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Climate Change and the Urban Political Ecology of Water

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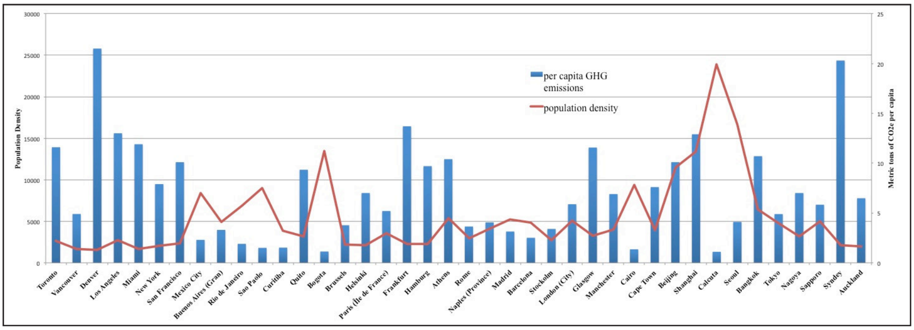
Introduction

Today, 52 per cent of the world's population live in urban areas. By 2050, this figure is expected to rise to between 64 and 69 per cent of the total world population (United Nations 2011). By this time, the size of urban areas is expected to have doubled or even tripled, depending on population and economic dynamics (Angel et al. 2011; IPCC 2014).

Cities consume between 67 per cent and 76 per cent of total world energy and are responsible for 71 per cent to 76 per cent of direct and indirect greenhouse gas (GHG) emissions (IPCC 2014). However, alone, the 380 developed region cities in the top 600 by GDP accounted for 50 per cent of global GDP in 2007 with more than 20 per cent of global GDP coming from 190 North American cities alone (McKinsey Global Institute 2013: 1). This positions such cities as practically the greatest consumers on the planet while the rest of urban settlements still play a minor role.

The foregoing is supported by the fact that although human urban settlements are growing at a rate of approximately 2 per cent per year, with outliers of 0.7 per cent for some developed countries and 3 per cent for some developing areas (United Nations 2011), this growth is not proportional to the amount of emissions that can be attributed to each case. Currently, similar urban settlements (by densities or the number of inhabitants per km^2) have very different GHG contributions – both historical and nominal (see Figure 1 for a comparative analysis of nominal emissions). Although, on the one hand, this divergence occurs partially in response to various factors such as land use, settlement form and extension, the length of time a settlement has existed, or the biophysical conditions of each case (e.g., latitude, proximity, and resource availability), on the other hand, the polarisation between cities and between inhabitants continues to be certainly significant not only in economic terms but also in the terms of energy and material consumption patterns.

Figure 6.1: Per capita GHG Emissions Versus Population Density for Selected Cities

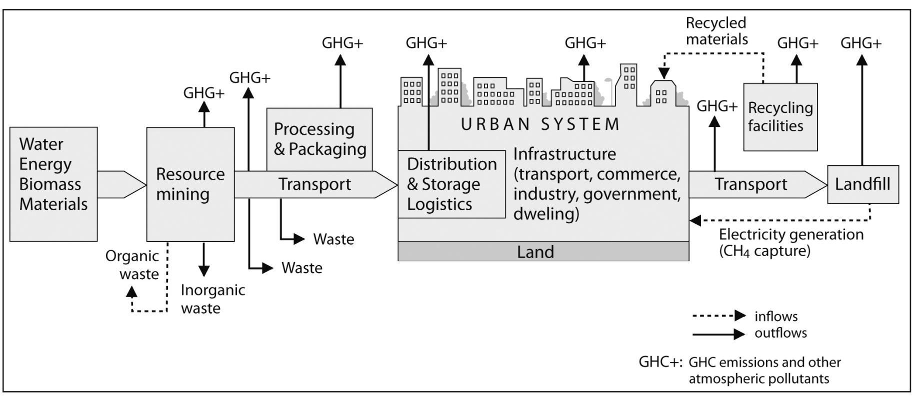


Source: author's compilation based on climate change action plans of selected cities and on UN-Habitat and World Bank databases.

Regarding *Urban Metabolism* and *Urban Political Ecology*

The unsustainable character of urban settlements is clearly visible when verifying its metabolic profiles, meaning, '…the process of contiguous de-territorialisation and re-territorialisation through *metabolic circulatory flows* organised through social and physical conduits' (Swyngedouw, in Swyngedouw et al 2005: 22).[1] Such analysis considers cities as systems open to energy and material flows, that is, those that take energy and materials from outside of the (urban) system and dispose depleted energy and materials inside but mainly outside of the system. See Figure 2 for an urban metabolism framework or the general urban inflows and outflows patterns.

