Sustainability in Energy and Buildings: Research Advances ISSN 2054-3743
Vol. 5. No. 1 : pp.11-20 : sebra16-002

An Approach to Lifecycle Design and Sustainable Management of Nigerian Water Infrastructure

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Abstract. Water is one of the essentialities of life and meeting water needs is one of the cardinal millennium development goals. However, many developing countries like Nigeria are struggling with the provision of adequate potable water for the inhabitants. This paper presents results of the study on possible solutions to potable water supply in Sango-Ota area of South-Western Nigeria. Causes of consumable water supply problems in the region were first examined through literature review and site visits to some water supply facilities in Sango-Ota. The framework for lifecycle design and sustainable management of water infrastructure reported in this paper was developed to address the main problems. The framework incorporated information gathered from the literature survey, note taken on the site visits to some water supply facilities in Sango-Ota, and interviews conducted with water stakeholders. The result of the study revealed a need for inclusiveness of all stakeholders and capacity building of the local technician for effective management of the system. A project is in the works for the demonstration of the framework and for its necessary upgrade. The sustainability principles based methodology is expected to facilitate systematic innovation in the design and management of water infrastructure in Nigeria. This would in turn result in adequate water supply services for the citizens.

Keywords: sustainable design; sustainable system, water supply infrastructure.

1 Introduction

Water is one of the main essentialities of life that human being cannot do without [Frohlich, 2001; Hanjra, et al, 2009; IFC, 2012; Ishaku et al, 2011]. Despite the enormity of the importance of water to life and for economic development, adequate water supply still remain elusive in many African countries [Akinwale, 2010; Bademosi, 2013; Mbaku, 2014; Okparaocha, 2014; Water.org, 2015]. Some people have to trek miles and spend hours to fetch water. Many people are suffering from waterborne diseases such as cholera due to consumption of unsafe water from unwholesome sources [IFC, 2012; Schaetti et al, 2013]. Consequently, a lot of effort has been made both locally and by many development agencies to provide this basic necessity of life.

adfa, p. 1, 2011.

1.1 History of Water Infrastructure Management in Nigeria

Governments at the Federal, State and Local levels as well as International Agencies have put in concerted effort at developing water infrastructure required for abundant supply of water for the populace. Billions of dollars has been invested either in form of loans or subsidy to fund the development of water facilities in Nigeria since its independence in 1960. However, according to the World Bank, many of these water supply facilities "rarely operate to capacity due to broken down equipment, or lack of power or fuel for pumping. As of 2000, about 80% of all government-owned water systems in small towns were non-operational" [World Bank, 2010]. Other reasons include costly error on the part of policy makers, developers and aid agencies by overlooking the socio-cultural factors that could affect the smooth running and effective management of the water supply facilities. Interdependency of some systems is often overlooked, resulting in the failure of projects due to non-availability of crucial resources needed for its maintenance. Most of the failed water projects are mega projects whose scales are beyond the technical management capability of the local people shouldered with the responsibility of managing them. In addition, the locals are in many cases not adequately trained on the "nitty gritty" of what it takes to operate, maintain and repair the system when the need arises. Therefore, to stop the failure trend, there is a need for reengineering of water infrastructural development process. The kind of reengineering needed is collaborative sustainable design process that would involve all the stakeholders, including those for whom the project is intended.

1.2 Necessity for Sustainable Design of Nigerian Water Infrastructure

Sustainability is a concept of meeting the current need without jeopardizing the future generations' capability of meeting their own needs [Bruntland, 1987]. It is an approach to meeting the current need with the future in mind. While this is a generally acceptable concept, there remain significant gaps on the approaches to operationalising in many sectors of the economy especially in developing countries like Nigeria where majority are struggling to make the ends meet.
Although the approach to design is essentially traditional whereby the design focus is basically on functionality, cost and aesthetics, the failure of traditional design based facilities that dots the entire Nigerian landscape is a pointer to the need for reassessment and to the need to do things differently. The world bank statement that " As of 2000, about 80% of all government-owned water systems in small towns were non-operational " is an eye opener and a good pointer to the need for a different approach. A new design approach that enables incorporation of technical, economic, institutional, environmental and socio-cultural factors into design is sustainable design.

