Application of cutting-edge environmental technologies for the development of resilient and sustainable cities

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Abstract The development of resilient and sustainable cities emerged as a solution to tackle the several challenges arising from the exponential growth of urban areas population worldwide. The implementation of environmental technologies represents a solution to minimize negative impacts of crowded cities on the environment and human health. The research presents and discusses the applications of advanced and innovative cutting edge technologies to develop sustainable, green and resilient cities. The study is carried out by distinguishing environmental technologies (ETs) on four principal sectors: water and greywater, air pollution, municipal solid waste and mobility. For each technology the strengths and weaknesses are analysed and pointed out. The application of the principal technologies evaluated with reference to real cases study of metropolitan area were highlighted. The work contributes to the development of sustainable cities, providing useful information to support urban planners and policymakers in order to minimize environmental pressures and improve the way they operate.

Keywords: sustainable development goals, climate change, urban agriculture, renewable energy, natural resource conservation.

1. Introduction

Nowadays the cutting edge technological advancements play an important role in the mitigation of climate change. In 2020, people that live in urban areas is increased up to 55% and it is predicted that by 2030, 5% more will move in cities (Mikulčić et al., 2019). The development of resilient and sustainable cities emerged as a solution to tackle the several challenges arising from the exponential growth of urban areas population worldwide (Nam & Pardo, 2011; Senatore et al., 2021). The implementation of environmental technologies emerge as a solution to minimizing negative impacts of crowded cities on the environment and human health (Dairi et al., 2019). However, the concept of the resilient city is still evolving, and it has not been incorporated worldwide due to technological, economic and governmental barriers. Self-reliance and capacity to manage disastrous events are the main characteristics that have been attributed to resilient cities. Several infrastructures and technologies have been applied to increase resilience and sustainability of cities e.g. multiple transportation modes, walking and cycling paths, electric cars sharing, green and blue roofs and implementation of renewable energy sources (solar, wind, biofuels) integrated in street furniture (Kamel Boulos et al., 2015). Another important aspect that future cities have to promote is urban agriculture. Thanks to green spaces a big amount of carbon is sequestered, while reducing urban temperatures and ecological footprint (Senatore et al., 2021).

This work presents and discuss how the application of sustainable and cutting edge technologies contribute to the advancement in the development of cities. The technologies have been analysed by distinguish four sectors: water and greywater management, detection and control of air pollution, municipal solid waste management and mobility. For each sector mentioned the principal technologies, their characteristics and benefits has been reported by critically analysing the results of existing studies. Finally, sustainable solutions were also provided with the aim to improve the quality of life of citizen in metropolitan areas in a holistic and proactive view

2. Environmental technologies applied in metropolitan cities

The increasing expansion of the cities has brought negative pressure on the urban environment like noise, pollutants, GHGs and odors emissions, boosted in solid waste production, increase in energy consumption and many others that directly and/or indirectly produce negative impact. These negative impact have consequences on the economics by increasing long term costs (e.g. loss of productivity, increase of sanitary costs, etc.) and on the environment by lowering the attraction of cities because of pollution that affect negatively the health of people (Weziak-Białowolska, 2016). This work explores the application of the environmental technologies in four principal sectors, such as water, mobility, waste, and air. In Figures 1,2,3 and 4 are reported the schematic distribution of the ETs examined in the present study.

2.1. ETs in water sector

According to Bediako et al., (2018) technologies for water and wastewater management are specialized in, floods prevention, production of clean water and, quality and quantity control. Mainly in Europe, more than 50% of water is wasted in the water grid due to the lack of early detection (Ramos et al., 2019). In fact, pipeline can degenerate due to the corrosion phenomena, further deteriorating water quality too. Therefore, timely monitoring and maintenance of pipelines are often required to ensure long-term water conservation (Chen & Han, 2018). In coastal region where there is shortage in soft water, desalination plants (e.g., reverse osmosis (RO) and capacitive deionization (CDI) stack) are vital for the development of such urban areas (Lado et al., 2021). Innovative integrated wastewater treatment plant that minimizes their environmental impact should be implemented close to urban areas to facilitate the reuse of the treated water for parks and others usages (Dairi et al., 2019). A schematic distribution of the aforementioned ETs implemented in the water sectors are shown in Figure 1.