Figure 6.2: Urban Metabolism Framework – Urban Biophysical Flows –



Source: author's own elaboration. Graphic design: Ángeles Alegre-Schettino.

Wolman's work is considered pioneering in empirical terms as it analyses energy and material flows into and out of a hypothetical 1960s United States-city populated by 1 million inhabitants. Wolman properly grasped the complexity and variability of said metabolic flows: such city required 625,000 tons of water daily and generated 500,000 tons of sewerage daily. In addition, 9,500 tons of fuel and 2,000 tons of food were required per day (Wolman 1965).

Diverse analyses of actual cities have been later completed, mostly in developed countries and focusing on various or specific metabolic flows (water, food, energy, etc.). The contributions made by Baccini and Bruner (1990 and 2012) as theoretical and methodological precursors, and later on by Kennedy et al. (2007, 2009 and 2011) and Minx et al. (2010), are notable because they provide a broad, integrated view of the evolution of urban metabolism research. In Latin America, the case of Bogota has been examined in detail (Díaz-Álvarez, 2011), while a generic comparative assessment has been carried out as well for the region's megacities and other capital cities (Delgado et al. 2012; and Delgado 2013).

Metabolic profile analyses of urban settlements and future projections allow, normatively speaking, to model more-or-less efficient routes for using resources and managing waste and, consequently, focusing efforts, for example, by planning metabolic dynamics starting from the design of infrastructure itself (or the so-called 'urban stock'), an objective that can be carried out through policies such as governmental incentives or even restrictions or coercive methods. Indeed, the metabolic challenge is to identify more efficient approaches and measures towards better-integrated human settlements, all with the purpose of minimising both, per capita and total consumption of energy and materials.[2] This certainly includes the prevailing need of reducing GHG emissions, which since 1970 have been generated up to 78 per cent due to burning fossil fuels and industrial processes – both intrinsically of urban nature (IPCC 2014).

This positive feature of urban metabolism as a potent analytical tool of the biophysical dimension of urban settlements must be, however, complemented with a socio-political analytical tool such as *urban political ecology* in order to be able to identify causes and processes leading to inequalities between rich and poor, or, in other words, the nature of space production that defines socio-political and biophysical conditions suitable for capital accumulation and thus uneven development (Harvey 1996).

Furthermore, it must be kept in mind that usually urban configurations are, at some point, outlined by land dispossession, grabbing, and speculation, followed – especially in a neoliberal context – by a much-more intense privatisation of the commons goods and state properties, including basic infrastructure for providing public services and amenities: this is, from water, sanitation, energy and transportation to green spaces. Hence, it can be said that cities are built to a significant degree under the impulses and needs of what Harvey (2004) has called *accumulation by dispossession*. It is a process that is possible with the support (or the 'absence') of the State, as it allows not only the segregation and gentrification of certain neighbourhoods, and the uneven erosion of public services and public space, but also a general loss of urban resilience and, therefore, an increase of vulnerability. This is, for example, an outcome of land speculation, irregular urbanisation and/or the loss of surrounding conservation space which has important ecological and climate functions for cities, such as: preservation of local biodiversity, water infiltration, carbon capture, cooling, among other so-called 'ecological services'. Yet, such negative outcomes mentioned above allow an appealing accumulation of capital, certainly based on a profoundly unequal model of space production that privatises benefits and socialises costs of all kinds, including those of socioecological nature. In this context, it is not by chance the increasing construction of gated communities; on the contrary, itis certainly a need of the middle and upper classes since they asymmetrically appropriate the positive aspects of life in the city.

Social resistances contending for a *right to the city* – a more equal, sustainable, inclusive, equitable, and supportive city – have given rise to the so-called *urban political ecology* since the revindication of said right involves the social right to manage the metabolic circulatory flows (Swyngedouw et al 2005).

As urban political ecology acknowledges, in current capitalist social relationships of production, '…the material conditions that comprise urban environments are controlled, manipulated and serve the interests of the elite at the expense of marginalised populations' (ibid, 6). Accordingly, and due to deep-rooted dominant power relationships, energy and material flows and stocks are unequally appropriated through market relationships or even straightforward dispossession.

The consequence of unequal purchase capacities is that the best constructions, highest-quality services, and the majority of increasingly privatised public space, are reserved for the 'best' consumers, that is, the upper and middle classes. Concurrently, the negative externalities of urban life tend to be exported as much as possible to poor-peripheral neighbourhoods or outside the city. Questions of class, race, ethnicity and so on are thus central to the process in terms of power relationship mobility capacity in order to define who gets access to, or control over, and who will be excluded from access to, or control over, natural resources and other components of the urban space (Swyngedouw et al 2005), including the imposition of the socio-environmental impacts that arise.

