ID 1525 | URBAN METABOLISM AND WATER-ENERGY-FOOD NEXUS, NEW CHALLENGES FOR SPATIAL PLANNING

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1 INTRODUCTION

Resource scarcity has been rising as an increasingly urgent matter in the last decades and particularly in the last years. A combination of factors such as climate change, population growth, rise of the middle class and deterioration of ecosystems contribute to increase the concern on present and future resource availability. Given the situation there is a need for new approaches to resource management in order to change the business as usual model and find sustainable and innovative solutions. To this end, the water-energy-food nexus (hereafter nexus) approach received particular attention in the policy and academic arenas. The rationale behind the nexus is to acknowledge and take in account relationships, synergies and trade-offs between water, energy and food sectors with the aim of finding sustainable and common solutions for the management of these resources (Hoff, 2011). Connections between water, energy and food undoubtedly exist in any circumstances and they occur more or less explicitly. Depending on how these connections are taken into account, they can become opportunities (best-case scenario), or if not considered they can become missed opportunities or develop in unexpected conflicts and problems (worst-case scenario). The nexus approach is still an immature and not well-defined concept (Allouche, 2015), but even so, researches from different academic fields and disciplines increasingly focus on it. Authors discussing on the nexus generally put water at the center of the debate and focusing on agriculture considering water and energy as inputs for the food production. Other researches argue on conflicts that rise for the use of water for agriculture and other purposes. Furthermore, research and analysis on the nexus are typically carried out on global, national, regional or river basin scale. In this panorama, where main focus is on agriculture and large scales, cities and their role on water, energy and food management have been neglected, which is quite bizarre considering the close connection between cities development and resources and the huge amount of energy and materials needed to sustain cities metabolism. Exploring an urban perspective on the nexus is even more important considering that more than a half of the global population is living now in urban areas and this percentage is bound to increase in the coming decades (UNPD, 2011). Developing of cities have been strongly linked to local resource availability for centuries, but this relationship between potential urban settings development and amount of resources available on site has weakened due to a series of events such as industrial revolution, green revolution, technological innovation and globalization (to mention most recent examples). This set of developments have enabled the development of larger urban areas that depend less and less on the local availability of resources such as water, energy and food. In this paper, we propose a path to follow in order to understand where the nexus of water, energy and food lays is in cities and which role it can have in turning cities in more resilient and sustainable systems. In doing so, simplified supply chains of water, energy and food are considered and decomposed in sequential steps to facilitate the identification of connection points between systems. This has the objective of making clearer which are the nexus aspects that more likely fall within urban areas, which is the domain of urban policies and urban planning.

