KKU Res.j. 2016; 21(2) : 102-109
http://resjournal.kku.ac.th

Blue Technology-The Water-Energy Interrelationship Renewable Energies and Nutrient Recovery

Nicholas Kathijotes

International Ocean Institute (Cyprus),Cyprus University of Technology, POB 50329 Limassol Cyprus,
Corresponding author: nkathijotes@ gmail.com

Abstract

Water resources are constantly under threat from pollution, overexploitation and urbanisation. The European Innovation Partnership on Water (EIP) has identified specific actions to meet the relevant needs which have been codified into 8 priority areas. Focussing on two of the five thematic priorities (water and waste water treatment, including recovery of resources; and water and energy integration, this paper amplifies Blue Economy models aiming to shift society from scarcity to abundance through these new and novel ways.

Inland and coastal waters are looked upon as ‘water resources’ that can contribute to the production of sustainable energies. In water reuse, the energy contained in wastewater is also examined in order to contribute to the understanding of the water/energy relationship. Energy is needed for water cycle management; water is needed for energy production and water reuse can help to save both. Biogas production, being an important green energy issue is also examined under the scope of wastewater treatment. Significant energy savings and recovery of nutrients can be achieved on major components of an ‘efficient’ wastewater treatment plant by applying novel blue economy principles. Zones where energy efficiency can be improved, as well as phosphorous recovery is explained always under a holistic water cycle management.

Marine based renewable energies are also outlined based on coastal blue potentials and future world energy needs-provided that conventional energy sources are approaching exhaustion.

Other general quality issues in coastal environments are presented and examined within the framework of the blue economy principle and thus suggesting actual novel sustainable management techniques.

Keywords : *Blue technology, wastewater treatment and reuse, water resources, nutrient recovery.*

1. Introduction

Recognizing that water of the right quality needs to be supplied, and there is a need to change the focus from treating wastewater and sludge to be ready for disposal to providing water fit for use and income generation from recovered energy and resources. In applying blue economy principles, our main concern will be savings in energy, recovery from wastewater, water quality improvement as well as the production of marketable sludge derivatives. Even though we all look reality in the eye, we seem to lack the vision and the tools to make a difference and steer our excessive consumption society in general and our competitive business world towards sustainability.

In conceptualizing 'Blue Economy', we can say that 'Blue economy' refers to the new system of Green Economy that interweaves creative neo-science and associated technologies.

I suggest then that introducing more innovative technologies to the market based on 'The Blue Economy Concept'. These innovative technologies will generate new cash flow, which will create jobs and build social capital. The top priority in this process is to develop entrepreneurship and to find more people who are willing to take risks. It is also important to find investors who believe that these are good opportunities. "The Blue Economy" is a social system created by through a step by step process. It is named after this beautiful mother Earth whose sky and ocean are blue, as long as there is no pollution. Therefore I suggest calling the social system "The Blue Economy" created through a truly sustainable process.

Apply mitigation and adaptation measures for global climate change, tsunamis, storms and other natural hazards. Ensure that all people are able to meet their basic human needs; i.e. food, clothing, housing, health, education and transportation. Increase access of local communities to technology, infrastructure, capital, markets, information and other productive economic assets.

Extra amounts of energy, fuels, water, fertilizers and human labor to produce one unit yield are lost. Additional financial subsidy and help are annually needed for agriculture in almost all countries around the world. Both (a) the ineffective consumption of energy, fuels, water, fertilizers and human labor and (b) the environmental damages in conventional agriculture can be reduced or completely removed by current scientific monitoring, estimating and managing the agricultural activities related to the water and nutrient statuses of each agricultural field (agro ecosystem).

Many of our technical processes of harnessing, extracting, and producing energy utilize water. Similarly, water extraction, treatment, distribution, and disposal processes consume energy. This interdependency, often referred to as the water-energy nexus, has been increasingly highlighted as an important issue for future planning and strategic policy considerations. The effects of global warming and climate change, amplify the need for managing energy and water along with nutrients in an integrated system adapted to the growing urban development.

2. Energy Saving Methods

Energy is mainly produced from fossil (oil, gas, and coal) and nuclear energies which have limited reserves. Globally, we currently produce about 10 billion toe (ton of oil equivalent). Due to the economic development of nations, a 50 to 300% in consumption is expected by 2050.