Urban Metabolism and the Political Ecology of Water: The Case of Mexico City and its Metropolitan Area

The case study that supports a better understanding and empirical evidence on the political ecology of urban metabolism comprises the *hydropolitan region*

(Perló and González 2009) of the Mexico City Metropolitan Area (ZMVM, for its acronym in Spanish), a territorial unit that Peña (2012) prefers to call the *city-basin*, which in this case refers to the interconnection of four basins that are not naturally related in any way: the Valley of Mexico, Alto Lerma, Cutzamala, and Tula basins. Such hydrosocial cycle (Swyngedouw et al. 2005), that is, the particular management of water in a given socio-environmental context has resulted in the appropriation/dispossession of water from neighbouring basins and the expulsion of sewerage towards another.

While the first three basins supply water inflows, the last is the destination of water outflows, including rainwater that cannot be infiltrated and that has historically led to the flooding of certain areas of the constructed space within the Valley of Mexico. The latter is due not only because of urban expansion itself, but also to the fact that the city is located over an endorheic system that has been progressively drained since the colonial period, specifically beginning with the construction of the Huehuetoca Royal Chanel (1607), the Nochistongo Tajo (1789), the first (1905) and second (1954) Tequixquiac tunnels, the deep drainage system (1975), and the more-recent Emisor Poniente deep-Tunnel (2010). Today, the system as a whole allows for the expulsion of some 57 m3/s.

It must be mentioned as well that, given to climate change, rains have become more intense over shorter periods, increasing water precipitation from 600mm in 1900 to 900mm at the end of the first decade of the 21st century (data form the Tacubaya meteorological station have registered a 7 per cent increase in water precipitation just since 1979). This situation, compounded with the climate change projection for 2050 regarding an increased amount and intensity of rainfall, especially during the rainy season (Aponte 2013), makes necessary to keep the water supply system, as well as tunnels, deep tunnels (*emisores*), and the deep drainage system that expels water outside the Valley, up to date as there is a direct relationship with the degree of the city's vulnerability to water availability (during dry seasons) and flooding (during rainy seasons).[3]

In spite of the above, the increase in the amount and intensity of rainfall by 2050 doesn't necessarily mean there will be sufficient water to cover the projected growing metropolitan demands (ibid). To better understand this condition it's necessary to analyse current water urban metabolism dynamics.

Inflows

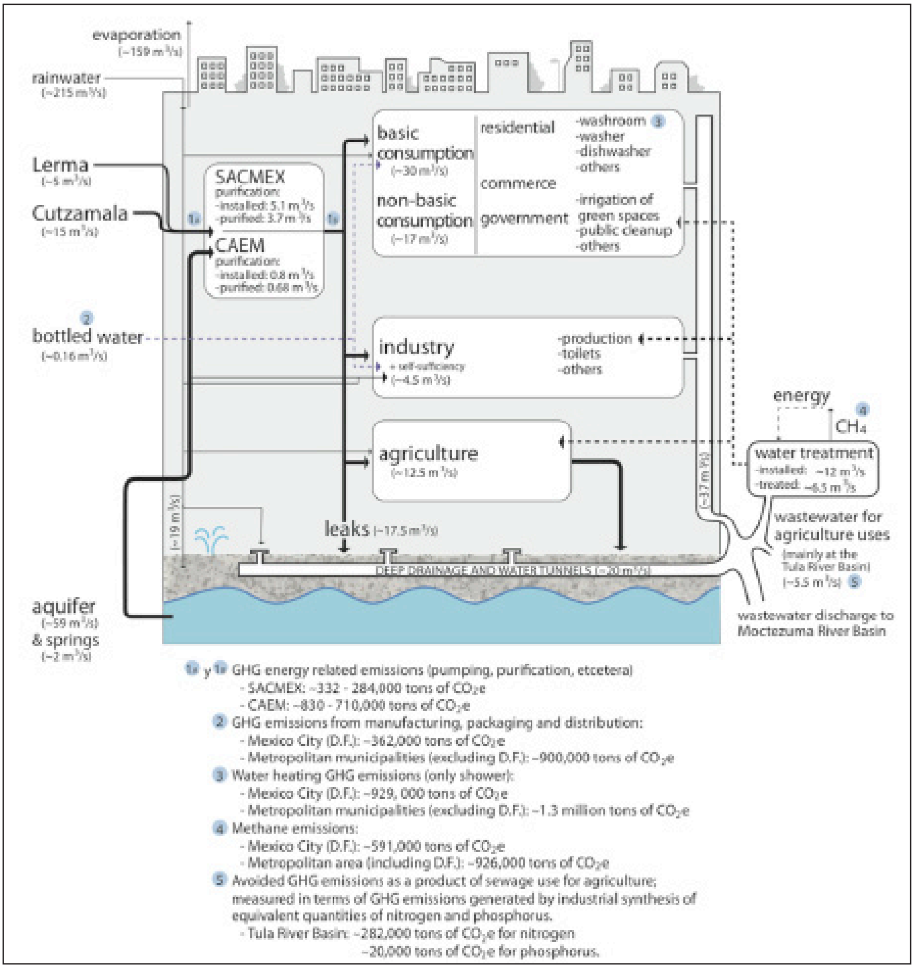
As seen in Figure 3, Mexico City Metropolitan Area water inflows mainly come from:

– more than 600 wells that extract water from the Valley of Mexico aquifer (approximately 59 m3/s) which is currently being overexploited at a rate of up to a 1 m drop per year in the static water level (with a deficit of approximately 28 m3/s)[4];

– the Lerma and Cutzamala basins system (approximately 5 m3/s and 15 m3/s, respectively); and
– urban rivers and springs (approximately 2 m3/s) (Burns, 2009).

All together supply the bulk of water which is distributed by two administration entities: in the Federal District by the Mexico City's Water System (SACMEX)[5] and throughout the State of Mexico by the State of Mexico Water Commission (CAEM) which delivers water to the corresponding metropolitan municipalities.

Figure 6.3: Urban Water Metabolism of Mexico City Metropolitan Area (ZMVM)



Source: Author's own elaboration based on Burns, 2009; Delgado, 2014B; SM-DF, 2012; SEMARNAT/CONAGUA, 2012; and date from INFO-DF, the local access public information entity.

Others minor sources include water self-supply systems, irregular water-truck delivery service (independent of the above government entities), and clandestine wells whose exact number is unknown but it is estimated at around 2,250 (Peña 2012).

In addition, the Mexico City Metropolitan Area imports bottled drinking water from several places, the bulk of which are domestic, and the remainder foreign. Bottled water consumption by the Federal District has been estimated at 2.07 hm3/year, and that of the metropolitan municipalities officially part of the states of Mexico and Hidalgo, has been estimated at 3.1 hm3/year. Together, this represents an inflow of approximately 0.16 m3/s, however, total demand for bottled water in the metropolitan area (ZMVM) has been calculated at 8.78 hm3/year when including the additional water necessary for its production or what is called *virtual water*.[6] At this point, it should be noticed that 76.94 per cent of the Federal District's population consume bottled water, while only 10.84 per cent boil it; 4.37 per cent filter or purify water by using other methods, and 4.58 per cent consume it directly from the tap (Jiménez et al. 2011). Similar patterns of consumption are seen in the rest of the metropolitan area.

Without including bottled water, water consumption in the Federal District averages some 327 litres per capita/daily; however, losses of between 35 per cent and 40 per cent due to leakage must be subtracted from this number (Jiménez et al. 2011; Peña 2012). In environmental terms, this is not a minor issue, especially when taking into consideration that about one-third of the total water consumed by the metropolitan area coming from the Lerma-Cutzamala system, must be pumped 1,100 m. The energy used for this purpose represents 80 per cent of the system's operating cost (Aponte 2013). Moreover, in the case of the Lerma system, installed capacity has been reduced from 15 m3/s to approximately 5 m3/s due to land-subsidence registered throughout the system as a result of over-pumping aquifers of the region. This has also contributed to the increase in the cost of pumping water from current low areas of the system to high areas.

Besides all difficulties and the economic and environmental costs just mentioned, it is obvious that water availability is greatly asymmetrical: distribution ranges from 177 litres in Tláhuac Borough to 525 litres in Cuajimalpa Borough. Boroughs with the highest incomes fall within the consumption range of 400 litres to 525 litres per capita daily (based on Jiménez et al. 2011).[7]

In addition to such water access inequalities in terms of quantity, there are as well disparities in terms of its quality (Jiménez et al. 2011; Díaz-Santos 2012); a reality that echoes SACMEX's purification capacity limitations: the entity has 38 purification plants in operation with an installed capacity of 5.1 m3/s but an actual purified flow rate of only 3.7 m3/s (SEMARNAT/CONAGUA, 2012; INEGI, 2014). Three additional plants (two in Chimalhuacan and one in Tlamanalco) corresponding to Mexico State municipalities belonging to Mexico City Metropolitan Area must be added: these plants have a total installed capacity of 0.8 m3/s and an actual flow rate of 0.68 m3/s (SEMARNAT/CONAGUA, 2012).