2 The Methodology

A thorough literature review of water supply in Sub-Saharan countries of Africa was undertaken. The purpose was to articulate historical trend in water infrastructure development from the colonial era to date. It was also aimed at discovering challenges faced with water supply in the continent. Furthermore, the goal of the review was to identify water supply infrastructure development and management challenges encountered, how they were addressed, and the outcomes.

Site visits to some water supply facilities in Sango-Ota were also undertaken with the aim of collecting information from the stakeholders. Informal interviews were conducted with some water facility operators and their clients. The visits also provided opportunities to observe and assess operational situation at the facilities visited. Moreover, the site visits enables one to articulate various water supply systems in use and differences in their infrastructures. It also provided a platform for subsequent analysis of infrastructural impacts on the efficiency of water supply services to the populace.

Some of the sustainability principles incorporarted in the framework include design for disassembly, resusability, recyclability, and the use of renewable materials and minimization of waste along the entire lifecycle of the water system..

3 Results

3.1 Water Supply Systems Infrastructure Problems in Sub-Sahara Africa

The study revealed that a number of the water projects were successful while many of them were not. Several reasons were advanced for the failure of water investments in Africa. Among the reasons are poor planning, inadequate funding, carelessness, and adoption of inadequate technology which failed to meet the local needs and didn't fit into the local culture [Ishaku et al, 2011; Kelly, 2009; Marks et al, 2014; Perkins, 2008; Pottas, 2014]. Other reasons include poor maintenance culture, political instability and lack of continuity of water policy. Some other problems include improper sizing of the facilities, corruption and vandalism. There is therefore a need for re-engineering.

3.2 The Lifecycle Design and Sustainable Management Approach to Municipal Based Water Supply System in Nigeria

It is clear from the ongoing discussion that there is a need for water infrastructure design that considers the social lives of the people for whom the facility is intended. The water system would also have to be self sustaining without causing any damage to the environment where it is deployed. In other words, socio-economic and ecological sustainability of the project have to be considered in the course of its development. Sustainability concept can be incorporated in the water supply system by de-

signing the system and its component parts for sustainability. Figure 1 is an illustration of various sustainable design concepts that need to be harmonized for a sustainable water supply infrastructure design. These design concepts include Design for Assembly and Disassembly, Design for simplicity and reliability, Design for manufacturing and remanufacturing, Design for Cost, and Design for Reuse and Upgrading. Furthermore, sustainable material selection for the system's hardware manufacturing, resource consumption minimization during system operational life as well as lifecycle extendibility are other things that would need to be put into consideration in the process of designing the water infrastructure for sustainability. This would ensure that sustainability is incorporated at the design, manufacturing, utilization and end-of-life management stages of the water supply facility's lifecycle. In designing a water supply system for sustainability, the energy requirement of the system and the source(s) of the energy need to be assessed and factored into the design. This is necessary in order to ensure availability and reliability of the requisite energy for the water system operation.

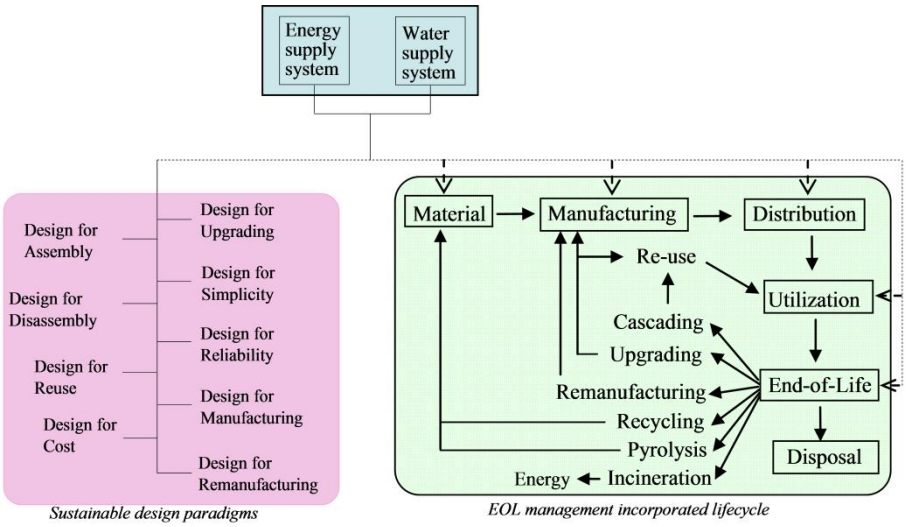

Fig. 1. An illustration of where sustainability can be incorporated
[Source: Dunmade, 2015]

