Proceedings

Sewer Mining as A Basis for Technological, Business and Governance Solutions for Water in the Circular Economy: The NextGen Athens Demo †

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Abstract: The Athens Water in the Circular Economy demo case examines all three of the following as associated with Circular Economy (CE) in wastewater streams: water, energy and materials. The application area is the Athens Urban Tree Nursery, which is located in the center of Athens, in order to address real world problems in water-scarce cities. The Athens demo application includes sewer mining, a technology first pioneered in Australia related to mobile wastewater treatment units in containers that are able to treat and provide reused water at the point of demand in dense urban environments. The installed pilot unit consists of a membrane bioreactor unit (MBR) and a UV disinfection unit. The sewer mining is achieved with a prefabricated pumping station that will be demonstrated in the main sewer network for feeding the sewer mining unit with wastewater. The unit will produce fresh water that will be used for irrigation needs, and also during the winter for aquifer discharge. The Athens Tree nursery also has significant amounts of pruning materials that, until now, have remained untapped resources. The excess sludge produced from the unit along with the green and wood waste will go through a rapid composting process in order to produce fertilizer. The first stage will be a pre-treatment unit that includes the shredding, homogenizing and sorting of the pruning materials. The second stage is rapid composting that will last approximately 2 weeks. The last stage is the compost that will be used again on-site as a fertilizer full of nutrients as part of a renewable energy solution for the area to support more complete autonomy.

Keywords: circular economy; sewer mining; wastewater reuse; composting; energy recovery; decentralized wastewater treatment

1. Introduction

Water resources are considered to be under great risk, as, according to the UN, it is estimated that by 2030 water shortages could reach 40% of total demand [1], and approximately half of the world’s population will suffer from water stress. Water availability is closely linked with water
quality, since the deterioration of the second can prohibit the use of water in certain cases (e.g., drinking water).

These pressures on the environment have led to an increased interest in exploring alternative solutions to reduce waste and resource usage. The world needs to move away from a systematic ‘take–make–consume–dispose’ behavior. This linear model assumes that resources are abundant, available, and cheap to dispose of. By embracing ‘circular economy’ principles and technological innovation, natural capital can be preserved, resources can be optimized and system efficiency can be improved, so as to boost sustainability and bring new market dynamics throughout the water cycle.

It is therefore essential to design a new circular water management system that takes into consideration the different elements in the water cycle and maximizes their efficient usage. Some measures that can be implemented, based on the principles of the Circular Economy model, are [2] first of all to avoid water use by redesigning products and services and eliminating inefficient practices, also to reduce water use by improving the efficiency of the water systems and the distribution of the resource. The next step is to reuse, by keeping water either within one system (closed loop) or redirecting it for use in other systems or communities. Recycling is also important in external systems and/or external practices, and last but not least, we must strive to replenish natural reserves by safely and efficiently returning water to the natural basins (rivers, lakes, oceans).

Water reuse in particular is a concept that is gaining traction, and is considered an innovative way to address water scarcity [3]. Within the context of the urban water cycle, water reuse translates mainly into using treated wastewater (a waste) to supply (as a resource) a usually non-potable water use [4], such as irrigation, industrial use, urban use (non-potable), or the replenishing of aquifers or surface water bodies, among others [3].

The NextGen initiative evaluates and champions innovative and transformational circular economy solutions and systems that challenge embedded thinking and practices around resource use in the water sector. It demonstrates innovative technological, business and governance solutions for water in the circular economy through ten high-profile, large-scale demonstration cases across Europe, and develops the necessary approaches, tools and partnerships in order to transfer and upscale.

The Athens Water in the Circular Economy (CE) demo case examines all three of the following aspects associated with CE in wastewater streams: water, energy and materials. The application area is the Athens Urban Tree Nursery, which is located in the center of Athens, and is used to address real world problems in water-scarce cities.

2. Athens Demo Case

The Athens Urban Tree Nursery is part of the Goudi Park, an area in the process of redevelopment and regeneration in order to become one of the key metropolitan parks in the capital. The area, which lies in the heart of Athens and is illustrated in Figure 1, is a mixed-use area, composed of urban green and urban agriculture spaces, as well as administration and residential uses. The regeneration is an effort to boost the local economy and improve quality of life for the 4,000,000 citizens of the Attica Region.

The Nursery covers an area of approximately 96 acres, 40 of which are used in the production, development and maintenance of the plants, while the rest are used for general purposes such as administration buildings and the offices of the Municipality of Athens. The Nursery supplies all the urban parks and green spaces of Athens with plant material, and uses potable water from Athens’s Water Supply and Sewerage Company (EYDAP) for its irrigation. Furthermore, the pruning waste of the urban parks is accumulated in the Nursery, not treated, and partly transferred to the Athens landfill. With regard to the use of fertilizers, these are bought from the market. With regard to the energy needs, the nursery gets electrical energy from the urban network, and for heating they use petrol oil. In this respect, the city is seeking alternative water sources to achieve environmental, social and financial benefits, so as to address real world problems in water-scarce cities. Figure 2 presents the current situation in the Athens Urban Tree Nursery in terms of water, energy and materials.
3. Technologies

3.1. Circular Economy Approach

The NextGen Athens case focuses on the demonstration of innovative concepts of alternative water sources to reduce the use of freshwater resources, and on the transition to a Circular Economy (CE) based water sector. In particular, the purpose is to produce recycled water from urban
wastewater with a sewer mining modular unit for urban green irrigation and other non-potable uses at the point of demand, in order to benefit the sustainability of the new Metropolitan Park.