Outflows

Metropolitan water outflows (see Figure 3) have been estimated at an average volume of 57 m3/s, most of which are not treated.

Treatment installed capacity in Mexico City is of about 6.7 m3/s, with an actual treated flow rate of only 3 m3/s, while in the municipalities of the State of Mexico belonging to the metropolitan area, the installed capacity is of about 5.1 m3/s with an actual treated flow rate of 3.6 m3/s (based on SEMARNAT/CONAGUA, 2012). The remainder wastewater and stormwater is conducted to the Tula Basin (Tula-Moctezuma-Pánuco River) via the aforementioned deep drainage system and the Grand Canal. Up to 60 per cent of such flow may be treated at the Atotonilco treatment plant in the state of Hidalgo, one of the largest treatment facilities in the world currently under construction.[8]

Most of the treated water in the Federal District is used in urban green spaces (83 per cent), and the remainder is reused by industry (10 per cent) or in producing food in peripheral urban areas (5 per cent). Treated water in the State of Mexico's municipalities is conversely used for agricultural activities.

Notice that water treatment process becomes a key matter for two central reasons. The first is due to environmental and sanitary reasons, and, second, because, in principle, it allows the private sector to define who receives treated water and who doesn't (unless regulations indicate otherwise). Peña (2012) has already warned about the chance of such *de facto* privatisation of treated water.

Socio-environmental Jjustice Movements and the Urban Political Ecology of Water

In addition to the foregoing, water political ecology in the Valley of Mexico is particularly intense due to limited availability of water in the face of a strong demand (mainly because of a very dynamic urbanisation process in previous decades).

It is no coincidence, therefore, that a review carried out nationwide between 1990 and 2002 of some 5,000 newspaper articles on water conflicts, found that 49 per cent of such conflicts took place in the Valley of Mexico (Jiménez et al. 2011). Social mobilisations included public demonstrations and facility takeovers. About 56 per cent were due to a lack of water and 24 per cent to a hike in prices. In the metropolitan area, the districts that experienced the most social unrest were precisely those with less access to water due to a lack of sufficient infrastructure, such as certain areas of the east of Mexico City and the conurbation (e.g. Cerro de la Estrella in Iztapalapa Borough) (ibid).

In addition to such type of conflicts, there are others in areas where water is captured (urban water inflows) and expelled (urban water outflows). The former involves records from the rural mobilisation in the 1970s against the construction of the Lerma system in the Toluca Valley because it signified the potential loss of harvests due to a lack of water that instead was going to be sent to Mexico City Metropolitan Area. This conflict was however 'solved' with the payment of damages, at first using corn and later money, but the damage of the water system regime and the loss of productive agricultural land – along with an intense installation of industrial parks – soon revealed the socio-ecological impacts of such water transfer system.

In 1990, another conflict arose in the Temascaltepec area, where an expansion of the Cutzamala system was planned in order to obtain an additional 5 m3/s; however the project was halted due to social mobilisation (Jiménez et al. 2011).

By 2003, the improper operation of Villa Victoria Dam, part of the Cutzamala system, flooded 300 hectares of cropland, an event that led to a rural mobilisation seeking to obtain an economic compensation. Due to a lack of government response, the social movement revindicated its indigenous identity, shortly emerging as the so-called Mazahua Women's Army in Defence of Water (*Ejército de Mujeres Mazahuas por la Defensa del Agua*). Once it gained public attention with such striking pacific social movement, the public was able to learn about the lack of water in Mazahuas communities due to the appropriation of large amounts for supplying Mexico City Metropolitan Area.[9]

Further conflicts can be mentioned, the most recent case being the May 2014 struggle in San Bartolo Ameyalco due to the intention of piping water from a local spring to transfer it to the Cutzamala system.

As already mentioned, other water battles relate to the 'wastewater usufruct', meaning wastewater capture for treatment and the ensuing takeover of a large portion traditionally used for crop-production, mainly by rural inhabitants which, in our case study, mostly applies to the Mezquital Valley in the State of Hidalgo. This is a region with the lowest national levels of rainfall (400 mm/year), yet some 85,000 to 90,000 hectares are cultivated and irrigated by using wastewater directly, which in turn provides about 44,000 tons of nitrogen and 17,000 tons of phosphorus (Burns 2009).

In 2011 the Irrigation Water of Agricultural and Cattle Producers Union (*Unión Productora Agrícola y Ganadera de las Aguas para Riego*) denounced, once again, a wastewater flow reduction (up to two-thirds) and hence the loss of grown vegetables and alfalfa. Such episode gave rise to proclamations such as the 'wastewater is ours!' (*Jornada, La*. 2011), reflecting the intensification of local conflicts between upland and lowland farmers in dispute for the 'white waters' from the Requena and Endhó dams and the 'black waters' discharged from Mexico City Metropolitan Area. In 2013 some 75,000 producers again protested against the lack of wastewater (Montoya 2013).