2 FOCUS ON CITIES

Cities are the center of human development and global growth. More than 80% of global GDP is generate in cities (World Bank, 2017) and, despite they occupy around 1% of the Earth's surface, they host more than a half of the world's population. This concentration of activities makes urban areas the greatest consumers of natural resources. The need for linking urban development with sustainable development is well-established and recognized worldwide, although the operationalization is far from ideal. The New Urban Agenda adopted at the Habitat III conference held in Quito in October 2016 set out principles for sustainable urban development, maintaining a close link with what is indicated by the Sustainable Development Goals. The New Urban Agenda often refers to efficiency and reduced consumption of resources in cities and, among other things, there are specific references to water, energy and food. In particular, the New Urban Agenda aims to ensure food security and nutrition strengthening food system planning, equitable and affordable renewable energy fostering energy efficiency and use of clean resources, access to affordable drinking water and sanitation promoting a sustainable use of water along all the water cycle. More generally the New Urban Agenda commits to reinforce the sustainable management of resources and promotes the local provision of basic goods and services such as water, energy, food and other materials, which usually rely on remote sourcing and thus increasing cities vulnerability to supply disruptions. Furthermore, it promotes "[…] the coordination of food policies with energy, water, health, transport and waste […] and other policies in urban areas to maximize efficiencies and minimize waste[…]". The New Urban Agenda asks for an "enabling environment" to be implemented. In the document one can distinguish a set of factors such as economy, laws, national urban policy, institutions and systems of governance, which try to control urbanization forces to achieve equitable growth. On the other hand, there are factors such as urban planning, local fiscal systems and basic services and infrastructures, which are more operational. Despite the New Urban Agenda is not a binding agreement, it is still important that the global vision on the future urban development is linked to sustainability principles and resource management plays a central role in it. Although not always explicitly, sustainable urban planning has been concerned about resource management. Agudelo-Vera et al. (2011) synthetically, but carefully, described this connection between sustainability and urban planning and its evolution in history. Furthermore, they conceptualized the link between resource management and urban planning in a sustainable development framework. The paper revealed that resource management and urban planning evolved separately because they faced different priorities. On one side, resource management deal with the demand for resources, on the other hand urban planning copes with increasing quality of life in cities. Urban planning could play a central role in sustainable development, but to do so, it must go beyond its traditional tasks and engage with different fields and sectoral planning. If resource management is a key connection between urban planning and sustainable development, what is the role of the water-energy-food nexus and urban metabolism approaches in the planning and transformation of our cities? Approaching the nexus from an urban perspective means to reconsider the cities role on the global resource availability. Considering and taking action at the urban-local dimension has the double advantage of improving the internal efficiency of the "city system" as regards resource management and it might reduce cities dependency on external flows and their negative impact on hinterlands and global resource availability. New challenges raised by the nexus approach are necessarily part of a global-local dialectic (Giatti et al., 2016). Water, energy and food security are global challenges, but it is necessary to identify analytical and geographical framework in order to implement actions able to contribute to greater systemic efficiency within the local-global dynamics. Independently from the scale chosen (city, community, river basin, country, etc…), it must be considered as an open and self-organizing system. In this case, one must recognize the system interdependence with other systems. It is therefore impossible to conceive all the elements of the nexus between water, energy and food as part of a single city. In this way, analyzing and taking action in an integrated way at the city scale requires to be able to recognize that sustainability is inherent to connections and dependences to external means. Once the territorial scale has been defined, optimization and efficiency should be sought within the object of analysis. Nevertheless, results must take into account impacts and external dependences. Decision-making on nexus issues is inevitability characterized by multi-level and multi-sectoral governance, which implies the involvement of a wide variety of actors. The nexus approach further complicates the multi-level governance, already very articulated, by adding complexity and indispensable new arrangements between sectors and supply chains concerned with water, energy and food (Giatti et al., 2016). Sustainable urban development can be achieved only through an integrated approach that meets the various dimension of urban life (environmental, economic, social and cultural). In the same way, the nexus can be operationalized at the urban level combining measures on economic development, social inclusion, education and environmental protection with physical urban transformation (urban planning domain). Furthermore, such an approach calls "[…for strong partnerships between local citizens, civil society, industry and various levels of government…]" (European Commission, 2016). Therefore, urban planning plays a crucial role in the implementation of water-energy-food nexus at the urban level, but a strong cooperation with other urban policies and sectoral measures is necessary. Depending on the current configuration of water, energy and food supply chains and the different objectives for the future development of cities, there are a number of different opportunities to affect the water-energy-food nexus for urban planning and urban policies.

3 GOING ALONG THE SUPPLY CHAIN

In order to identify areas of intervention and understand the flow of resources, it is useful to visualize, albeit simplified, the water, energy and food supply chains and their components (Fig. 1). Every supply chain consists of nodes and connections that may or may not be associated with nodes and connections of other supply chains. The water supply chain, which is embedded in the hydrological cycle, may be different depending on local conditions, but it will normally include collection, treatment, distribution, consumption and wastewater treatment stages. The energy supply chain is composed of energy sources, generation/production, distribution, consumption, emissions stages. Furthermore, the food supply chain may differ greatly from case to case, but it is traditionally composed by production, processing, distribution, consumption, food waste management. Understanding resources supply chains is essential for operationalizing both urban metabolism and nexus approaches. Supply chains changes from context to context and they interest urban areas in different ways and at many levels of the chain. Local urban authorities are therefore able to take action only on certain segments of the supply chain by implementing urban policies and urban planning practices. We here identify some of these fields of action.

