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Research Article

APPLYING SUSTAINABLE ARCHITECTURE IN A RESEARCH REACTOR DESIGN

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ABSTRACT
Sustainability consists of three main goals which are economic, social and environmental optimization. Sustainability is inconsistent with the negative impact of various developments on the environment. Sustainable design should be in a manner to fulfill the requirements of people without threating the future generation's life. Research reactors are industrial complexes and play an important role in the development of today's society which is critical facilities to expand nuclear technology for peaceful applications and for socio-economic development. They should be built near the research centers; therefore, research reactors usually locate in urban spaces. Strength and performance assessment of research reactor is essential due to the fact that it contains hazardous radioactive materials. These nuclear installations comprise various buildings. Generally selecting an appropriate material and also construction style for vital structures due to their function and special geometry, play an important role in sustainability of a research reactor (RR) project. Besides, their site selection is a critical item to achieve sustainability requirements. Also reducing the risks and hazards by an adequate design in different aspects is a reasonable way to reach the sustainable development. Consequently, architects should take into account the different aspects of sustainability to align with its goals. This study aims to present some practical recommendations to expand the sustainability of a research reactor. This paper makes available background information regarding the document and the strategy developed to design a sustainable research reactor.

***Keywords**: Sustainability, Research Reactor, Internal Hazards, External Hazards*

INTRODUCTION

The World Commission on Environment and Development has put forth a definition of "sustainability" as meeting the needs of the present without compromising the ability of future generations to meet their own needs (London: Oxford University Press, 1987)" (Kim, 1998). Three main areas of sustainable development are shown in Figure 1.

The term sustainability in construction industry is not just applied in products, but also in construction strategies, building design and orientation, landscaping, building operations, maintenance, and so forth. The less impact a building has on human health and the environment, the more green it is (Satterfield, 2009). Impacts of energy utilization in buildings should be considered in their whole life cycle from early design stage till demolition stage.

Ventilation, lighting and air quality are major criteria in order to have a sustainable building. In such sustainable cases, we should increase application of clean and natural resources. Usage of renewal energies such as wind, sun and planting has a vital role in reduction of pollutant and consequently climatic changes (Todorovic, 2012).

Research reactors are critical facilities to expand nuclear technology for peaceful applications and for socio-economic development**.** "A research reactor project is a major undertaking requiring careful planning, preparation and investment in time, money, and human resources. It requires strict attention to nuclear safety, international safeguards, nuclear security, and the control and accounting of nuclear materials" (IAEA, 2012). A research reactor site layout of vital areas is shown in Figure 2.