Predictions show that demand for energy will be increasing drastically

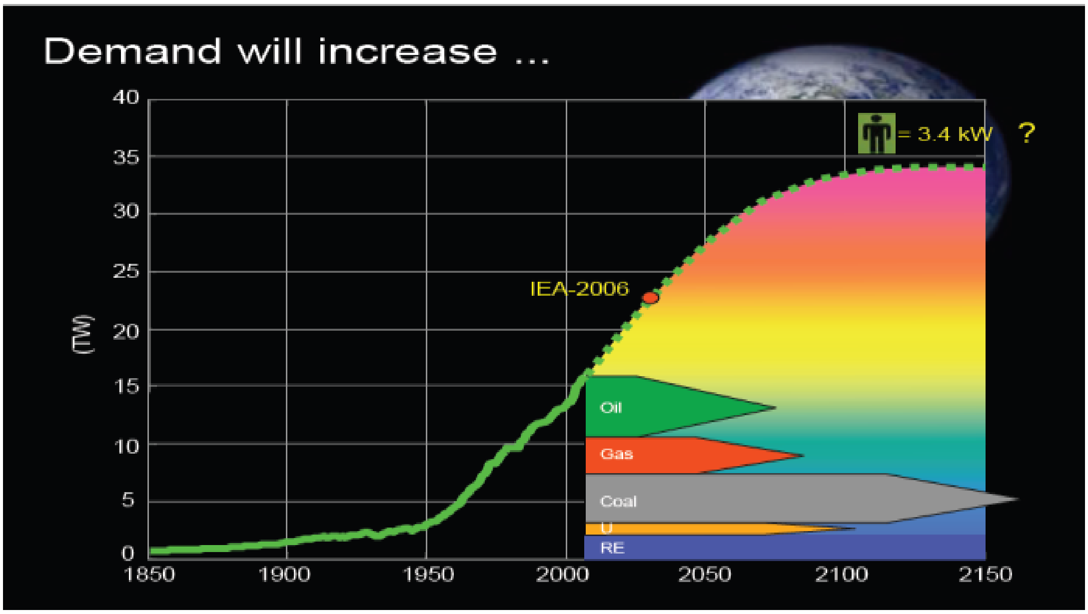

Figure 1. Estimated world energy supplies and needs [8]

2.1 Marine-Based Blue Energy

It is a priority to reduce the use of fossil fuels and simultaneously use renewable energy including solar energy, wind power, wave energy, tidal energy, Ocean Thermal Energy Conversion (OTEC) and biofuel from marine algae and sea grasses. Marine energies have the potential to enhance the efficiency of harvesting the energy resource, minimize land-use requirements of the power sector and reduce the greenhouse gas emissions [3]. These include: Wind-driven marine waves; Gravitation induced marine tidal (tidal-range barrage); Tidal stream (marine currents); Marine salinity gradients; and Thermal gradients between warm surface water and deep (> 1000 m) cold water (also called ocean thermal energy conversion, OTEC). Extreme care should be given to the prevention or interference with natural processes

2.2 Energy cost for water

We then need to increase ‘energy efficiency’ which entails reducing and optimizing the energy consumption of a process while maintaining its efficiency. The possibility of producing green energy, and using it directly to power facilities or supplement energy to grids, reduces greenhouse gas emissions and carbon footprint of plants, producing great cuts on energy costs.

Conventional water treatment, for producing drinking water with the deterioration of resources is no longer inexpensive. Indicative costs range from 30Wh/m3 for classic treatment to 120 Wh/m3 for activated carbon and ozone, and to 200 Wh/m3 for membrane ultrafiltration. A key point for energy optimization in membrane technologies, is the design of pretreatments in order to reduce waste discharge from membrane treatment.

General desalination water costs 3.5-5 KWh/m3, even though high efficiency plants like Ashkelon in Israel has a cost of 2.9 KWh/m3 [5]. Treated wastewater 1.2 KWh/m3, with higher efficiency plants like Strass in Austria, achieving a very low cost of 0.35 KWh/m3 , but also producing electricity achieving self-efficiency[6]. Rainwater costs only 0.0012 KWh/m3 basically attributed to pumping needs

The use of non-conventional water resources, such as desalinated water, treated water from wastewater treatment plants, grey water and storm water in water supply for various uses can substantially alleviate the pressures on the freshwater resources which are already high in Cyprus [3]. Following, the progress made so far in Cyprus regarding the use of non-conventional water resources is presented.

3. Reuse of municipal wastewater

Water reuse provides additional drought-proof water supply, favours a more local sourcing of water and avoids the use of high quality water sources where this is not necessary. The potential for water reuse depends on the availability and accessibility of wastewater, i.e. the wastewater infrastructure, and the acceptability by potential end-users and consumers.

