the same processes. If processes differ, it becomes impossible to disentangle them from the contexts.

With this in mind, the case study draws on written sources to reconstruct mitigation from 1990 to present. These encompass official documents articulating local mitigation and air quality policies, a broader range of related policy documents (e.g., assessments, by-laws), journalistic sources, and research contributions (see Supplementary Materials for an overview). As usual in case study research, multiple sources were drawn upon for both analysis (that is, answering the research question) and contextualization (that is, taking additional, contextual information into account while interpreting the evidence for analysis). Documents addressing climate action and air quality were retrieved through internet searches until the saturation point was reached, that is, when additional documents stopped providing new elements to the narrative that emerged thus far. After consolidating a corpus of written documents for all three cities, a coherent narrative for each case was developed through a process of meaning condensation (Kvale and Brinkman 2015) based on the conceptual framework presented in Fig. 1. Specifically, documents were systematically reviewed to determine whether and how arguments regarding the biophysical linkages between reducing GHG emissions and reducing air pollution (e.g., in terms of public health) were incorporated into strategies and policies of the respective local governments. The output of this process is presented in the following section, providing a qualitative account of climate mitigation in the three cities.

4 Results

4.1 City of Moscow

Moscow is the main political, economic, and business center of the Russian Federation. With over 12 million residents and a metropolitan area of over 20 million, it is Russia's only megacity and one of the very few megacities on the European continent next to Paris, London, and Istanbul. Over the last 20 years, Moscow's economy has experienced a growth in the service sector, with particular emphasis on trade (wholesale and retail), real estate transactions (renting and service provision), and finance [mos_11].[1] Featuring more than 100 public universities and a broad range of research and development centers, the city has an affinity with technology and innovation, further fueling its transition towards a full-service economy. Historically, however, the city has relied on manufacturing and heavy industries for its prosperity: mechanical engineering, food industry, metallurgy, chemical industry, and building materials industry still play a key role for the city's economy today and have done so for the last 20 years. With its mix of industries and services, Moscow represents the economically most developed region in the country. However, it faces social inequality issues, mainly due to the shortcomings of local distribution policies [mos_06].

Air quality considerations in Moscow's development are best understood in the context of the overall poor environmental conditions characterizing the city up to the 1990s. The heavy industry shaping Moscow's economy during Soviet times and the reliance on private means of transport for the mobility of the increasing population left a legacy of extremely poor air quality [mos_02]. By then, air pollution had reached levels that authorities perceived as a threat to public health [mos_01]. The fall of the Soviet Union was followed by a drop in industrial production, providing some relief to Moscow's air. Yet, air quality remained an issue: in the early days of the new Russian Federation, Moscow saw the

[1] The labels in square brackets correspond to the different pieces of evidence used; see Supplementary Materials for more detail on each piece.

introduction of improved traffic management, emission standards for motor vehicles, the electrification of public transport, and a monitoring system for air quality [mos_03]. Since 2010, Moscow's new mayor has made improving urban transport and reducing traffic congestion, as well as the associated improvements in air quality, part of his political legacy [mos_10]. In the years that followed, air quality improved dramatically, making Moscow one of the cities with the cleanest air by international comparison [mos_12].

As of 2021, the city of Moscow does not have a stand-alone climate plan. Rather, climate considerations feature in both sectoral plans and in the city's overall environmental planning—Moscow's climate policy, in other words, is implicit in the city's urban development processes. Climate change features explicitly in Moscow's planning only from 2010 onward, and mainly in relation to adaptation, not mitigation [mos_04; mos_05]. Yet, a broad range of mitigation-relevant, greenhouse gas-reducing measures can be found in the city's planning [mos_04; mos_05; mos_08], including the new "Environmental Strategy of Moscow until 2030" [mos_09]. These documents emphasize the electrification of the public transport system, the introduction of fuel standards, and the expansion of the city's urban green. This way, green areas in the city reached 54.5% in 2014 and are expected to grow to 61% in 2030, while by 2021, greenhouse gas emissions have decreased 25% since 1990 [mos_12; mos_13].

