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Water – energy nexus: case study of Rwanda

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ABSTRACT

The water – energy (WE) nexus approach seeks to assess relevant and consistent strategies to address challenges to the development of both water and energy sectors, to meet the demand and achieve a sustainable development. Water and energy are the most indispensable elements for life and development respectively. Besides that, the production and cost of one depends highly on the performance of each other. Not any country could attain a sustainable development without first developing the two sectors and satisfy the demand. Most of developing countries face the challenges in handling the management of water and energy resources due to different reasons. Among those reasons the most predominant are high population growth, lack of skills in water, low use efficiency and energy resources management and impact of climate change. This research seeks to find out the best ways to handle barriers to both energy and water development with the target to satisfy the need in a sustainable way.

Keywords: Water – energy nexus; Nexus strategy; Sustainable development

1. Introduction

Water and energy are two interdependent sectors, water is required to generate energy, and at the same time energy is needed for water treatment, distribution and pumping on long or high lift head. Therefore, the development of one or both sectors has to be well coordinated, due to inevitable influence one might have on the other in case of bad management.

The rise in population goes with the rise in resources demand to meet the need. Therefore, as the population increases, the demand in energy and water increases as well. As a result, much pressure is being put on water and energy resources.

Water and energy resources management is the most important tool for a sustainable development. In developing countries however, the case of Rwanda, limited human resources, institutional systems, and infrastructure hinder the development of those sectors. Besides that, water sector is much affected due to ecosystems degradation, pollution and climate change in terms of quality and quantity [1] (GoR, 2011). In case water resources are disturbed, the energy generation from hydropower plants will be affected as well.

The water – energy nexus (WE) seeks to assess relevant and consistent strategies to address challenges to the development of both water and energy sectors, to meet the demand and achieve a sustainable development [2].

2. Water – energy general overview

According to UNICEF/WHO, 61% of people from Sub-Saharan Africa (SSA) have access to clean water, while the remaining 40% lack access to improved drinking water sources. Besides that challenge to access to clean water, only 28% of SSA population, excluding South Africa, accesses the electricity [3]. The energy consumption in Africa is 30 times less than the one consumed in North America, however, the continent presents much potential in energy resources [4].

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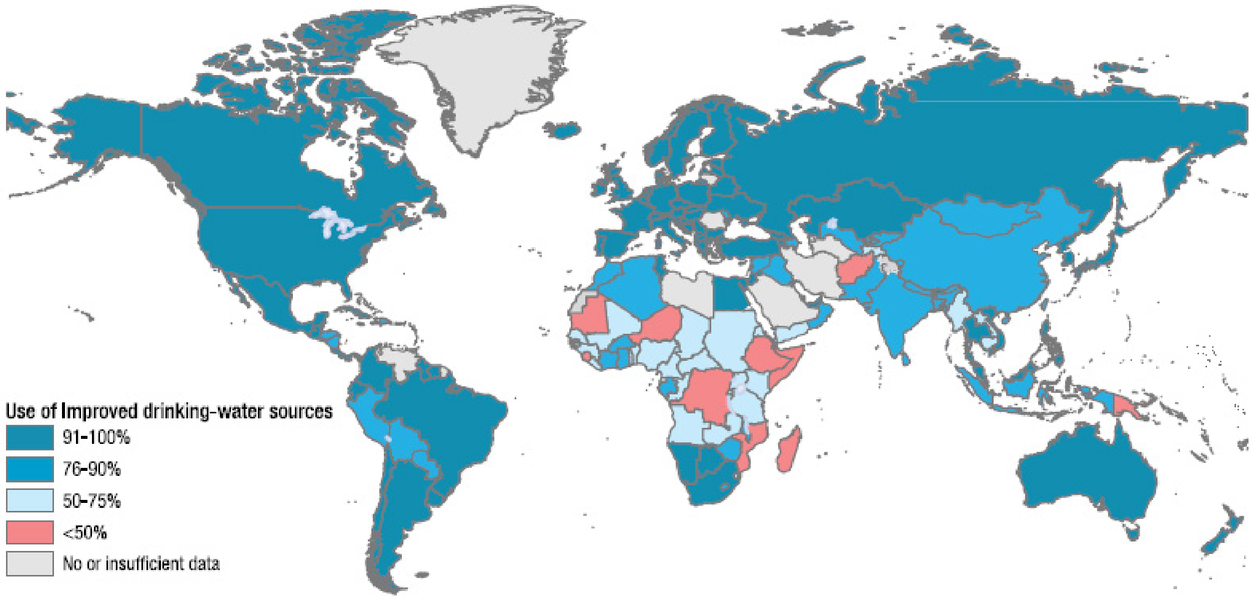

Fig. 1. Worldwide use of improved drinking water sources in 2008.