3.1 FOOD IN URBAN NEXUS

The food sector is heavily dependent on water and energy inputs along all the phases of the supply chain. The level of consumption of water and energy varies in every phase and depends on factors such as kind of product, technologies and techniques, climate, culture and behaviour, regulations. Despite the differences between countries and cities, the energy consumption in the food sector counts for about 26% of final energy consumption in EU and the energy embedded in food products changes along the supply chain (European Commission, 2015). The energy embedded in the food consumed is distributed as follows: production of food (agriculture and breeding) counts for 33%, 28% processing, 9% logistic, 11% packaging, 13% consumption, 6% waste management and disposal. Dealing with food issues in cities encounters a first major obstacle, food has not been considered an urban issue neither in people's mind nor in urban agenda for a long time. On the other hand, the urban dimension cannot be neglected any longer. Although food has been forgotten by urban planners for a long time on the pretest that it is a subject associated to rural planning rather than urban, it is also true that food is related to many other sectors such as land, transport, social justice, public health, water and energy, which are of main interest for planners (Morgan, 2009). The food system is a quite large matter that comprehends a set of connected actions (Pothukuchi and Kaufman, 2007), and each of these stages has a different level of connection with urban planning and the urban dimension, furthermore they have distinct impacts on water and energy sectors.

3.1.1 URBAN AGRICULTURE AS GREEN INFRASTRUCTURE

Food production is not a function commonly attributed to urbanized areas, cities have indeed become more and more places of consumption rather than production. This has not been always the case, ancient civilizations survived through time also because of the proximity of food systems to urban settlements (Barthel and Isendahl, 2013). Despite the proven importance of local food systems in increasing the resilience of urban settlements, the bond between place of production and place of consumption has been fading. Lately, urban food come back in the political agenda due to events such as the 2007-2008 world food price crisis and an increasing interest by the civil society in initiatives such as urban agriculture and horticulture. Cities such as Belo Horizonte in Brazil, Toronto, London or Amsterdam turned this increasing interest in urban food policies. The city of Belo Horizonte has been a pioneer in the introduction of urban food policy a decade earlier than London did. Main goal of this policy was to tackle hunger and malnutrition, equal access to quality food through several programs such as subsidized food sales, food and nutrition assistance, supply and regulation of food markets, support to urban agriculture, education for food consumption, job and income generation. Although the importance of such programs, it is clear how they are geared to respond to social and economic needs in order to achieve food security whereas, instead, sustainability concerns such as relieving the pressure on water and energy resources are neglected or no expressly addressed. This is also the case of the Toronto Food Policy in which security, hunger and social justice are priority objectives rather than sustainability. That is because sustainability is a much more political issue that may not be welcomed by industry and agriculture representatives (Blay-Palmer, 2009). Urban food strategies have a crucial role in transforming the current food system.