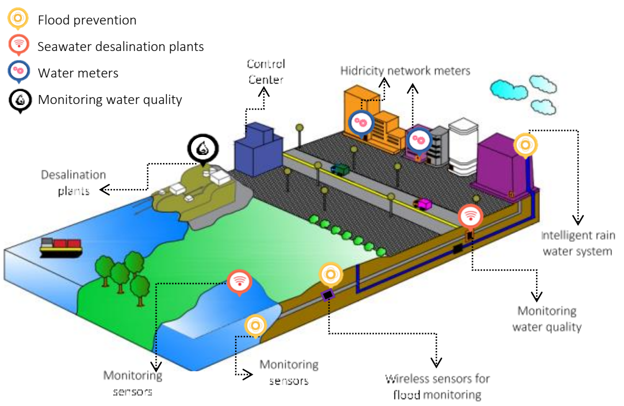

Figure 1. ETs in water sector

2.2. ETs in air sector

The Environmental Protection Agency of the United States introduced the Air Quality Index (AQI) for the evaluation of air quality (USEPA, 2014). The AQI considered five air pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and particulate matter (PM_{10}). According to USEPA, (2014) interconnected monitoring station able to show real time data and generate alert are necessary to preserve citizen health. A schematic example of the interconnection of different monitoring station is reported in Figure 2. Odorous emissions related to several source are becoming a new challenge that compromise the quality of life of people in urban areas (Senatore et al., 2020; Zarra et al., 2019). Novel electronic nose, IOMS that integrated ANN has been identified one of the best solution to monitor in real time odorous emissions that allow to act immediately on the sources (Oliva et al., 2021). Generally, air monitoring networks are used to control air quality and ensure measures to minimize negative impact of sensitive receptors. Complex urban areas continuously generate GHGs that contribute to increase average temperature in such environment. Integrated carbon capture and utilization (CCU) technologies are a promising technology able to minimize GHGs (Senatore et al., 2021). Biological CCU e.g., photobioreactors integrated in urban landscape are one of the best candidates to be implemented in metropolis for the reduction of CO_2.

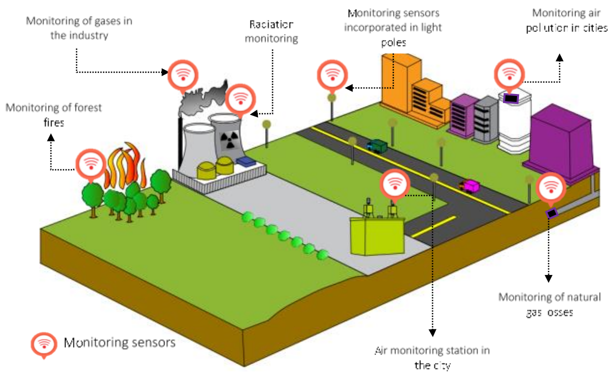

Figure 2. ETs in air sector

2.3. ETs in mobility sector

As reported by Aletà et al., (2017); Behrendt, (2016) in the mobility sector, traffic represent the most visible and widespread problem. It well knows that traffic increases the travel time decreasing productivity, fossil fuel consumption, GHGs and pollutants emissions. The ETs can provide a series of solutions that integrated into the city can reduce traffic congestion. To monitor and control the traffic on the streets, cameras and sensors are installed at traffic lights to provide information and manage the traffic flow in real time (Talas et al., 2012). In Figure 3 are reported the main technologies to improve mobility in cities.