Figure 2 is an illustration of the lifecycle design and sustainable management framework developed as a result of the study. It is a multi-stakeholders' collaborative/participative approach. An application of the lifecycle design and sustainable management based water supply infrastructure development model would start with the assemblage of coalition partners. Their first assignment would be to identify credible water needs of the community and to articulate their groups' interests in the project. The next step involves making arrangement for how the needs will be addressed. This would be achieved through an evaluation of existing policies suitability and possible reformulation of such policy to facilitate incorporation of innovative approach

if/when necessary. This is expected to be followed by an assessment of water sources and their conditions in the locality, utilizable options, required energy and affordability. The next step would be generation of conceptual designs and applying various lifecycle design concepts (DFXs) on the conceptual designs. DFX refers to design for X where X could be material (DFMt), modularity (DFMd), assembly (DFMA), manufacturability (DFMf), disassemblability (DFD), maintainability (DFS), use and reuse (DFUR), upgradability (DFUG), remanufacturability (DFRm), recyclability (DFR), energy efficiency (DFEE), minimum residue (DFMR) and so on. Each conceptual design is then evaluated in turn for environmental friendliness by using E-LCA.

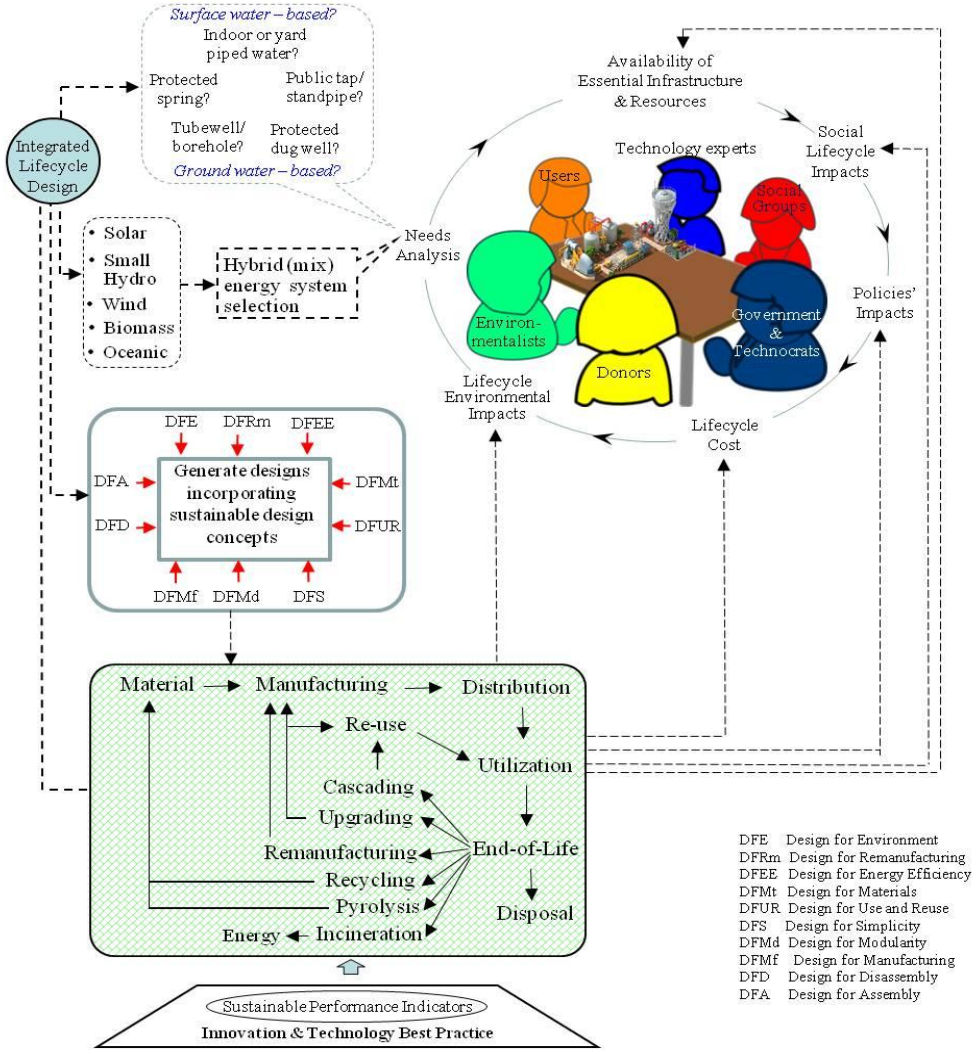

Fig. 2. An illustration of Lifecycle design and sustainable management based water supply system infrastructure [source: developed from literature review, interviews and knowledge acquired from previous sustainability projects]