Nonetheless, in activities such as urban and peri-urban agriculture, although ecological benefits are expressed both among motives and objectives, they are rarely considered at the design stage. This can be better understood with two classic examples of climate change effects in urban areas with an inherent potential through the lens of nexus thinking: urban flooding and urban heat island effect. Storm water is a major cause of flooding in urban areas and it is also a threat to human and environment health due to different pollutants transported by storm water (Barbosa et al., 2012). One of the main causes of urban flooding is the combination of extreme storm water events and impervious surfaces. The latter contribute to exacerbate urban heat island effects in some areas. It is thus clear how a different land management, which prefers permeable and green surfaces, may contribute to a better storm water management and to reduce the effects of heat wave in built-up areas. Scholars and practitioners identified green infrastructures as one of the possible (soft) solutions in response to this kind of problems. But following a nexus thinking, which seeks for synergies between water, energy and food, and that prefers solutions that incorporate a greater variety of co benefits, why should not we consider urban agriculture as a green infrastructure? Urban and peri-urban agriculture have the potential to be a challenging socio-economic activity, but at the same time, it can contribute to increase permeable surfaces, reducing runoff and lowering the urban heat island effect. In order to achieve such results more efficiently, the areas intended for food production purposes have to be identified according to a set of criteria. Despite this, re-thinking green infrastructures including food production purposes requires a considerable step forward in terms of research and understanding of the compatibility between different typology of urban agriculture, type of soil, and type of vegetation and ecosystem services that can be provided. In order to do so, urban agriculture initiatives cannot be considered in isolation and implemented randomly, which has been often the case until now, but they have to be part of a more extensive and broader strategy for green infrastructure planning. This can be reached only with regulatory framework and the political commitment of city authorities, which should lead the design process of an urban agriculture system across the municipal territory. Urban agriculture has evident and direct connections with urban planning such as transport sector, land use, economic development, housing, storm water management and other. Including urban agriculture in day-to-day city planning means, for example, to rethink zoning regulations and land use indicators to facilitate urban agriculture development in certain areas. Local authorities might set specific goals including, for example, the preservation of existing urban and peri-urban agriculture areas, conversion of a certain portion of municipal land (e.g. vacant lands) into food production areas, or establishing how much of the food consumed in the city should be produced locally. In this sense, inserting urban agriculture as category in the land use management may facilitate control of such activities, promoting the development of different urban agriculture typologies, each of which is more suitable for specific urban areas. Despite the potential of urban agriculture, it is very unlikely that cities have the capacity, farms, gardens, land or space to even get close to meet their own food demand. A study conducted on the city of Cleveland (Grewal and Grewal, 2012) demonstrated how using 80% of every vacant lot, 9% of every occupied residential lot and 62% of every industrial and commercial rooftop, the city of Cleveland can meet between 46% and 100% of Cleveland's fresh products needed depending on the vegetable production practice, 94% of poultry and eggs and 100% of honey. These kinds of results show how even post-industrial cities have the chance to become more self-reliant in food using proper typologies of urban agriculture. By the way, this can be achieved through massive transformations in cities which are unlikely to happen in the near future. Despite the scepticism in the vision of cities producing entirely their own food, urban agriculture activities can still have their role in bringing back food issues in cities putting them to the attention of city dwellers and encouraging the consumption of healthy and sustainable food, reducing also energy consumption due to long distance transportation. Furthermore, urban agriculture and local food systems more generally shall be considered and designed beyond the food production function, taking maximum benefit from other ecosystem services and to reduce pressure on water and energy resources. Although local food systems are often portrayed as the solution, a local-scale food system is not inherently more sustainable than a global-scale food system (Born and Purcell, 2006), much more important than the scale are the actors and agendas involved and it has to be less dependent on fossil fuel and chemicals fertilizers, occupy less greenfield lands and reduce the "food miles". Characteristics of the site are also very important, it is clear for example that trying to impose a food local system in arid territories could bring ecological benefits for the reduction of fuel in transport that would be outweighed by the need of large water inputs (Born and Purcell, 2006).