In addition, since 2011, Moscow has been actively involved in Transnational Municipal Networks on climate change and international emission reporting activities such as, respectively, C40 and CDP [mos_09]. The Moscow government has made a priority of furthering international cooperation on climate action [mos_12]. While drawing benefits from the common infrastructure of city networks, the city could also achieve greater international recognition, raising its attractiveness as a site for investments and business. The development of the city of Moscow as a global international center has indeed been among the strategic objectives of the Government of the Russian Federation and the most important activities of the Moscow City Government. Environmental protection and greenhouse gas emission reductions are seen as functional to that aim [mos_07].

4.2 City of Paris

The capital and largest city of France, Paris, represents the country's main economic, cultural, and administrative center. Arguably due to the centralized nature of the French state, the national government has invested heavily in the urban development of Paris and its surroundings (specifically, the Île de France region), managing the city directly through state officials until the 1990s. As a result, the Paris region hosts a large portion of the nation's industrial development, including the headquarters and research centers of France's largest firms [par_05]. This has led to urban sprawl, suburbanization, and the subsequent congestion problems related to the high number of commuters flowing in and out of the city every day, many of which by car [par_14]. The historical industrial development of the city has now transitioned to services (in particular finance and IT) and high-tech (electronics, optics, aerospace [par_12]). This has made Paris increasingly wealthy, although at a slower pace than cities in other advanced economies. The city still faces social inequality issues, making housing and access to basic services a regular item on the local government's agenda [par_09; par_14].

Paris faces a severe air quality problem: values of PM_{10}, $PM_{2.5}$, and other pollutants (NO_2) are above legal thresholds and have already led to infraction procedures at EU level in 2015 and 2017. Air quality has improved since the 1990s but remains a major public health issue [par_13]: the 2014–2016 period has seen the "worst pollution in a decade" [par_07; par_08], not as severe as back in the 1990s, but enough to trigger temporary restrictions on car use [par_06]. Most importantly, air pollution is mostly emphasized in connection with the increasingly frequent, climate change-induced heatwaves. Heatwaves have played a key role in both French and Paris climate planning: the heatwave that hit Europe in 2003 caused 15,000 excess deaths in France alone [par_01; par_02]. An extensive stakeholder involvement process followed, captured in the "Livre Blanc des Parisiens sur le Climat" (the "White book of Parisians about the Climate" [par_03]), and paving the way for the city's first community-wide climate plan (the "Plan Climat de Paris" [par_04]) to be updated every 5 years.

A clear continuity of objectives, themes, and approaches emerges from the various iterations of the Plan Climat: a holistic approach considering "the city as an ecosystem"; emphasis on energy production within the city; a strong role of environmental justice and broader social considerations; an emphasis on the economic benefits of the energy transition as a way to address inequality and social tensions in the city; and the "exemplary" role of the local administration both in relation to the local community and on the international stage. Against this background, the city aims at reducing emissions by a "factor 4" by 2050, corresponding to a 75% reduction against a 2004 baseline. The 2017 iteration of the plan [par_10] raises ambition further by aiming at carbon neutrality by 2050, which is understood as reducing energy consumption by 50%, and meeting the remaining energy needs through 100% renewables within the city limits and through compensation otherwise.

Within the Plan Climat, the above goes under the header of the "Energy Transition," capturing the climate mitigation aspects of the plan. "Resilience" represents instead climate adaptation. Arguably in light of the events portrayed above, adaptation is no afterthought in the Plan Climat. Rather, it is a main thematic cluster, at the same level of mitigation. Most importantly, this distinction plays a role in relation to air quality: the Plan Climat puts much more emphasis on air quality in relation to adaptation than it does in relation to mitigation. Under "Energy Transition," air quality is referenced (barely) in relation to mobility ("managing and limiting the role of cars" in the city). Under "Resilience," it is articulated in terms of mobility, construction, heating, and waste. The rationale for that is that the lack of precipitation can significantly increase pollutant concentrations, amplifying the impact of heatwaves [par_10; par_13].