Despite the low access to electricity in SSA, African water utilities are qualified of consuming more energy, where 60–70% of water operators' revenue is being spent on energy for water supply. Means the cost of water is much influenced by energy cost, therefore by addressing energy cost; water cost would be addressed as well (Fig. 1) [5].

Obviously, water and energy sectors are important input to modern economies and they inter depend on each other [6]. Water being used in electricity generation and energy used in water treatment and distribution at different level, it is evident that to eradicate the poverty and attain a sustainable development in developing countries, the nexus approach is the key.

The Nexus approach to environmental resources management seeks to examine the correlation of environmental resources and their transitions and fluxes across spatial scales and between compartments. Therefore, rather than addressing one sector's challenge apart, which may harm the other sector, it is recommended to address all the sectors jointly using a nexus approach. Note that those resources include water, soil and waste (UNU-FLORES).

By understanding the link between water and energy, this might help to identify both suitable needed solutions; and where to integrate appropriate policy and management strategies, as well as to find out barriers that hinders the achievement of that integration [6]. Generally, the main challenge to sustainability of water and energy security is thought to be on the side of policy makers and industry; where those last lack the capability to develop effective policies, processes and analytical tools that incorporate water – energy nexus into policy and investment decisions [6]. Also the Water – Energy – Food (WEF) security are much affected by high rise of population that put much pressure on WEF, economic growth and urbanization that boost WEF demand, and climate change which critically hampers the sustainability of WEF security [7].

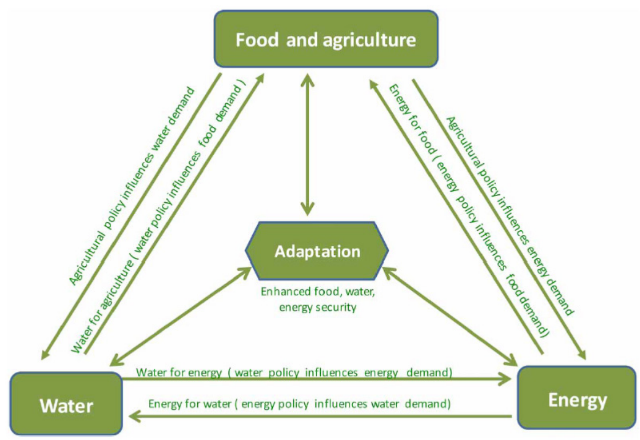

Fig. 2. The interfaces among water, energy, food, and adaptation [8].

Climate change adaptation and nexus approach are linked, with the same principle and goals (Fig. 2). Basing on the fact that water and energy management has effect on adaptation, and Strategies and policies aimed at climate mitigation and adaptation do significantly involve nexus challenges; therefore, good application of nexus approach would facilitate climate change adaptation as it enhances resource use efficiency and greater policy coherence [8].

Despite the link between nexus approach and climate change mitigation and adaptation, those two last may negatively affect the water – energy – food security due to their much demand in water and energy; much use of water in renewable energy technologies for climate change mitigation and use of a lot of energy in desalination, irrigation and water pumping for climate change adaptation [7].

3. Water – energy situation in Rwanda

Officially founded in 1907 by Germans and became later the capital city of the Republic of Rwanda after the independence in 1962 [9]. Kigali is extended over 730 km², at an altitude of 1567 meters and with an average temperature of 21°C [10]. Besides being the capital city, Kigali constitutes the economic and administrative center of the country. At the beginning of its existence in post-colonial period, it was supposed to be occupied by 300,000 people. In 2012, among the 10,378,021 people of total Rwandans 1,114,634 people, equivalent of 10.74% of total population were living in Kigali city (NATIONAL INSTITUTE OF STATISTCS OF RWANDA, 2014) (Fig. 3). From 2002 to 2012, the annual population growth rate was 4%.

Due to lack of master plan, that unexpected extension of the city put much pressure on infrastructure and challenged, drainage system, waste management and supply of reliable and sufficient water and energy [11].

Generally, Rwanda constitutes a water scarce country with only less than 1000 m^3 of available fresh water per capita. The main source of water is precipitation which in turn is unevenly distributed in different parts of the country. The worst is that, despite of scarcity of fresh water, water use efficiency is very low, where 30 to 40% of water is wasted due to inefficient supply systems [1].

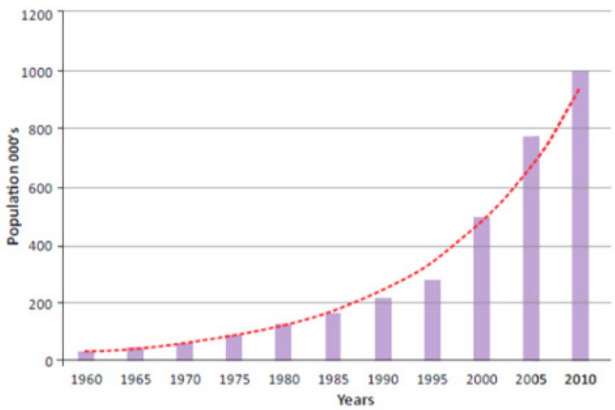

Fig. 3. Kigali city Population growth trends (REMA, 2011).