Additionally, an integrated energy and nutrient recovery technology is implemented. In particular, schemes of recovering energy directly from the sewer mining unit are tested to cover thermal energy configuration needs. Finally, a high-quality compost-based eco-engineering growing media product has been designed to be produced as an on-site fertilizer, derived from mixing wastewater sludge with treated wood and green wastes. This circular economy approach is presented in Figure 3.

This demo case will serve as a significant step towards autonomous, transferable, local, modular, scalable and circular solutions, enabling decision-makers to invest in such schemes by widening their acceptance by the local authorities, end-users, civil society and entrepreneurs (including SMEs). The impact of this approach on the sensitive challenge of using potable water for irrigation purposes in the urban environment cannot be overstated. This case delivers a full-scale example of CE at work with very high economic, environmental and social impacts.

![Figure 3](image-url)

**Figure 3.** Circular Economy approach for the Tree Nursery in terms of water, energy and material.

### 3.2. Sewer Mining Technologies

Sewer Mining is a concept that is gaining traction, and is considered an innovative way to address water scarcity. Within the context of the urban water cycle, water reuse translates mainly into using treated wastewater (a waste) to supply (as a resource) a usually non-potable water use, at the point of demand. This technology involves extracting untreated wastewater from the local sewers through a prefabricated pumping station, treating them at the point of demand and supplying local non-potable uses.

Sewer mining technology is applied by using typically a compact, sometimes portable advanced treatment plant. On the other hand, conventional wastewater treatment plants present many difficulties as regards applying this technology [5]. Most of the existing sewer mining operations use...
their reclaimed water for public space irrigation and toilet flushing [6–8]. In some cases, though, the reclaimed water is used to supply non-potable domestic water demand.

Sewer Mining is a technology that is gaining momentum due to its mode of high efficiency treatment and the limited space required for its installation. Due to its decentralized form, it can be installed in situ, and therefore is closer to the circular economy concept. A variety of benefits can be yielded when sewer mining is well planned and designed; it can relieve overtaxed wastewater systems, trim water and wastewater infrastructure costs, reduce energy and chemical use, and save drinking water for activities that really need drinking-quality water.

The membrane bioreactor (MBR) technology is composed of a hybrid UV and biology unit. A biology study has been performed. The construction of the unit was done by incorporating biology tanks and a membrane bioreactor tank. A machine room was also installed with all the electromechanical equipment.

Sewer mining technology is still in its beginning stages, and as a result there are several challenges and issues that need to be addressed. These challenges consist of engineering challenges, such as the efficiency of the technology itself, regulatory challenges such as the different water quality requirements per country or area, financial challenges in finding the appropriate business model regarding sewer mining investments, and social challenges that deal with the social acceptance of the practice.

The Athens demo application includes sewer mining, a technology first pioneered in Australia that is related to mobile wastewater treatment units in containers that are able to treat and provide reused water at the point of demand in dense urban environments. The installed pilot unit consists of a membrane bioreactor unit (MBR) and a UV disinfection unit. The sewer mining is achieved with a prefabricated pumping station that will be incorporated into the main sewer network so as to feed the sewer mining unit with wastewater. The unit will produce fresh water that will be used for irrigation needs, and during the winter will also be used for aquifer discharge.

More specifically, a prefabricated pumping station, with a capacity of 25 m³/h, will be installed and fed with wastewater by the main wastewater sewer pipeline that passes through a well which is located within the premises of the Athens Tree Nursery (Goudi). The small pumping station will consist of two pumps in case of failure. Wastewater will be pumped firstly into the MBR hybrid unit. The wastewater will be treated by biological treatment for organic oxidation, and also for nitrification, denitrification and by membrane filtration as well. The effluent water will be a high-quality water. A previous sewer mining study that was applied in an FP7 project proved that the effluent water can fully meet all the national criteria set by the Greek Legislation [9]. After the MBR unit, the water will be driven to a UV disinfection unit. After the UV unit, the reclaimed water will be suitable for irrigation and aquifer recharge during the winter. Figure 4 illustrates the flowchart of the NextGen project.

![Figure 4. The Athens pilot configuration.](image_url)
3.3. Production of Compost and Energy Recovery Technologies

The Athens Tree Nursery also has significant amounts of pruning materials that have, until now, remained as untapped resources. The excess sludge produced by the unit, along with the green and wood waste, goes through a rapid composting process in order to produce fertilizer.

The first stage is a pre-treatment unit that performs the shredding, homogenizing and sorting of the pruning materials. The second stage is the rapid composting, which lasts approximately two weeks. The last stage is the production of the compost that is used again on-site as a fertilizer full of nutrients, as part of a renewable energy solution for the area in order to support more complete autonomy. The Composting Bioreactors system is illustrated in Figure 5.

4. Conclusions and Discussion

This paper presents a holistic, circular approach and viable solutions for real world problems in water-scarce cities, enabling autonomous, decentralized resource recovery schemes towards sustainable water management.

The installation and testing of a sewer mining modular unit for urban green irrigation at the point of demand is clearly of direct benefit for the sustainability of urban water management. To address resource efficiency issues in a circular economy context, compost-based eco-engineered growing media are produced and reused as on-site fertilizers, and thermal energy recovery schemes are being investigated to minimize the pilot’s environmental footprint.

These technologies are being applied and tested for the first time in Greece in real world applications, and the results aim to serve as a significant step towards transferable, modular, scalable and circular solutions.

The project also engages local authorities, end-users, civil society and entrepreneurs to test social acceptability, policy and regulation support for implementing the particular technologies, and it enables decision-makers to invest in such schemes for the future European roadmap for water in a circular economy.

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