Furthermore, an increased attention to air quality and broader environmental health can be observed over time. Later iterations of the plan put increasing emphasis on air quality, paralleled by additional plans issued around this time: the "Environmental Health Plan" [par_11] and the "Resilience Strategy" [par_09]. The planning document most explicitly addressing the link between air quality and climate change is the "Plan Climat Air Énergie Métropolitain" [par_13], a plan produced at the level of Greater Paris[2] articulating air quality predominantly in adaptation terms: reducing pollution makes the city less vulnerable to climate impacts. Formally, air quality and emission reductions represent "converging objectives" (p. 269) to be tackled with the same cross-cutting measures. Yet, the document

[2] Greater Paris ("Grand Paris" in French) is an administrative level created in 2016 between the municipal level (including the City of Paris) and the district level (the "Île de France" district). It is governed by councilors representing the municipalities involved and thus not elected directly. For the purposes of this paper, it represents an arena in which the City of Paris can act rather than an autonomous level with its own political system. Similar considerations hold for the Montreal Agglomeration.

devotes considerably more space to air quality in relation to climate vulnerability than in the context of mobility and greenhouse gas emission reductions.

4.3 City of Montreal

A city of about two million within a metropolitan area of about four, the City of Montreal represents the main economic center of Quebec and the second most populous city in Canada. Its location on the Saint Lawrence River has made Montreal a logistics hub of international importance at the confluence of road, rail, and waterway infrastructure [mon_10]. Next to the port and the overall logistics and transportation sector, the city's economy is driven by services and high-tech: aeronautics, bio-pharmaceutics, IT, and the media industry are among its most important employers [mon_03; mon_10]. The city's socioeconomic structure represents an instance of the "doughnut effect" with high levels of unemployment in the mostly francophone city center, a wealthier middle class commuting into the city from the surrounding suburban areas (hence from outside the city's tax base), and an impoverished rural hinterland [mon_11]. As a result, the City of Montreal is not affluent: it faces persistent problems of unemployment and poverty [mon_16; mon_08], while struggling with congestion and suburbanization [mon_14].

During 2005 UNFCCC Conference of the Parties ("COP 11"), taking place in Montreal and hosted by the Quebec government, Montreal's local government signed the "World Mayors and Municipal Leaders Declaration on Climate Change" and pledged to reduce emissions by 30% by 2020 and 80% by 2050, both against 1990 levels. At the same time, it released its "First strategic plan for sustainable development of the Montreal community" [mon_01]. The plan lays down the key characteristics of Montreal's climate governance to come: community and business mobilization, exemplary role of the administration, ecological transition as a way to stimulate the local industry. Crucially, air quality is presented as a key issue, both per se and with reference to climate mitigation. In the years that followed, four further plans have defined Montreal's climate action: (1) the "Sustainable Development Plan 2010–2015" [mon_02]; (2) the "2013–2020 Citywide GHG Emission Reduction Strategy" [mon_04]; (3) "Sustainable Montreal 2016–2020" [mon_05]; and (4) the "2020–2030 Climate Plan" [mon_12]. In line with the First Strategic Plan, they all show a broad and encompassing approach, with emphasis on mobility electrification, energy efficiency in the housing sector, and (to a lower degree) circular economy. In terms of emission reduction targets, the plans consistently reflected the commitments made with the World Mayor Declaration above. Recently, the city has increased its ambition further, aiming at carbon neutrality by 2050 [mon_12].

Montreal achieved 24% greenhouse gas emission reductions against 1990 levels already in 2014 [mon_09]. Air quality, instead, remained relatively stable, with some improvements in terms of pollutant concentrations but stable counts of smog days per year [mon_13]. This detachment between greenhouse gas emissions and air quality trends is reflected in the climate plans. The link between air quality and greenhouse gas emissions is still present in the "Sustainable Development Plan 2010–2015" [mon_02]. It disappears thereafter: later plans justify the emphasis on energy efficiency in the housing sector and sustainable mobility entirely with the aim of reducing greenhouse gas emissions, without any reference to air quality considerations. Rather, reference is made to Quebec's large hydropower capacities and the goal to become a global leader in sustainable mobility.