They are also subjected to socio-cultural compatibility assessment (SCA), risk assessment (RA) and economic assessments (LCC). Further details on how these sustainability assessment concepts are applied from the system lifecycle stage of conceptual design options screening through to the prototype development and testing stage can be found in Dunmade (2010).

Assurance of sustainability of the water system infrastructure thus developed would be enhanced by building the capacity of local technicians in all the lifecycle design and sustainability assessment areas, and by incorporating continuous monitoring mechanism into the system in order to facilitate future improvement on the performance of the water supply system. The monitoring would include all the stages of design and development, utilization, maintenance, and end-of-life management. Taking these steps would result in a water supply system that is not only affordable but also appropriate for the level of technological knowhow of the community where it is deployed. It would also facilitate continuous adaptation of the water supply system to changes in the social, economic, environmental and technological situation of the locality.

The model is considered to be a viable design and management framework that would yield an appropriate and sustainable water infrastructure development for Nigeria.

4 Sustainable Water Infrastructure Design Implementation Benefits and Challenges

The sustainable principles based collaborative water infrastructure design and management has a lot of benefits. However, its implementation also has many challenges that must be overcome before the benefits can be achieved.

4.1. Potential Benefits of the Collaborative Sustainable Water Supply System Design Approach

This design approach facilitates improved understanding among the stakeholders because everyone is involved as participants right from the beginning through to the end of the project lifecycle. It also instills sense of co-ownership of the system by the stakeholders. Furthermore, developers would have first hand information and local factors that are essential for the success of the project and thereby incorporate such factors into the design of the system. Moreover, the local people and policy makers would be able to provide enabling environment for the smooth running of the system because they were involved in the evolution of the project. Such collaboration would

also enable the developer to scale the systems to what is needed and to adapt the design in line with the socio-cultural orientation of the consumers.

Moreover, designing Nigerian water infrastructure for sustainability would improve availability of potable water to the community. It will also result in the development of technical know-how of the local technicians. Furthermore it will reduce wastefulness in investment, and eliminate psychological and social problems associated with disappointments that come when project fails. It would lead to increased economic activities in the area, improve public health and reduce ecological damage. Consequently it would result in the improvement of the overall standard of living of the communities where the facilities are sited [Dunmade, 2001, 2002, 2010, 2014; Esposto, 2009; Kees, 2014; Klöpffer, 2003; Levin, 2011].

4.2. Possible Challenges in the Sustainable Water Infrastructure Design Implementation

Development and management of Nigerian Water Infrastructure for Sustainability may involve a number of risks and may face many challenges. Some of the challenges include the current lack of sustainable design knowledge, tenacious adherence to conventional /traditional approaches to infrastructure management, and the degree of willingness to learn the new "rope". Other challenges include the huge cost of “settling” the locals whenever new project would have to be undertaken in their region and how to wean them from personal aggrandizement and take ownership of the new system. Overcoming these challenges would require tact, consistency and patience in the process of educating the "unruly stakeholders" and managing incidences along the collaborative sustainable design and development process

5 Conclusion

A framework for lifecycle design and sustainable management of water supply infrastructure in Nigeria was presented. It provided another perspective on how water supply problems in Nigerian could be addressed. It also highlighted some potential hick-ups along the implementation line and how they could be addressed. It is believed that the proposed municipal scale lifecycle sustainability concept based integrated energy and water supply system would be found helpful in solving both electrical energy and potable water supply problems in Africa and beyond. Further research work on this topic involving the development of experimental and pilot scale water system has already started. This would facilitate real life application of the system design concept and lead to improvement in the management process. All things being equal, sustainable water supply will go a long way in improving the standard of living of people in many rural and urban municipalities in Nigeria in other countries of Africa that may choose to adopt the same approach in the future.

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