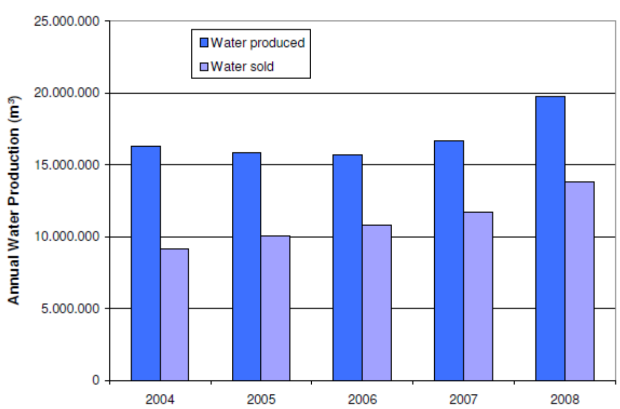

Fig. 4. Annual water production and sales, 2004 to 2008 (MININFRA, 2010).

65% of the population accesses clean water [5]. Therefore, due high percentage of population lacking access to clean water, as a result, 80% of diseases affecting Rwandese are waterborne [12]. Besides that, around only 14% of the population have access to electricity [5].

Around 32% of the whole population, in 2009, had access to piped water; and among them only 3.4%, 17% of them in urban areas and 0.9% of them in rural areas, accessed water up to their household. The normal stand of daily per capita water consumption is 20 L, while in rural areas of Rwanda the per capita daily water consumption is only 6–8 L. This is on one hand caused by the high cost of water, the cost varies from 1 US$/$m^3$ to 3.52 US$/$m^3$ for pumped systems. The electricity cost accounts almost half of the utility's recurrent budget for water supply and treatment and supply. By 2008, the total water demand was 80,000 m^3/d while the utility was only able to supply 37,000 m^3/d (Fig. 4) [12].

It is not only the water sector that is still facing many challenges that hinder its development; the energy sector development is also still at low level. Rwanda still has a low electrification rate of 16% [13]. The major part of the energy consumed is produced from biomass that is being used in conventional way, then diesel and Hydro. For electricity side, the big share of it is produced from hydro, at 59.1%, thermal by using diesel generators, at a share of 40.5%, and a small share comes from solar. The incorporation of thermal stations was due to extended drought that affected the production of hydro power plant. The per capita electricity consumption is only 22 kWh/ inhabitant and 70% of it is consumed in Kigali, thus the marginalization of other parts of the country [14] .

Energy and electricity are mostly consumed in residential, energy mainly used in form of traditional biomass [15].

Much effort are being done to increase the production, however, the demand is highly increasing as well, in 2014 the total number of household customers was 450,775 and 170 of them were industries [15]. Despite of the supply that is insufficient, the cost per unit is also high. The cost per unit of electricity is 50% higher than the average tariff in East Africa [15]. Before the electricity tariff for residential and commercial consumers was 22 US$/kWh, while for industrial customers it used to vary from 16US$/kWh to 28US$/kWh depending on the hours of consumption [13]. Even though the cost was already high, recently it has raised again, where for low voltage consumers the tariffs increased of 35%. It is not only the electricity whose cost increased, but the one for water increased by 19% (Republic of Rwanda, 2015). Thus this emphasizes the nexus of water and energy.

4. Subsidies and policy

Since 2012 Rwanda has adopted the Feed in Tariff – FIT policy for mini (> 50 kW) and micro (< 10 MW) hydro power plant (Fig. 5). The adoption was done in the framework to enhance the development of renewable energy technologies and reduce the dependency on fossil fuel through the use of diesel generators [16]. More policies have been adopted with the aim to increase the energy efficiency and ensure sustainable extraction, supply and consumption of energy. Those policies will as well enhance the supply of reliable,