These aspirations combine with the issue of Québec's autonomy and francophone identity: Québec has the highest levels of environmental consciousness [mon_06] in a country, Canada, that had no climate policy until 2015. The resulting policy void made climate change a topic in which Quebec could distinguish itself from the rest of the country, show affinity to European values, and join the world stage as a nation [mon_07]. This provided a favorable institutional environment for Montreal's climate action. Parallel to that, air quality becomes an autonomous topic related to wood-burning—a culturally embedded and therefore politically sensitive practice linked to home heating (fireplaces) and commercial processes (e.g., bakeries). The local government has put conspicuous efforts in limiting wood-burning in the city [mon_13; mon_15] justified on air quality and subsequent health considerations, with no link to climate-related discourses (emission reductions, resource efficiency, etc.).

4.4 Comparison

Table 1 provides an overview of the main characteristics of the three cases. As expected in a "most similar" multiple case study design, the three cities show considerable similarities: all represent the main center of their politico-administrative systems, enjoy a wide degree of autonomy and a supportive institutional environment, are members of transnational municipal networks, and can pursue a green growth agenda relying on a local economy that has successfully transitioned from industry to services, with a strong role of research and innovation. All three cities face challenges linked to a growing population and the resulting congestion problems. Despite these similarities, the link between air quality and climate policies takes a quite different shape in each city.

Figure 2 provides a graphical representation of the links between public health, air quality, and emission reductions in the three cities. The three diagrams summarize the process emerging from the respective case description, focusing on those issues and policies that the documents at stake explicitly and directly link to the concepts of interest (public health, air quality, and emission reductions). The figure shows how the three local governments articulate the link between public health, air quality, and emission reductions very differently. In Moscow, air quality represents a key concern, driving those efforts that led to the city's emission reductions—although that was not the main aim. Later on, these achievements were reframed and communicated as climate mitigation, providing the city the international recognition it aimed at. For Paris, a direct link between air quality and emission reductions is barely observed. Parisians, in a nutshell, did not reduce their greenhouse gas emissions because they value air quality; rather, they addressed air quality in order to be less vulnerable to heatwaves. In Montreal, finally, an initial link between air quality and climate mitigation faded out over the years: leadership in sustainable mobility took an increasingly prominent role in the city's overall planning, but air quality considerations became a separate issue.

5 Discussion

We can now turn to our research questions. First, do local governments exploit the advocacy potential of air quality co-benefits to make local climate mitigation more acceptable to the local constituencies? Moscow does so, but in an effort to present itself as an attractive global city, not to increase the acceptance of some emission reduction measures. Paris also does, but with way more emphasis in the context of adaptation than mitigation. Montreal used to do so, but stopped. Thus, none of the three cities really exploits the advocacy

Table 1 Key attributes of the three cases

Attributes		City of Moscow	City of Paris	City of Montreal
General information	*Population*	• 12.7 million residents (city) • 21.5 million residents (metro)	• 2.1 million residents (city) • 11.1 million residents (metro)	• 1.9 million residents (city) • 4.3 million residents (metro)
	City area	• Russian and European megacity	• Largest city of France	• Largest city of Quebec Province • The second most populous city of Canada
	Political-administrative structure	• Capital city • Main political, economic, and business center	• Capital city • Regional city center • Main economic, cultural, and administrative center	• Regional city center • Main regional economic center
	Socioeconomic structure	• Industrial and innovation center • Service economy with a focus on trade, real estate transactions, and finance in the economic structure • Social inequality problems	• Industrial and research center • Service economy and high-tech industry • Social inequality problems	• Port city • Service economy and high-tech industry • Social problems: unemployment and poverty
Air quality	*Main source of air pollution*	• Heavy industry • Transport, congestion	• Transport, congestion	• Transport, congestion • Wood-burning (home heating and commercial processes)
	Policies tackling air pollution	• Urban transport policies incl. reduction of traffic congestion • Green and healthy streets	• Temporary restrictions on car use	• Several by-laws on wood-burning • Wood-burning ban

Table 1 (continued)