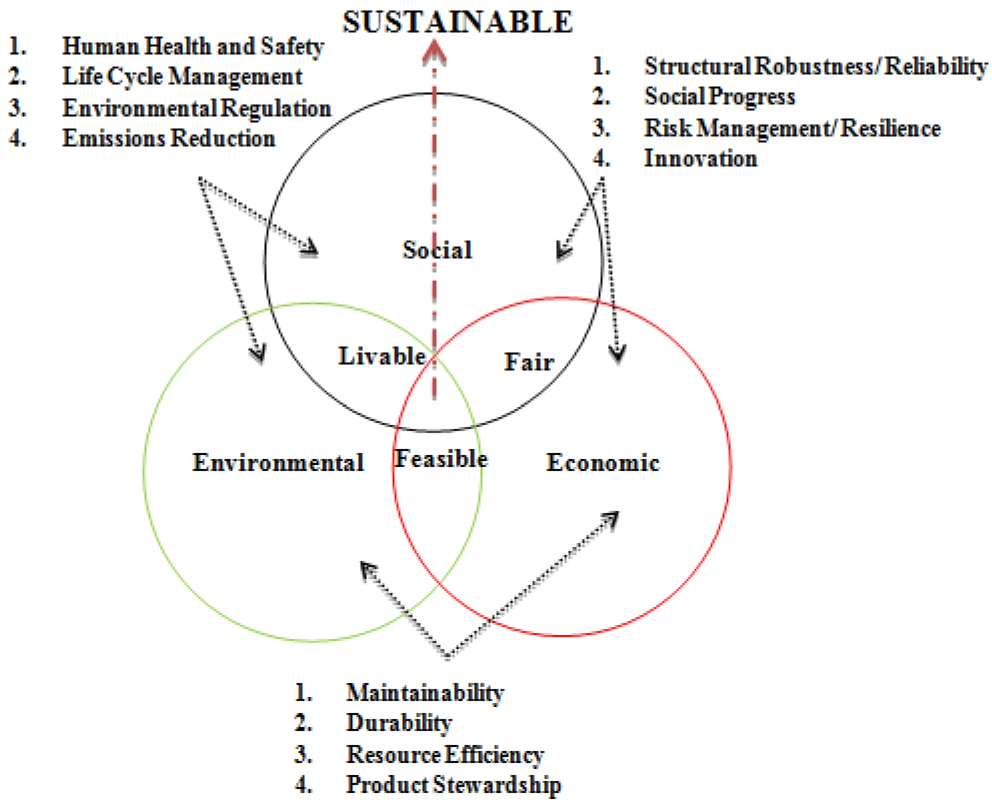

Figure 1: Three main areas of sustainable development (Menna *et al.*, 2012)

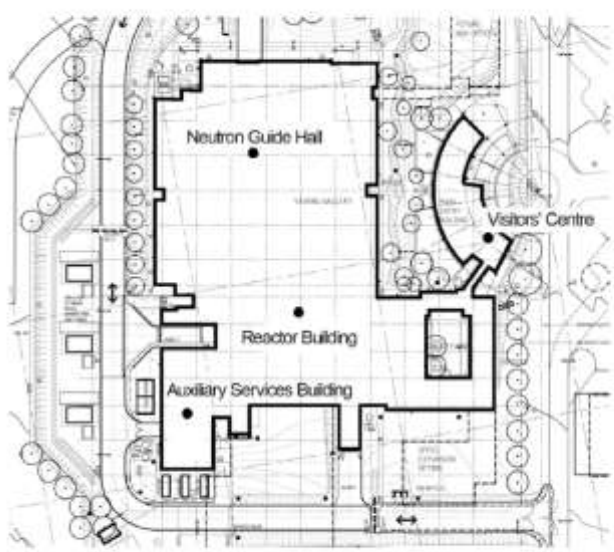

Figure 2: Site Plan of Lucas Heights Research Reactor Facility (Evans *et al.*, 2014)

The reactor containment which is the most important building of a research reactor complex, enclosing the reactor vessel (Figure 3) comprises physical barriers reflecting the safety design and construction codes, regulations and standards so as to prevent the community and the environment from uncontrolled release of radioactive materials. It is the third and the last barrier against radioactivity release. It protects the reactor vessel from such external events as earthquake and aircraft crash as well (INVAP, 2004;

Hessheimer and Dameron, 2006; Lundqvista and Nilsson, 2011; Hu and Liang, 2000). Safety and security considerations in a building design are crucial factors to increase sustainability. Safety and durability evaluation of the research reactor containment is non-negligible and it should be assessed against all probable internal and external hazards. Building durability, proper site selection and applying an aging management plan (AMP) improve building and environment quality. Assessing the various buildings of a research reactor against all kinds of loads can be performed by finite element methods. Designing a more reliable and resistant building results in a more sustainable structure. More than aforementioned items, one of today life's negative characteristics is reduction of people's cooperation in designing their living environment. This study aims to consider some of these issues to conduct a research reactor project toward sustainability.

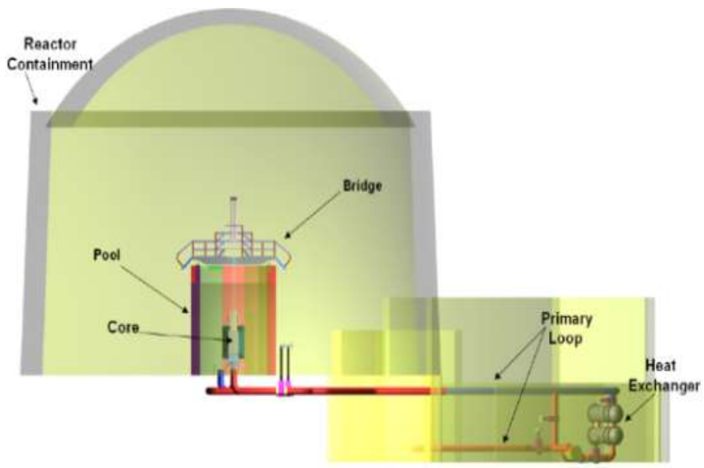

Figure 3: Schematics of containment building (Gharib, 2006)

RESULTS AND DISCUSSION

Building Durability

While an internal or external hazard occurs, less damage leads to less required costs, less human resources for the purpose of reconstruction, in addition, less material waste, therefore, this trend is more sustainable environmentally and economically. Besides, this approach causes more public acceptances of industrial buildings and increases the safety and security of people which are essential criteria for social sustainability.