Furthermore, concerned about the installation of the Atotonilco treatment plant, the Council of Users in Defence of the Wastewater (*Consejo de Usuarios en Defensa de las Aguas Negras*) have already requested the local Congress of Hidalgo to ask the National Water Commission (CONAGUA) for an official document that could guarantee an equal volume of free wastewater for its croplands in relation to the volume currently being used given the possibility that treated water could attract charges (*NewsHidalgo* 2012).

In short, the complex conflict over Mexico City Metropolitan Area wastewater is certainly ongoing as well as its socio-environmental implications.

Water-Energy Nexus: A Climate Change Challenge

In 2013, Mexico City's Water System (SACMEX) used a total of 570.98 million kWh of which, among other things, 715,141.8 billion m3 of the total 953,522 billion m3 of distributed water was pumped (the remaining volume was moved using gravity) (INFODF 2014). As indicated in Figure 3, water inflows related emissions per cubic meter of water managed by SACMEX that same year reached 0.349 g - 0.298 g of CO2, for an annual total of about 332,000 to 284,000 tons of CO2.[10] Estimations for the case of conurbation municipalities served by CAEM, suggest a range of about 830,000 to 710,000 additional tons of CO2e.[11]

Total metropolitan water outflows related emissions, in terms of methane emissions, have been estimated at ~1.5 million tons of CO2e, of which 591,000 tons of CO2e correspond to the Federal District (SMA-DF, 2012).

End-user emissions, among which residential emissions play the greatest role, and must be added to the above. Such energy use corresponds to water heating/cooling processes. In the case of Mexico, the Ministry of Energy (SENER 2013) considers that only water heating stands for at least 13 per cent of the total amount of energy consumed in this sector while representing the third-highest home expense.

Heating water energy consumption in Mexico City Metropolitan Area has been estimated for 2006 at 31.2 petajoules, or 46 per cent of the total amount of energy consumed in the residential sector. Related emissions were in the order of 1,949,224 tons of CO2e (SMA-DF, 2008: 45). Data in this regard for 2010 indicated energy consumption at 33 PJ, that is, an annual per capita consumption of 1,654 GJ, with average per capita annual emissions at 105 kg of CO2e (SMA-DF, 2012).[12] If the current population of 22 million people in the metropolitan area is taken into consideration, emissions from heating water round to 2.3 million t of CO2.

Meanwhile, emissions related to the consumption of bottled water, including manufacturing, packing, and distribution, reached 362,400 tons of CO2e per year at the city level and 900,900 tons of CO2e per year at the metropolitan level.[13] In addition, plastic waste generated by the consumption of bottled water reached 80,351 tons at the city level and 199,742.4 tons at the metropolitan level.[14] This is waste that must be collected and recycled or disposed of, as the case may be, which demands significant energy consumption that could be decreased or even avoided (in addition to the environmental impact derived from the disposal into the environment of increasing amounts of plastic) if tap water was treated to safe-drinking standards or if other drinking water options, such as public water fountains, were available.

Likewise, avoided emissions due to the use of 'black water' through a process that recovers nutrients (phosphorus and nitrogen) from water and that, therefore, are no longer needed to be industrially synthesised, have been estimated at some 414,500 tons of CO2e for both, the cropland area of Tula and of the Valley of Mexico.[15] In this context, it must be pointed out that although there are methods for safely using wastewater (Duncan and Cairncross 1989), these certainly were not implemented in the case under review.[16]

Taking into consideration that total GHG emissions from the metropolitan water-energy nexus described above reach some 5.5 million tons of CO2e annually (or 10 per cent of total metropolitan GHG emissions estimated for the year 2010)[17], it seems evident that an integrated water management planning should include all the complexity of urban water metabolism dynamics in order to generate smarter mitigation solutions at diverse space scales and timeframes, but also for achieving better (water) systemic outcomes, synergies and co-benefits of diverse kind, including those of social justice.

Co-benefits can be particularly significant in terms of electricity generation from methane capture and thus for climate mitigation; for land and water conservation through reducing plastic pollution and thus bottled water consumption (but also by effectively protecting conservation land and promoting reforestation programmes); for avoiding GHG emissions by properly using wastewater for crop production (meaning taking the necessary precautions for protecting health and the environment); among others related, for instance, to public health improvement.

Final Remarks: A Focus on New Paradigms

The capacity to transform urban settlements in developed countries is incomparably greater than that of developing ones, not only because they have greater means of economic and technological innovation, but also because many hidden or indirect socio-environmental and climate costs are usually 'exported' or internationalised (in spite of the fact that all cities do this in one way or another using their own hinterland).