Attributes		City of Moscow	City of Paris	City of Montreal
Climate policies: mitigation	*Climate plan*	• No climate plan • Mainstreaming of climate issues into sectoral and environmental planning	• "Plan Climat": a holistic approach considering "the city as an ecosystem"	• Sustainable development plans (since 2010) • Climate plan (since 2020)
	Emission reduction target	• Environmental strategy of Moscow until 2030: reduction of CO_2 emissions by 30% by 2030 (analogous to national target) • "Green and Healthy Streets" declaration at the III Climate Forum Cities (C40): "zero" GHG emissions by 2030 within the old borders of the city	• "Plan Climat" (2018): carbon neutrality by 2050	• Climate plan (2020): carbon neutrality by 2050
	Policies	• Electrification of the public transport system • Introduction of fuel standards • Expansion of green area	• Energy transition (mobility plans)	• Mobility electrification • Energy efficiency in the housing sector • Circular economy
	Emission reductions	• 25% GHG emission reductions since 1990 (as of 2021)	• 20% between 2004 and 2020 (as of 2020)	• 24% GHG emission reductions against 1990 (as of 2014)
	Driving force	• Political leadership (an engaged mayor)	• Extreme heatwaves in Europe and in France	• "World Mayors and Municipal Leaders Declaration on Climate Change"
Climate policies: adaptation and resilience		• No dedicated adaptation plan	• Integrated climate plan	• Integrated climate plan
Other relevant policy fields		• Environmental strategy	• Environmental Health Plan • Resilience Strategy • Plan Climat Air Énergie Métropolitain (Grand Paris)	• Electrification of the transport sector

Table 1 (continued)

Attributes	City of Moscow	City of Paris	City of Montreal
Membership in the biggest Transnational Climate Networks	• C40 • GCoM • ICLEI	• C40 • GCoM • ICLEI	• C40 • GCoM • ICLEI
Interplay between climate policies and air pollution	Air quality represents a key concern, driving efforts (esp. in the transport sector) that led to the city's emission reduction	Air pollution is mostly emphasized in connection with climate vulnerability than in the context of mobility and GHG reductions	No link between air quality and climate change mitigation

C40 stands for "Cities Climate Leadership Group"; *ICLEI* stands for "International Council on Local Environmental Initiatives" often dubbed as Local Governments for Sustainability; *GCoM* stands for "Global Covenant of Mayors for Climate and Energy"