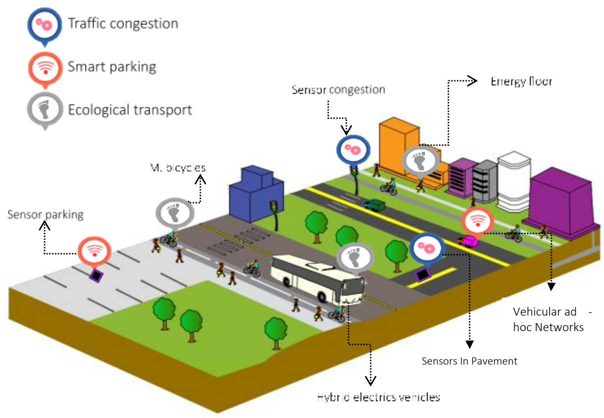

Figure 3. ETs in mobility sector

Especially in metropolitan cities, congestion is often caused by the scarcity of parking areas (Wilberforce et al., 2017). The technology applied to mitigate this problem is based on sensors deployed to detect the presence of vehicles in parking facilities and redirect information to the users of space availability, decreasing travel time in search of free spaces (Hauber-Davidson, 2009). Among other solutions, to overcome the challenge of fossil fuel reduction is the use of Hybrid Electric Vehicles (HEVs) and All-Electric Vehicles (AEVs). HEVs and AEVs are considered environmentally friendly and are expected to help in the process of reducing GHGs and pollutants emissions into the atmosphere (Wilberforce et al., 2017). Other strategies include a modal shift towards low-carbon transport systems, encouraged by increased investment in walking and cycling infrastructure (Zhao & Li, 2017), that thanks to the use of piezoelectric pavement are able to generate clean energy.

2.4. ETs in waste sector

Turning waste into resource is one of the keys point to a circular economy strategy (Ghisellini et al., 2016). European legislation introduces specific objectives with the aims to improve waste management, stimulate innovation in recycling, limit the use of landfills and creating incentives to change consumer behaviors. If solid wastes are reused and recycled, can become raw material in other production cycles different from the original one. This has led to a more circular economy framework with effective waste disposal, while resources are used efficiently and sustainably (Malinauskaite et al., 2017).

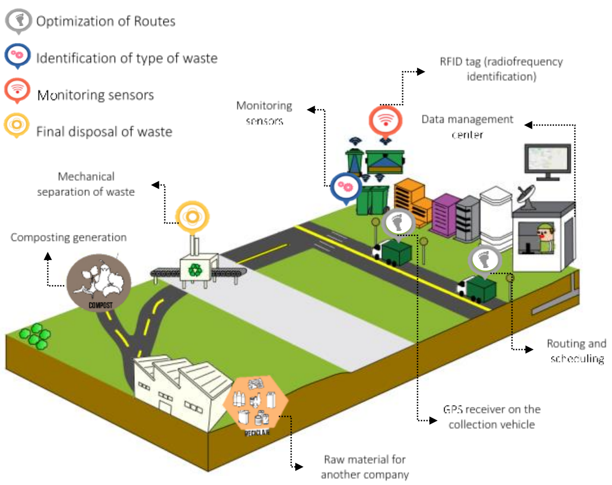

Figure 4. ETs in waste sector

In addition, the waste collection process is becoming a critical aspect for service providers because of the growing market in waste management. In recent years, there has been a growing adoption of radio frequency identification (RFID) technology in many areas of application, such as logistics, inventory, public transport and security (Rajaraman, 2017). From this perspective, RFID would be an important opportunity for waste management, as RFID tags could be used to improve existing waste management processes (Dey et al., 2015). Therefore transport systems, intelligent infrastructures, rational operations and strategic asset management contribute greatly to the development and operation of smarter waste management alternatives (Glouche & Couderc, 2013). For example, robust transport networks are necessary for the efficient collection and transport of debris to material and energy recovery facilities as well as to landfills. IT resources, such as geographic information systems, are valuable for planning collection routes, locating processing facilities, as well as for choosing locations for transfer stations, landfills and recycling facilities (Medvedev et al., 2015). Figure 4 report the main ETs implemented in the waste sector.

3. Future perspective

This document presents the concept of a sustainable and resilient city taking into account environmentally friendly technologies applied in different countries in water, mobility, air and waste sectors. Thanks to the rapidly growing of the Internet of Things (IoT), and cloud computing, smart technologies are already applied in many cities. Whereas there is no clear sustainable smart city approach yet and a guideline should be developed. But it also true that a universal fixed protocol may be difficult to define with the variety of characteristics of cities worldwide. However, it is possible to define checklists that show the best technologies to be applied in the various fields mentioned above, to make the city smarter and environmentally friendly. Finally, the development of the cities should be thoroughly planned to take in to account their goals, their actions and impacts on the different sectors in a holistic point of view.

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