There is an immense potential for growth of water reuse practices driven by both the demand for water and the increasing volumes of treated effluent [4]. Aiming at compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significantly expanded and upgraded. Providing recycled water for irrigation began in 1998, with a small amount of around 1.3 Mm3 and reached 12 Mm3 in 2010, from which 9 Mm3 were supplied for irrigation and about 3 Mm3 for artificial recharge of aquifers. The capacity of the new Waste Water Treatment Plants in 2012 amounted to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85 Mm^3 for long-term (2025). The annual water recycling is expected to reach 28.5% of today's agricultural water demand [1].

Regarding the use of recycled water in agriculture, specific quality standards have been established as well as measures for the protection of public health. The compliance with both quality standards and protection measures is obligatory.

In general, the treatment of wastewater in Cyprus includes tertiary processes followed by filtration. Treated wastewater is used for the irrigation of green spaces, athletic fields and crops (excluding edible raw vegetables) as well as for aquifer recharge.

Further treatment of certain quantities of the effluent with the Reverse Osmosis (RO) process is under consideration in order to reduce water salinity and the final effluent to be used for the irrigation of sensitive soils and crops. At the same time, the RO process is expected to enable the integrated management of all irrigation water resources. However, the application of RO presents some disadvantages, such as the high costs for the construction and operation of RO plants, and more significantly, the difficulty in selecting a management option for the brine produced which will be both techno-economically feasible and socially accepted. For example, the suggestion for thermal treatment of the brine from the RO plant, which is going to be constructed in the area of Aradippou, is socially acceptable, but it is quite expensive, while the conventional disposal of the untreated brine is not considered [1].

General aim is to use the increasing quantities of treated effluents produced for the irrigation of the agricultural crops, thus substantially alleviating the pressures posed to the agricultural sector due to water scarcity.

The acceptance of the use of treated wastewater from farmers was, at first, slow and reluctant. However, the water cuts imposed on agriculture during the recent drought periods in conjunction with the lower water tariffs set for recycled water in comparison with those of freshwater, led the farmers to turn to the use of recycled water, thus increasing the exploitation of this source. In the beginning, the recycled water was applied in fodder crops, while after the experience gained from its application, its use was expanded to other crops, such as flowers, olives, citrus, grapes, potatoes and dry onions [1].

Furthermore, treated wastewater is also used in Cyprus for aquifer recharge. So far treated wastewater from Paphos is used for the recharge of Ezousa's aquifer. The expansion of this measure to the aquifer of Kiti and Kokkinochoria is under investigation as well [1]. The Moni wastewater treatment plant plant is energy supported to about 50 percent, produced from sludge digestion. Cognisant of the criticality of phosphorus as a raw material and the need to deliver the resource efficiency agenda established under the Europe 2020 Strategy for smart, sustainable and inclusive growth [9]. Major attention should now be focussed on technologies for recovering, enhancing their functionalities, and delivering the phosphorus products as marketable commodities to suit local condition.

Table 1. Water demand management measures and estimated savings [2]

Measure	Water savings (Mm^3/yr)	Data coverage (years)
Replacement of water supply networks	3.3	2000-2010
Use of non-conventional water resources		2005-2008
Recycled water	12.5	
Desalinated water	55.5[1]	
Stormwater	0	
Subsidies for reducing domestic water demand		1997-2010
Borehole drilling	1.3	
Borehole connections with toilets	0.3	
Grey water recycling	0.03	
Hot water circulators	0.05	
Water allocation and cuts	41.5	2000-2010
Use of water meters	8	1986-2009
Redistribution of irrigated land	4.4	1991-2009
Irrigation systems	20	1960-2000
Total	*91.4*	

3.1 Phosphorous recovery options

Issues like, Water Quality (delivering safer drinking water and meeting the good water status), Value Recovery (reducing chemical and energy consumption in secondary treatment, generating more biogas from sludge, and phosphorus recovery), Product Quality Enhancement and Application (adding value to and making efficient use of the recovered products), and Sustainability (techno-economic assessment of the innovative processes) should be addressed when considering a holistic approach in environmental management. In managing nutrients, public safety, closed loop phosphorus management reducing carbon dioxide emissions (climate change) and improving the security of the land recycling route together with economic opportunities developed by changing the technology basis of water and wastewater treatment should be closely considered.