3.1.2 FOOD WASTE

Another segment of the food supply chain directly linked to urban areas lies in the food waste management and disposal. Food waste is one of the metabolic outflows of materials after consumption and transformation processes that took place in the city. Nexus thinking, on the other hand, recognizes waste food intrinsic value and the opportunities for more sustainable solutions that involve also the water and energy sectors. Every year around 88 million tons of food are wasted only in the EU (FUSIONS, 2016). This is not just an economic issue, but it implies some serious environmental impacts and it puts under a great deal of pressure limited natural resources. The "waste management hierarchy" proposes a hierarchical order of preference of waste treatment and disposal methods based on sustainability principles and environmental impacts. More specifically, there is the hierarchy for the bio-waste management, in which prevention is still the most desirable solution followed by recycle (preferably composting and anaerobic digestion), energy recovery (incineration), final disposal. Food waste prevention and reduction has a great potential in decreasing water and energy consumption. Encouraging a more efficient consumption of food will result not only in the reduction of waste flows volume produced by cities, but it will also have the effect of reducing food demand and thereby reducing inputs of food flows into cities. This will change the metabolism of cities, reducing also their ecological footprint, water footprint and carbon footprint. In fact, food flows are comprehensive of other virtual elements such as water, energy and nutrients (phosphate, nitrogen, etc.). The reduction of food production should lead to a reduced waste of water and energy with global environmental benefits. But there are also more specific synergies between food waste and energy. Embedded in waste there is a great potential for direct and indirect energy production. Different forms of energy come from a variety of renewable sources such as waste from dwelling, agriculture or industries (Kothari et al., 2010). In cities is more likely that a great portion of waste comes from dwellings (household waste) and a great portion of this waste is composed by food waste. There are of course different models to deal with food waste, and some of them treat food waste in order to preserve the highest value in it. However, even considering that other approaches such as reducing food waste production by changing consumer behaviour, nutrients recovery, compost production for farming purposes, alternative markets for low quality food (e.g. not meet aesthetic standards) or other forms of recycling could reduce significantly the amount of food waste, an unavoidable residual food waste is likely to still remain. According to nexus perspective and a closed loops model, this residual food waste can still become a valuable resource for energy production purposes. Incineration with energy recovery does not seem to be a noble end for food waste, but still it is a practice that provides a certain payback in terms of energy and it is a valid alternative to fossil fuels resources, especially considering decentralized local-based energy production systems. Amsterdam for example, is planning to abandon the domestic use of natural gas by 2050, switching to a centralized system of district heating working on a variety of different resources. Waste, and food waste in it, is already an important alternative source for the waste to energy incinerator that provide heat to 70000 houses of the city through the district heating system (DutchNews, 2016). If incineration still raise doubts and uncertainty regarding efficiency energy transformation, security and air pollution problems, other systems of producing energy from food and organic waste may be considered. The anaerobic digestion of food waste, for example, is a complicated process, which results depends on technology, composition of the waste and others. The composition of the waste is quite important for successful results, it is then fundamental that the organic waste is collected separately from the other materials in order to produce good quality biogas through anaerobic digestion process. Treating organic waste with anaerobic digestion rather than other alternatives, such as composting, has the advantage of producing biogas that has a high percentage of methane that can plays like fuel, composting on the other hand, produce biogas that contains a high percentage of carbon dioxide with no energy value (Curry and Pillay, 2012). More than that, what remains after the digestion process is rich of nutrients that can be used as fertilizer. But, despite potential benefits coming from anaerobic digestion, it is still not a common practice in urban areas. Despite food waste management should have a central role in urban sustainable strategies, urban planning contribution is rather limited compared to other urban policies. Urban planning can contribute to redefined areas intended to food waste management, identifying suitable areas for facilities and respecting criteria of security, self-sufficiency and proximity. At a smaller scale, urban planning can contribute to develop areas in which food management and urban agriculture are combined, but it must be done in strength coordination with other urban policies.

3.2 WATER AND ENERGY IN THE URBAN NEXUS

Water and energy, in addition to being central elements in the nexus approach, are also main flows to consider in urban metabolism assessment. In fact, they are a large proportion of cities inputs and, more than other materials, are essential for almost every activity. In urban metabolism studies, water and energy are considered separately most of the time, failing in highlighting connections between these flows which could otherwise bring out sustainable integrated solutions. The connection between energy and water flows in urbanized areas appears to be a little bit clearer compared to food related issues and it is strongly related to the infrastructure systems related to these resources. Water and energy are generally connected by a two-way kind of relationship, water use along the energy supply chain and, on the other hand, energy use along the water supply chain. Actions to reduce water and energy consumption can be taken along both the supply chains and they include introduction of new techniques and technologies, institutional arrangements, changing in regulations, involvement of actors, policies. Some of these solutions fall within the urban domain both with local and global effects.