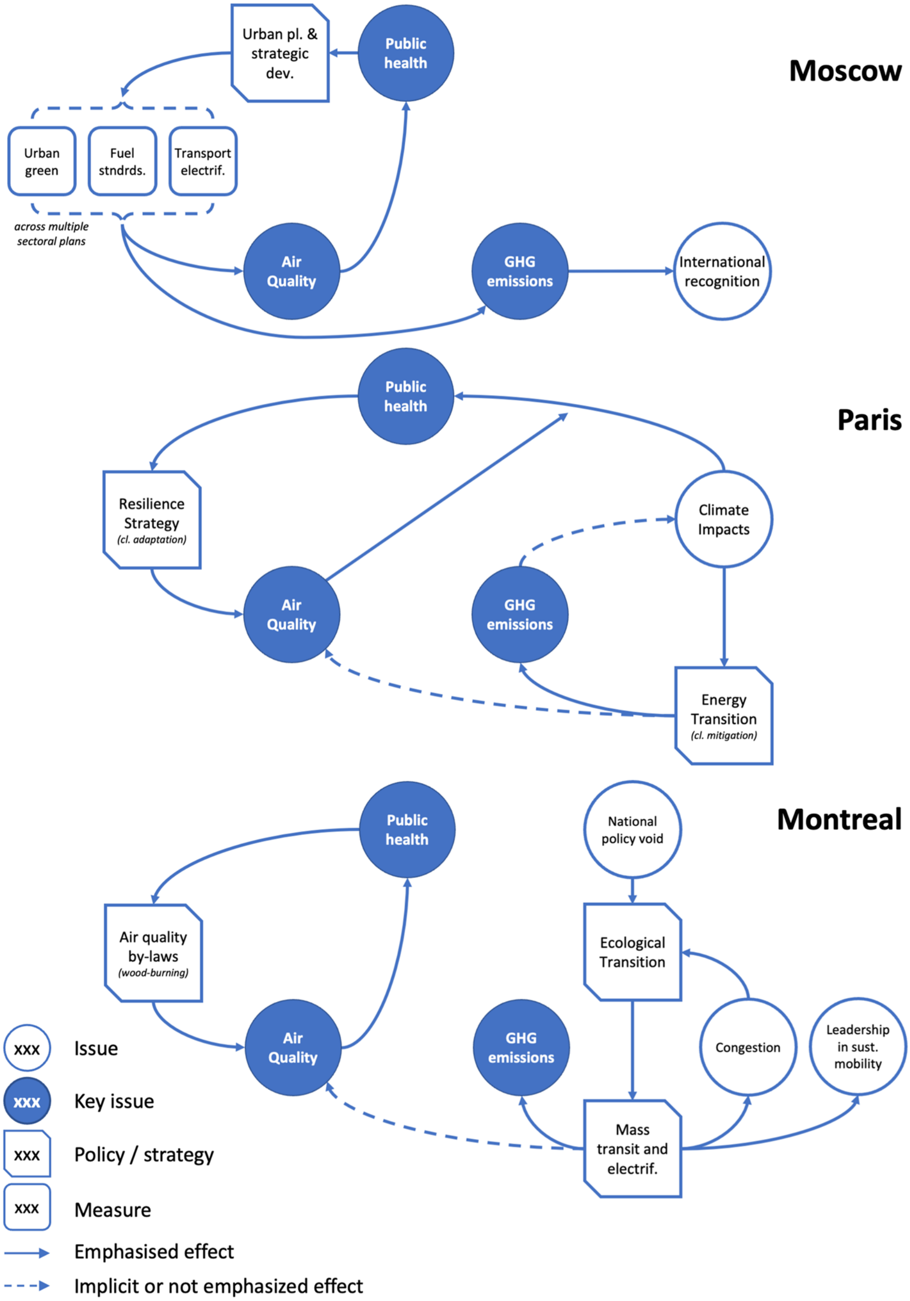

Fig. 2 Link between air quality and greenhouse gas emissions as observed empirically in the three cases

potential of air quality co-benefits to make local climate mitigation more acceptable to the local constituencies. Second, do local governments take air quality co-benefits into account in their mitigation policies and strategies? The answer is still negative, albeit with some qualifications. In Moscow, there is no actual climate mitigation to begin with: emission reductions are an unintended by-product of air quality efforts, re-packaged at a later stage as climate action for city-marketing purposes. In Paris, adaptation policies are those that really take air quality co-benefits into account, while mitigation policies do so to a much more limited extent. In Montreal, air quality and emission reductions represent separate issues.

More generally, the question was posed whether air quality co-benefits represent a key factor for climate mitigation by local governments. Despite the above, the answer here is (almost) yes. For Moscow, climate mitigation is an unintended by-product of air quality control efforts. As a result, air quality is the key factor driving local climate mitigation. Similar considerations hold for Paris, where climate adaptation triggered air quality measures, contributing to climate mitigation in the process. Here, we observe air quality as an adaptation co-benefit for mitigation, not air quality co-benefits as an argumentative rationale to promote emission reductions—a testament to the importance of adaptation co-benefits (more on that below). For Montreal, the efforts related to the wood-burning issue make it unlikely that the local government is blind to air quality co-benefits while reducing emissions. Hence, it must have reasons for not emphasizing that. Overall, a link between co-benefits and mitigation is observed empirically, but it is more complex and heterogeneous than implied by the literature.

The above results have implications for policy and academia, calling for a closer look at the potential limitations of our analysis. The absence of interview materials is worth highlighting. Interviews would have provided access to insights and perspectives that do not leave traces on written sources. Given the long time span of the processes at stake, though, ethnographic approaches would have been extremely resource intensive, beyond the resources available for this analysis. From this angle, focusing on a variety of written materials (from policy documents to journalistic sources) seems like a good compromise between accuracy, diversity, and resource intensity. A second limit relates to case selection, which relies on well-known drivers of urban climate action from the literature. This way, our analysis inherits the same limitations of the extant literature: a bias towards large cities in the Global North. To our defense, it would be difficult to disentangle the role of co-benefits for urban climate action in contexts (e.g., small cities in the Global South) where knowledge of urban climate action is scarce to begin with. Keeping those limitations in mind, three main lessons can be drawn from our case study.