Therefore, urbanisation in developing countries tends to be more problematic and complex due to a limited or overburdened capacity to take measures and actions, a scenario in which urban poverty is an enormous further challenge to any type of more human and sustainable urban reconfiguration.

The design and execution of public policies needed for transforming the current trend of constructing, operating, managing, and living in cities must be proactive, imaginative, and based on an integral metabolic planning. Accordingly, urban metabolic analyses seem to be essential to policy tools, but in general urban planning (which includes land planning), can be adjusted to overarching contextual changes and to historical trends and socially desirable futures.

The sum of multiple actions, provided these actions commence with the aforementioned integrated planning with social justice, may have a heightened impact while allowing synergies and co-benefits of various types. Consequently, traditional sector-based management is no longer sufficient or viable.

Even more, a profound transformation of existing urban settlements demands, not only considering the urban *form* design and its metabolic profile, but also a profound reformulation of the urban territorial *function* or the purposes of urban territorial configuration; this means moving from schemes intending capital accumulation as a priority, to those that promote human development or well-living instead. In that sense, and as Swyngedouw et al (2005) correctly claim, it's then crucial to ask who produces what type of urban configurations, who gains and who loses and in what ways, and who benefits and who suffers from particular urban territorial configurations (within and beyond the cities).

Likewise, given that the *construction of space* is dynamic, it is equally important to understand which are future perspectives, and based on which cultural, historical, and environmental notions this or that approach provides, or does not provide, alternatives (as well as alternatives to what).

We are currently in a position in which not only technological solutions regarding the type and design of infrastructure play a part, but also in which a deep-seated change in prevailing logic and, therefore, the nature and desirability of the solutions themselves, is crucial.

In the specific case of the hydrosocial cycle of Mexico City Metropolitan Area, the challenge is of great significance, though there are certain factors that are already evident. In this regard, in spite of the fact that the population is growing slowly in the area that is already urbanised (there has been a significant increase in some municipalities of the conurbation), there is a confirmed need for 1 m3/s of additional water by 2015 alone. This represents a demand being managed against a backdrop of a decreasing flow rate in supply of 3 m3/s over the past decade. Therefore, in the coming years, it is clear that the highest pressure will be seen in the conurbation area, though changes in social expectations regarding the amount and, especially the quality of water, could also pose significant challenges for the supply system (Jiménez et al. 2011).

In recognition that the availability of water has already reached its maximum viable point in spite of all technological innovations and big infrastructure development, a projected solution, not free from social dispute, is committed to expand the water system's into more-remote regions such as in the case of the fourth phase of the Cutzamala system aimed at making use of the high-altitude Tula, Tecolutla, Valle del Mezquital, and Amacuzac rivers, which in most cases will yield comparatively lesser volumes of lower-quality treated water.

A long-term solution cannot be that simple, nor can it be merely or mainly centred on large-scale engineering solutions. The so-called 'new water culture' centred around a moderate and responsible, though socially fair consumption, is certainly an important issue, though addressing the issue of leaks in present and future systems; attempting to effectively plan the use of land, especially peripheral urban land; protecting conservation land while restoring its vegetation as well as that of the city itself for the purpose of, among others, increasing evapotranspiration capacity and reducing city temperature; are all extremely important issues as well.

Given the heterogeneity of water conditions and territorial infrastructure that hinder the ideal homogeneity of the equal supply of water in terms of quantity, quality, and frequency throughout the entire Valley of Mexico, it is also desirable to decentralise the water system by adding to multiple spatial scales other systems of less import that might increase the flexibility, transformation, and resilience of the whole system in the face of external shocks, including those resulting from climate change (e.g., rainwater harvesting, local water reuse/treatment, and so on).

In summary, new paradigms for managing water that are more fair from a social and ecological perspective and that are more harmonious in the short, medium, and longterm, demand a combination of new technologies, practices (including planning and regulation), and values that must be developed and implemented by all inhabitants, including the social, political, and economic players of each territory. This process is feasible, though certainly slow due to both, the 'infrastructure lock-in' (to certain metabolic dynamics and patterns) and to the persistent nature of practices and interests grounded in traditional management criteria.

A genuine bottom-up management of water infrastructure (and certainly of the urban built environment as a whole), which goes further than just citizens' participation is and will be of more importance in order to formulate new manners of democratic self-management with a sense of community. This is a scenario of genuine participative democracy, which, from a broader perspective, must be viewed as a mechanism for empowering the people inhabiting the same territories for the purpose of, among other matters, guaranteeing human rights, such as the right to water and sanitation or a healthy environment, but more over for supporting people's right to a fair city.