The applied sludge when properly treated, it is expected to provide significant improvement in biogas yield while at the same time producing marketable products. BIOPOL, is obtained through a recovery process using a micro-milling technique that causes cell disruption a breakthrough innovation in sludge-derivatives. This blend of biopolymers, has many exciting potential applications in wastewater treatment. It exposes intracellular products to enzyme actions and leads to a significant enhancement in the biogas yield during digestion while substantially raising the soluble phosphorus content in the digested liquor. Phosphorus recovery becomes then more viable (BIOPHOS), and may play may play a very important role in sludge and phosphorus management in Europe that should be moving towards a circular economy (COM 2014).

In view of the criticality of phosphorus as a raw material and the need to deliver the resource efficiency agenda established under the 'Europe 2020 Strategy' for smart, sustainable and inclusive growth, the investigation and application of the underpinning technologies for recovering, enhancing their functionalities, and delivering the phosphorus products as marketable commodities to suit local condition as well as to provide flexibility in its agricultural use is absolutely essential.

By using BIOPOL, BIOPHOS can be produced and can recover soluble phosphate from digested sludge liquor. BIOPHOS contains at least 20% Phosphorus (as P_2O_5, dry weight basis) of which at least 80% is Citric Soluble.

Digested sludge that has been treated by micro-milling from the BIOPOL when used with further anaerobic digestion will lead to at least 40% increase in biogas yield while also raising the soluble phosphorus content in the digested liquor by at least 100%. It is believed that such a treatment will solubilise at least 75% of the phosphorus content of surplus activated sludge. Further, and after P recovery, the sludge residue would give rise to a sludge cake with a considerable reduced P content (at least 50% lower) and would make a more suitable alternative to conventional biosolids for agricultural recycling.

4. Conclusions and Suggestions

The aim then in optimizing the energy from a treatment plant is threefold, that is; to improve energy efficiency, to maximize the energy extracted from untreated water and eventually from sludge, and to recover other renewable energies and nutrients. The following suggestions for achieving the above are:

Energy recovered from sludge could be above 60% of the total energy needs of a sewage treatment plant.

-innovative technologies in digester design, and sludge pre-treatment before digestion

-Use of power generation and combined heat from digester gases electricity for various treatment needs.

-Direct use of gas after purification to the gas grid.

- Use of the biosolids in agriculture, and as a solid fuel in industry. Sludge contains numerous nutrients that can assist crop production provided that all precautions are applied.

Improving treatment technological practices and following 'best practice' suggestions for low energy consumption can produce savings about 20 %. [7].

- Energy recovered from sewage flows, improved topography designs to reduce pumping needs, as well as using other innovative technologies such as photovoltaic-thermal systems, wind turbines and others can produce considerable savings in energy to another 20%.

- Solar radiation is abundantly available in Cyprus with 330 days of sunshine a year as well as in many other countries.

Photovoltaics can be used to produce electricity that will drive the desalination or water treatment processes. As an example in the Arabian Gulf photovoltaics produce a capacity of about 6000 m3/day of desalinated water.

- Huge amounts of nutrients stored in municipal sludge can be exploited.

- Further research is necessary in order to develop a thorough scientific understanding of the mechanisms of phosphorus release and uptake from BIOPHOS

5. References

(1) Water Development Department (WDD), Cyprus River Basin Management Plan, Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus, 2011 (a).

(2) Water Development Department (WDD), Study on the investigation of water demand management measures'. Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus, Nicosia, 2011 (b).

(3) Kathijotes N. (2013). Keynote: 'Blue Economy - Environmental and Behavioural Aspects towards Sustainable Coastal Development', Elsevier Procedia - Social and Behavioural Sciences, Volume 101, 2013, Pages 7-13

(4) Petrov K. and Kathijotes N., "Wastewater Treatment and Reuse for Irrigation" International Water and Irrigation-Israel vol.19, No.2, 1999

(5) Voutchkov N. (2010), Seawater desalination: current trends and challenges. Desalination-Filtration + Separation Publication, 5(2), 4-7.

(6) Novak O., Keil S., Fimml C. (2011), Examples of energy self-sufficient municipal nutrient removal plants. Water Science and Technology, 64(1) 1-6

(7) Lazarova V., Choo K.H. and Cornel P. (2012). Water Energy interactions in water reuse. IWA Publishing, London, UK.

(8) Miguel Prado - The Netherlands July 2009 http://wavec.org/client/files/Part1-Energy-Problem.pdf

(9) COM (2010) 2020, COM (2011) 21. COM (2014) 398. Towards a circular economy: A zero waste programme for Europe. COMMUNICATION FROM THE COMMISSION, Brussels, 2.7.2014.