3.2.1 WATER

Discussing about water and cities is important to make a first distinction between direct and indirect water issues as explained by Renouf and Kenway (2016). Cities directly rely on local/regional water sources to meet basic needs (drinking, cleaning, etc.) and productive uses (energy production, manufacturing, etc.) and they are usually supported by centralized urban water infrastructures that extend far from cities to exploit water supplies. On the other hand, cities have also a great impact on the indirect consumption of (virtual) water embedded in the products consumed such as food. While acknowledging the importance of both direct and indirect water issues, in this section we focus on direct water, which we consider closer to urban policies and planning domain. The water supply chain is heavily dependent on energy. Around 3 % of the electricity used in the US is, for instance, related to the water sector for pumping, treating and transporting activities and in some cases, it represents the municipality's largest operating expense (OECD and IEA, 2016). To reconfigure the urban water system in order to reduce the pressure on the energy sector is a challenge to be faced at different levels of the supply chain. Water utilities are main actors to be involved in the transformation of urban water systems since they manage different parts of water systems on behalf of national, regional or local authorities. Furthermore, they can play a main role in planning and manage urban water in coordination with urban planners. However, cities have also other opportunities to improve the water supply chain rather than leaving it entirely under the utilities control and this include the support of decentralized systems and grassroot activities. Energy conservation in the water supply chain can come from the combination of different activities at different points of the supply chain. Fields of action can be a compound of the use of alternative water resources with decentralized systems, infrastructure renewal, water conservation and alternative energy use. Since cities are increasingly dependent on imported water from far hinterlands, finding local alternatives such as storm water, rain water and reuse of wastewater can drastically contribute to the reduction of energy consumption and to make urban areas more resilient. Wastewater reuse is less energy-intensive than imported water or desalinization practices (although it must be considered on a case by case basis). The city of Los Angeles is a good example, in which has been proven that recycled water is less energy intensive than imported water from the California Aqueduct. For this reason, the Los Angeles Department of Water plans to increase the share of recycled water in water supply. Recycled water is a clearly viable solution for Los Angeles in which the imported water negatively affect the city energy balance (Younos and Grady, 2011). Other cities might not present the same characteristics and other water supply options should be considered. Besides wastewater, decentralized systems based on the reuse of storm water runoff (both for potable or non-potable uses) is an alternative to overcome energy issues due to water pumping on long distances and difficult topography. Rainwater harvesting systems, as well as reducing urban flood risk, are much more energy efficient than recycled water systems. In this respect, physical readjustments of the urban fabric are necessary and urban planning has a central role both in identifying suitable areas for implement decentralized systems and in the defining the best design criteria. When it is not possible to reduce the energy consumption of the water system, alternative energy use might be considered to reduce GHG emissions. Usually, particular attention has been paid on the wastewater treatment stage because the possibility of energy production from biogas and industrial symbiosis projects (e.g. between energy and water utilities), but energy alternative uses can be implemented along the entire water supply chain by the responsible water utilities. Energy needs of the water system can be met, for instance, through the implementation of renewable energy forms such as wind turbines or use of photovoltaic panels, which are less water consumptive than fossil fuels. Nevertheless, more appealing and challenging for water utilities and providers is the potential energy embedded in water. Water itself, in fact, contains energy in form of thermal and chemical energy. Examples of water thermal energy is the use of surface water and groundwater temperature for both cooling and heating purposes (van der Hoek, 2011) depending on the period of the year. Other form of thermal energy is embedded in household or industrial wastewater. Part of the drinking water used in household is heated and leaves the house with a temperature that can be still recovered utilizing heat exchangers and heat pumps at different scales (single shower, building, sewage system, etc.). Similar utilization can be applied to heat wastewater streams coming from industries and other productive activities that heat water in their operations. Chemical energy recovery, on the other hand, comes from wastewater and is based on anaerobic sludge digestion and anaerobic treatment of wastewater, which produce biogas usable in both electricity and heat generation. Biogas is also a valuable resource for green gas production, which can be used in houses instead of natural gas or as fuel for vehicles. Chemical energy can also be recovered from drinking water, recovering methane from the drinking water processes. More explicit integration of water and energy (and waste) sectors demands for cooperation between utilities. Waste-to-energy plants and wastewater treatment plants can both benefit from exchange of flows with positive impacts also for the environment. Waste-to-energy plants can, in fact, burn biogas and sewage sludge coming from wastewater plants and produce energy in form of electricity and heat that can be directly used for the plants operation or delivered to the energy network (e.g. district heating) of the city. Utilities can be guided and encouraged to taking such initiatives by the public authorities, but cities have also other options rather than rely only on centralized solutions and they imply a greater involvement of urban planners, civil society and implementation of other urban policies. These kinds of solutions require paying particular attention to the spatial dimension, the link between different city functions, the proximity between potential producers and consumers of resources.