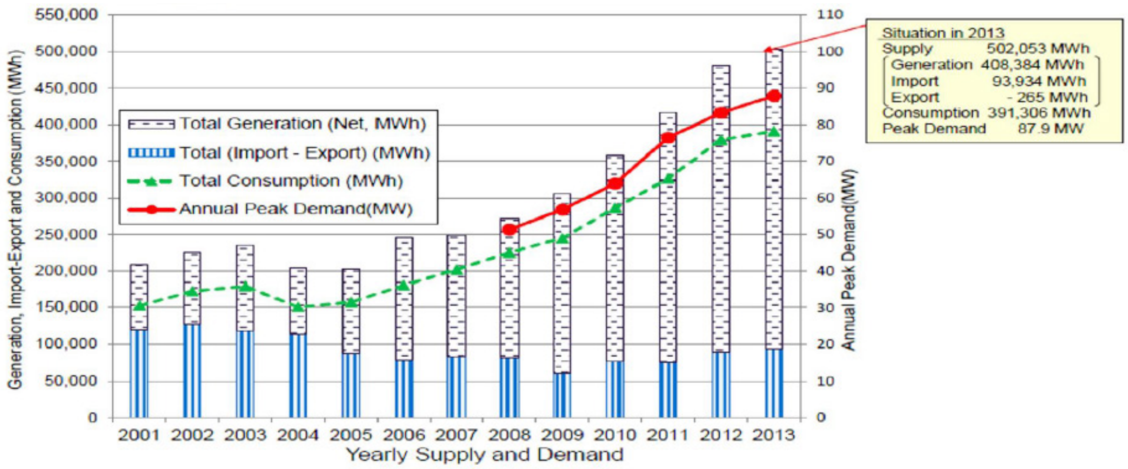

Fig. 5. Yearly energy supply and demand from 2001 to 2013 [15].

Table 1
Rwanda's Major river systems and corresponding basin extent [12]

	River system	Surface area (km^2)	Average rainfall (mm)	Location
1	Nyabarongo upstream	2700	1500	Northern highlands
2	Nyabarongo downstream	4450	1200	Central plateau and South-Eastern plains
3	Rusizi	650	1300	South-Western parts draining into L. Kivu
4	Sebeya	300	1400	North-Western parts draining into L. Kivu
5	Mukungwa	1500	1300	Northern parts
6	Akanyaru upstream	2650	1200	
7	Kagera upstream	5000	900	
8	Akagera downstream	4550	800	
9	Muvumba	1450	1000	North Eastern part; drains into Akagera river and the Akagera protected area lakes
10	Mulindi	200	1100	Northern province

affordable and enough energy to the demand. A comfortable environment has to be created to facilitate and motivate private sector to invest in energy sector [15] .

To protect the consumers from excessively high prices, the government subsidizes the energy sector with 43% of revenues taken from the energy utility returns [17]. Note that the energy sector in Rwanda is monopolized by the government.

Different policies in water sector have been set to increase access to clean water and ensure affordable and reliable supply of water in both rural and urban areas. Capacity building is planned to be developed for ensuring suitable maintenance and functionality of installed infrastructure. The development of adequate management structure of water resources and development of storm water management to alleviate their impact on environment and population have been considered to be handled in the set policies [13].

5. Main water and energy sources

Rwanda's water is available in four forms; rainfall, surface water bodies, ground water aquifers and wetlands. The main form of water source by which Rwanda's ground water aquifers and surface water are recharged through is precipitation. Rwanda receives annual renewable water of 9.5 billion m^3, with a per capita renewable water of 977.3 m^3/y compared to 4008 m^3/y of Africa's per capita renewable water. Thus Rwanda being among the countries provided with the lowest water in Africa (Table 1) [12].

About 22,000 of ground water resources were discovered with a discharge of 66 m^3/s. However the exploitation of these resources still faces different challenges that hinder their management. The nature, physical and geo-chemical characteristics, discharge capacities of the aquifers and main recharge areas have to be found. Besides that, there must be an assessment of the quality of ground water aquifers, which is still unknown, as well as the functionality of the existing infrastructure [12] .

6. Conclusion and recommendations

Water and energy are two inseparable and interdependent sectors whose fluctuations are correlated to each other.

Due to that interdependency, it is more effective to deal with the development of both sectors together rather than focusing on each one apart. This is proved by the fact that the fail in production of one of those two sectors influences the production of the other. This often results in crisis of both sectors and sometimes stimulates the rise in cost for the utility to be able to fill the gap through alternative technologies in order to meet demand.

To attain a sustainable development economically, socially and environmentally there might be enough supply in energy and clean water at affordable prices to ensure the well-being of the population.

In order to avoid the use of water and energy resources at a rate higher than their replenishment, measures to enhance water use and energy efficiency should be incorporated and sensitized to the population for the sustainability of those resources.

Even though developing countries' contribution to greenhouse gas emissions that led to climate change is little, but renewable energy technologies should more developed than fossil fuel for the sake of water and energy cost reduction and green economy development. Note that Rwanda does not have relevant potential in fossil fuels, it is of great interest to focus more on the use of available resources, like hydro, biogas and solar, by integrating energy mix of alternative technologies. This would lead to meet the demand, reduce the shortage of water and electricity and reduce the overdependence use of traditional biomass. The use of improved cooking stoves has to be more sensitized and lower their cost in order to reduce the rate of deforestation and save the environment.

Household wastewater should be treated and reused for irrigation and recharge surface water recharge to avoid environment pollution with wastewater and to boost water conservation and recycling.

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