First, the Moscow case raises questions on the understanding of co-benefits as selective incentives. Relying on selective incentives (air quality co-benefits) to explain the private provision of a public good (emission reductions) suggests the presence of strategic interactions, implying that actors value a certain public good, but are held back by the collective action problem. This does not seem to reflect the action situation in Moscow, where the local government values a certain private good (local air quality) and provides it accordingly. The fact that a by-product of doing so (emission reductions) has public good characteristics does not seem to credibly play a role in the decision-making—the more so in light of Moscow's efforts to gain international recognition as a global city. In the absence of the strategic interaction, the link between air quality and climate mitigation is a mere positive externality.

Second, the Paris case questions the model of causality implicit in the concept of co-benefits. The key idea is that local government actions reflect a plurality of motives because of their multiple implications—which is plausible. Viewing such motives as "ancillary," however, masks the possibility that such motives lead to action *together* (conjunctural causation). Consider the interplay of adaptation, air quality, and mitigation in Paris: air quality does not seem to play a role for mitigation, but rather in conjunction with adaptation. Our reading of the documents found no strong evidence of an explicit link between air quality co-benefits and mitigation in Paris, but only because it sought for a direct link between the two, excluding a priori the possibility of a more complex interaction. This is a shortcoming both per se and in light of the growing role of adaptation co-benefits and their synergies/trade-offs with mitigation (Luyten et al. 2023; Sharifi 2021).

Third, the Montreal case raises the question of strategically underplaying specific co-benefits, detaching them from mitigation because of potential controversies. Research has shown how, regardless of the public health benefits, addressing air quality issues may be politically costly, with effects on the type and ambition of local policies (Eckersley et al. 2023; Maltby 2022). If tackling air quality is unpopular among constituents, it won't be effective as an additional motivation in support of mitigation. Montreal's wood-burning issue is a point in case, but similar situations can be found elsewhere: the city of Milan is phasing out wood-fueled ovens in pizzerias (Comune di Milano 2020), while summer barbeques bans in Beijing and San Francisco (BAAQMD 2008; BBC 2014; The Guardian 2013) impose limits on culturally important practices for air quality reasons. It would not be surprising if future climate plans in these cities underplay air quality considerations, focusing instead on other co-benefits. By the same token, the advocacy potential of air quality co-benefits grows with the awareness of air quality issues among constituents, possibly opening avenues for a more systematic linkage between local climate mitigation and its air quality co-benefits.

The above has implications for policy. The same co-benefit can range from being the driving factor for local emission reductions (as in Moscow) to being a liability for local climate action (as in Montreal). If so, decision-makers at higher levels seeking to provide favorable enabling conditions for climate action by local governments should prioritize flexibility over standardization: not making the integration of specific co-benefits (e.g., air quality) into local climate plans mandatory, but providing local governments with the means (e.g., personnel, know-how, reliable data) to deliver on integrated climate planning overall, prioritizing the areas (and hence the co-benefits) they see as most appropriate in their context. Furthermore, transnational municipal networks could translate the diversity of processes through which co-benefits affect local climate action into dedicated city-matching processes (Kern et al. 2021), promoting knowledge sharing between local governments that do or intend to exploit the same co-benefit in similar contexts.

The above has also implications for research. Air quality did arguably play a role in each of the three cases, but the role changed in every instance, and never really reflected the concept of co-benefit portrayed in Fig. 1, raising questions on its analytical merit. Several authors critique the emphasis on the advocacy potential of co-benefits (Mayrhofer and Gupta 2016; Workman et al. 2018) as a way of re-framing climate action in more positive terms, away from the trade-off between environment and economic development. Actual implementations of the concept, however, proved to be challenging (Mendez 2015; Shimamoto and McCormick 2017) and highly context-dependent (Slovic and Ribeiro 2018; Ürge-Vorsatz et al. 2014). Our cases are consistent with all that, showing in addition how political realities and contextual factors may lead to a substantial departure from the ideal type of air quality improvements as an "ancillary" benefit to local mitigation.