Acknowledgments

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Notes

1. For Swyngedouw (Swyngedouw et al. 2005: 22 and 25), 'metabolic circulation' refers to the merging of existing (bio)physical dynamics with the set of conditions that regulate and frame current social relations of production in this or that territorial space.
2. It is notorious that 'green economy' policies only pay attention to per capita efficiency or at the level of subcomponents of the system. Since such relative efficiency does not guarantee an absolute efficiency, a rebound effect is a usual outcome.
3. Certain areas of the city consistently demonstrate flooding; including the overflow of wastewater in areas such as Valle de Chalco and Ixtapaluca caused by a lack of sanitation in the city's drainage system and by rains that increase in intensity. In 2010, overflows left almost 25,000 people homeless.
4. The aquifer is currently overexploited. The historic level of water extraction is estimated at 2 m3/s for 1870; approximately 22 m3/s for 1952 (which shows already a deficit, as the there were only 19 m3/s of recharge); and some 59 m3/s extracted by 2007 (Burns, 2009).
5. Mexico City Water System is an entity that articulates private concessionaries of water public service, geographically arranged in four operating areas: (1) Proactiva Media Ambiente SAPSA of the Mexican ICA and the French Veolia; (2) Industrias del Agua de la Ciudad de México S.A. de C.V. of the Mexican Peñoles and the French Suez; (3) Tecnología y Servicios de Agua S.A. de C.V., which is also property of Peñoles and Suez; and (4) Agua de México, S.A. de C.V., of national capital.
6. Estimate based on 2009 national per capita consumption of 235 l/year (Delgado, 2014B). Average indirect water demanded for each litre of bottled water, or virtual water, has been estimated at 700 additional millilitres according to figures provided by FEMSA Coca-Cola and Nestlé Mexico in 2010.
7. About 38.4 per cent of the Mexico City's population receive water only a few hours per day, while 61.5 per cent receive it all day. Yet, on average, 52-53 per cent of the poorest and moderately poor areas of the city receive water only a few hours per day. This figure is only 18-19 per cent in the least-poor areas where in addition most of inhabitants have economic means to invest on proper dwelling water tanks and pumping infrastructure (Jiménez et al. 2011)
8. Operated by DEAL, a company owned by Carlos Slim, is supposedly capable of treating 60 per cent of the metropolitan sewerage at an energy cost of 166 million

kWh/year and an average generation of 917 t of sludge daily. The plant is expected to come into operation in February 2015. It's located in the ejido 'Conejos', right in the middle of a road that communicates San Antonio and San José neighbourhoods, both lacking of basic water and sanitation services.

9. The Mazahuas movement also opposed the then new National Water Act, which excluded community water management systems in indigenous territories. In spite of being criminalised, this social struggle still continues (Ávila-García 2011).
10. Calculation based on two different methodologies used for estimating electricity production-related GHG emissions in Mexico: 1) the National Commission on Efficient Energy Use approach which estimates emissions at 0.5827 tons of CO2e/MWh based on electric power consumption, and 2) the Programa México approach that estimates emissions at 0.498 t of CO2e/MWh based on electrical power generation data (SEMARNAT/INECC, 2012: 42).
11. Calculation derived from SACMEX's estimate, assuming the same emission factors per cubic meter, and considering that CAEM's users sum about 60 per cent of the total users Mexico City Metropolitan Area.
12. The calculation for both years is based on four showers per week per inhabitant of Mexico City Metropolitan Area using 45 litres per shower (SMA-DF, 2008; SMA-DF, 2012). Said calculation depends on one person's habits: taking six showers per week, using 65 litres of hot water, will instead generate 208 kg of CO2e per year (SMA-DF 2012).
13. The emissions estimate is based on a factor of 175g per litre of bottled water according to information provided by Nestlé-Mexico (Delgado, 2014B).
14. Plastic waste generation was estimated at 38.8g (bottle plus secondary packing) per liter of bottled water according to information provided by Nestlé México (Delgado, 2014B).
15. Wastewater contains 97 per cent water and 3 per cent solid materials (organic and inorganic). The following are the factors used in calculating emissions: 6.41 kg of CO2e per kg of nitrogen and 1.18 kg of CO2e per kg of phosphorus (based on estimates by García et al. 2011).
16. For instance, it is well known that treatment processes are indeed required to remove toxic substances and pathogens before any irrigation can take place. Nonetheless, as already described, treatment capacity of Mexico City Metropolitan Area is still extremely low.
17. Total 2010 emissions for Mexico City Metropolitan Area were 54,700 Gg of CO2e (SMA-DF 2012).

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