3.2.2 ENERGY

Local initiatives at the city levels on the energy sector are less likely to have direct effects on the local water cycle, mainly because a great part of energy and energy resources that are consumed within the city are instead produced somewhere else. It is here possible to use a similar rationale to that used for food sector. Taking action in the energy sector at the local level is more likely to have effect on water systems at national or global scale rather than locally. Different forms of primary energy production and power generation, such as oil and gas, coal, biofuels, thermal power generation (fossil fuel, nuclear, bioenergy), concentrating solar power, geothermal and hydropower, affect differently water systems both in quantity and quality terms (OECD and IEA, 2016). Other non-thermal renewables, such as wind and solar photovoltaic use very small amounts of water and for this reason they are much more suitable for the future of the energy sector that will have to be less dependent on carbon but also on water. These technologies use less water at the electricity generation stage, but they also have almost no water consumption for the production of fuel inputs and they have a minimal impact on water quality. Biofuels usually need of water for irrigating feedstock crops and for fuel transformation, but on the other hand, biofuels derived from waste products require no water for feedstock, since water is allocated to the activity of primary value such as food production. Wind energy, photovoltaic panels and biofuels from waste are all energy generation systems that help to decrease GHG emissions, but also reduce the pressure on water resources. Furthermore, PV and second generation biofuels from waste are suitable to be implemented at the local-urban level more than other renewable sources. Priority areas for the transition to renewable energy in cities are buildings, transport and smart grids (IRENA, 2016). At the building level is possible to act both with decentralized and centralized renewable energy production. Decentralized measures are focused on the building itself and the implementation of PV panels, thermal collectors and biomass heating systems for each building. On the other hand, centralized systems use renewable resources to produce energy, heat and cold to be supplied to buildings through energy networks (e.g. district heating network, smart grids, etc.). Buildings have the potential to change their status of the largest energy consumers in cities and become the most available urban resource thanks to the large potential of rooftop PV panels installations. Transport sector also counts a great deal of cities energy consumption, although it might change significantly between a city and another with great differences between high, middle and low income cities. It counts, for example, for the 53% of energy consumption in Mexico City, while it counts for 28% in Bologna (Italy) (UN-HABITAT, 2008). Projections show that energy demand for transport will increase further in the future, but fossil fuels cannot be the main source in the transport sector due to their impact on GHG emissions. At the same time, great investments in first generation biofuels will lead to further stress water resources. Finding alternatives is therefore crucial and cities might have a key role as well. Within cities, transition towards more sustainable systems have to tackle both rail and road transport. Rail transport, trains, metro systems and light rails should be planned in order to rely on electric power. The same applies to road transport that also can count on biofuels and hydrogen technologies. It is important to note that initiatives must be supported by a certain degree of coherence. It is not standing the obvious to say that electricity used for transports must be generate by renewable energy sources. Biofuels are a good alternative, but it is important to distinguish between first and second generation biofuels in order to understand their potential both in nexus and "city" perspective. First generation biofuels (mainly biodiesel, ethanol and biogas) come from agricultural products such as crops and sugarcane and other commodities that are currently used for food (Naik et al., 2010). Although these are prevalent in the global biofuels market, they are source of conflict for the land destination and they put great pressure on water resources. Furthermore, they are not suitable, at least at the production stage, to be considered in urbanized environments. On the other hand, second generation biofuels are made of biomass not from edible feedstock and they largely consist of waste and lignocellulosic material (Naik et al., 2010). Second energy biofuels might be a valiant resource for energy generation in urban and peri-urban areas where there is a large production of municipal organic waste, in which food waste is a substantial part. It is clear that this kind of energy production will not be sufficient by far to meet cities energy demand, even considering only the transport sector, but cities are called to give their contribution in every field of sustainable development. Extending the area in analysis beyond the city's boundaries, and considering metropolitan areas is more likely to find a larger supply of local renewable resources. For example, The Metropolitan Region of Lille is a good example as it started in the early '90s to use half of the city's organic waste for energy purposes and to produce biomethane for use in public buses (GIZ & ICLEI, 2104).