From a similar angle, critical contributions argue that the overly optimistic perspective underlying the co-benefits concept may mask the presence of trade-offs between mitigation and other policy areas (Grafakos et al. 2020; Mayrhofer and Gupta 2016; Newell et al. 2018), including adaptation (Eisenack 2016; Luyten et al. 2023; Sharifi 2021). The Montreal case brings that thought one step further: controversies may undermine the advocacy potential of a given co-benefit, regardless of actual biophysical trade-offs. In the end, co-benefits cover a much broader spectrum than economic and environmental considerations (Karlsson et al. 2020; Sovacool et al. 2020)—and so do the trade-offs they may imply. Capacity considerations are often brought up as a reason for a sub-standard inclusion of co-benefits in real-world processes (Boyd et al. 2022; Dale et al. 2020; Mendez 2015). Moscow, Paris, and Montreal certainly do not lack the capacity for integrated planning, yet they show different levels in the emphasis they put on the link between air quality and greenhouse gas emission reductions, mirroring prior studies (Shimamoto and McCormick 2017) and raising the question whether the literature's emphasis on capacity may mask political costs. Tellingly, Paris emphasizes the same co-benefits (air quality) in very different ways in different contexts (adaptation vs. mitigation), suggesting a conscious, strategic choice.

Finally, the complexity of the link between co-benefits and climate action calls for analyses that move away from single factors and rather explore patterns of multiple attributes recurring across cases. Doing so would serve the double purpose of better understanding how certain co-benefits interact with other contextual factors, and which configurations of factors (including possibly multiple co-benefits) are systematically associated with climate action. First empirical contributions are available that identify specific archetypical configurations of attributes recurring across cases (Eisenack and Roggero 2022; van der Heijden 2017). Future research could further expand the palette of configurations so far identified. To do so, it could take clues from the growing body of research on archetype analysis, discussing methodological options and conceptual implications of searching for recurring patterns across multiple cases in the context of socio-ecological research (Eisenack et al. 2019, 2021; Sietz et al. 2019).

6 Conclusion

The extant research on urban climate action shows a large gap between co-benefits as an argumentative rationale for emission reductions and co-benefits as an empirical factor explaining actual mitigation in cities. Motivated by this gap, the present paper has focused on the link between air quality—the largest and most studied source of co-benefits according to the literature—and climate action in Moscow, Paris, and Montreal, three cities that faced air quality problems in the 1990s and have substantially reduced their greenhouse gas emissions since. A multiple case study was carried out, relying on the analysis of policy documents, research articles, and other written sources. The analysis showed a very different link between air quality and climate mitigation in the three cities: an unintended effect exploited for the sake of international recognition (Moscow); a central element of local adaptation, not mitigation (Paris); and a potential source of controversy (Montreal).

On the surface, the three local governments do not seem to bring up air quality co-benefits to justify local climate mitigation, nor do they seem to take co-benefits into account in their mitigation policies and strategies. Yet, we argue that air quality does play a key role in all three cases—just not the one the co-benefits literature would expect. The link between air quality and greenhouse gas emission reductions, in other words, appears more complex and heterogeneous than expected: the case studies are illustrative of how co-benefits may incorrectly cast a collective action perspective on specific action situations (Moscow), obfuscating interactions with other contextual factors (Paris), and masking important trade-offs (Montreal).

In light of this complexity and heterogeneity, it is no wonder that the extant literature has so far struggled to establish an empirical link between co-benefits and urban climate action. Concepts such as conjunctural causation and equifinality have only recently started to make their way into urban climate action research and socio-ecological research more in general. Embedding them into future research at both a conceptual and methodological level may provide a better understanding of both their interaction with contextual factors and the many, different ways they contribute (or not) to emission reductions.

Ultimately, the advocacy potential of the co-benefits concept—co-benefits as a rationale for urban climate action—is possibly only one of the many ways biophysical and technical interdependencies can lead to emission reductions. Urban climate action research and climate governance overall will benefit from a better understanding of these many ways. Failing to recognize this means putting the same square peg of co-benefits into the many round and oddly shaped holes of local politics and institutions—a likely frustrating experience that the climate community should rather avoid.

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Declarations

Competing interests The authors declare no competing interests.

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