4 THE ROLE OF URBAN PLANNING

Cities are great consumers of resources, but they also have the potential to reverse this trend and make a huge contribution to the sustainable development process, the only possible on the long term. Moving towards a more sustainable resource management at cities level will have effects at different scales. It is crucial to understand that exists a strong bilateral cause-effect relationship between global dynamics and what happens at the local level. And this is not different when it comes to resource management. Urban metabolism studies try to give a scientific dimension of how cities work and what impacts they have on resources. Indicators such as ecological footprint, water footprint and carbon footprint have also similar purposes, but they all fail at the operationalization stage. Change the metabolism of cities, reducing their impacts on global resources, but maintaining high quality of life and economic development is a major challenge. Water-energy-food nexus approach might help to give a common vision and a set of principles shared by departments, utilities and stakeholders engaged in resource management and that usually work in "silos". Local authorities are called upon to be leaders in this transition process establishing a clear vision for the future of cities and urban planners have an important role in this. Urban planning is the profession that more than others can coordinate the many factors involved in the transformation of the urban environment and its functions and it can support a fair process of transition towards a more sustainable resource management and city development, bringing together stakeholders and considering the prosperity of the entire population. In addition to this role of coordinator, urban planning in conjunction with other urban policies can act directly on specific fields of the nexus to improve cities resilience and sustainability. Identify the water, energy and food supply chains and their connections allow to distinguish areas of intervention in which urban planners can contribute and it helps to identify main actors that need to be consulted and involved. It is also important to acknowledge cities as open system and be aware of the dependency with other systems and the cause effects relationship between them. Planning departments and urban planners across the world have the skills to give a great contribution to the transition towards more sustainable cities. However, this is not going to happen without a close cooperation with other local stakeholders both from the public or private sector. Planning systems are different, they are subjected to different regulations and they have diverse degree of responsibilities on resource management issues. There are different dimensions in which spatial planning can be integrated and they have different impacts on city metabolism and the nexus. Spatial planning cannot be central in every aspect of the cities transition towards resilient and sustainable systems, there are many other tools that can be predominant in specific aspects (e.g. technology innovation, regulations and financial system among the others). We here focused just on certain areas of interest in which spatial planning is called to give a significant contribution and we proposed a path to follow, which nevertheless need to be tailored to the specific cases.

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ID 1629 | BUILDING URBAN PLANNING FOR A SUSTAINABLE FUTURE THROUGH URBAN METABOLISM

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1 INTRODUCTION

In the last years, we have been tackling such challenges as rapid population growth, increased materials and energy consumption, growing resource scarcity, climate change, loss of biodiversity, increasing social inequality and poverty (Bina et al., 2016). Cities are the centre of all these challenges, as world population is more and more urban: some 70% of the world's population in 2050 will live in cities (UNDESA, 2015). As a consequence, the combination of urbanization and sustainability results one of the crucial challenges of the coming years (Girardet, 2003; Agudelo-Vera et al., 2011; Musco, 2011). Understanding the relationship between the city planning, urban life style, and the availability of necessary environmental, social and economic resources, is only the first step to build a sustainable and resilient future. City and urban planning become respectively a place and a privileged tool for achieving these two goals (Bulkeley & Betsill, 2003; Pickett et al., 2013).

In recent decades, Urban Sustainability (US) and Urban Resilience (UR) have been two concepts widely studied, both theoretically (WCED, 1987; Jabareen, 2008) and practically (Jabareen, 2006; Jabareen, 2013; James, 2015). However, despite the world scientific community shares a number of issues regarding the achievement and development of sustainable and resilient cities (for example: integrated approach and management, green cities, dense and compact cities, use of renewable energy sources, equity and participation, etc.), it has not yet defined a unique methodological framework. In this regard, in recent years, a series of studies have been developed on the Urban Metabolism (UM), which could represent the nexus able to develop an integrated approach to planning, capable of contributing to the achievement of both US and UR (Kennedy et al., 2011; Thomson & Newman, 2017), also in ecological terms. Nevertheless, these studies remain very generic in connecting UM with spatial planning, and in most cases dealing only with very specific themes like energy and transport (Pincetl et al., 2012).

Within this context, this paper aims to suggest an approach to fill this gap, exploring how the UM can be used as scientific framework, within designing specific plans and policies for cities having as main objective to build US and UR. The theoretical framework presented in this paper stems from researches and studies developed in a Horizon 2020 Project (URBAN_WINS). The URBAN_WINS objective is to develop and test methods for designing and implementing innovative and sustainable Strategic Plans for Waste Prevention and Management as to enhance urban environmental resilience, in 7 different urban areas (Turin, Cremona, Rome, Bucharest, Sabadell, Manresa, Lleira), located in 4 EU country (Italy, Romania, Spain, and Portugal), according to an inter-disciplinary and participatory approach. Specifically, the development of Strategic Urban Plans will be built on the basis of improved knowledge of the factors that influence the UM of the cities.

The work is organized in 4 sections: first, the analysis of relationship between US and UR in urban planning approach; second, introduction to UM; third, analysis between metabolic flows and sustainable and resilient urban planning features. Finally, implication for urban planning and introduction of a new planning paradigm.