Aging Management Plan

Aging is defined as a general process in which characteristics of systems, structures and components (SSCs) gradually change with time or use. The abnormality of SSCs may result in enlarged risks if it is not duly curbed or diminished. The process of aging contains gradual changes in quality and properties of SSCs with time even during the normal operation of the reactor. Aging may cause degradation of functional and performance properties, change of material properties, and degradation of structures' reliability (Nitoi, 2008; Rónaky, 2007; Kharpate, 2005; IAEA, 1995; IAEA, 2010b). There may be two kinds of time dependent changes in aging of a RR. One has to with degradation of SSCs that cause changes in the physical characteristics. The other is the obsolescence of SSCs when compared to the current regulations, standards and technologies (IAEA, 1995; IAEA, 2010a).

Development of an aging management plan (AMP) is a vital contributor to maintaining the reactor safety and controlling the risk of degradation of the concrete reactor building (Aldea *et al.*, 2011; Naus, 2009). The AMP aims to determine the requisites for specific structural concrete components of the reactor building that entail regular inspections and maintenance to ensure safe and reliable operation of the plant (ACI, 2008).

The safety of a RR necessitates the provision which is made in its design to facilitate aging management. Aging management of RR's structures is one of the vital factors to safety, to ensure continued adequacy of the safety level, reliable operation of the reactor, and compliance with the operational limits and conditions (IAEA, 2010a).
The AMP is applied to the reactor building structure, but it does not include the internal components of the structure. The environmental conditions include climatic conditions such as humidity, frost and winds as well as site conditions such as salinity, sand, dust or chemical agents. They are all considered in AMP. All the effects of these conditions are considered as corrosion, erosion or undesirable chemical reactions occurring at the equipment exposed to such conditions. Routine observation, general visual inspections, leakage rate tests, and destructive and nondestructive examinations are done to identify areas of the RR degradation (Naus, 2009).

Design for Maintainability

One of the items which should be considered in the architectural design of a research reactor is design in a way to ease physical access to components for repairs and maintenance without disturbing accessibility and also stability and use redundant structures if applicable and reasonable (IAEA, 2008).

Site Selection and Site Layout

Principles for a site-related layout protected from severe accidents including an unfavorable potential for event is to avoid radiological hazards from occurrences same as and even less than the design basis; and to make certain that the risk accrued by the possible exposed people from greater occurrences is retained at a satisfactorily small amount (IAEA, 1987).

Site selection as well as investigation is an essential area of a research reactor construction that could considerably have an impact on expenses and also community acceptance. Site studies are required to figure out the accessibility in addition to appropriateness of potential locations. Basic evaluations need to originally categorize and priorities potential sites in order of value by some requirements reflective of domestic and social concerns, which includes the safety and nuclear security aspects (locality of populated zones, surrounding area agriculture or even further field of activities, etc.). Since the research reactor project creation progresses, sites needs to be lessened to those most affordable along with the final site elected for characterization for the bid specification. The preferred location must be protected at an early time to guarantee its accessibility as well as integrity. Site evaluations could be subdivided into a few particular stages:

- Regional examination and recognition of potential sites;
- Screening of potential sites and also selection of potential candidate sites;
- Comparison of candidate sites (IAEA, 2012).

The siting, layout , manufacturing, operation and decommissioning of the Reactor Facility necessitates an upgraded information together with investigation of site properties that influence the facility's safety and any possible health and safety impacts.

The design and functionality of the Reactor Facility consider site capabilities that can influence the safety of the facility. These site characteristics consist of:

a) The site's population distribution and current population areas, seismology, geology, topography, ecology, hydrology, and also meteorology.

b) Neighboring facilities and territory application.

c) Offsite and onsite services including electrical power, water, transportation, and communication systems

d) Additional features related to the feasibility of emergency response (INVAP, 2004).

Practical Recommendations

Some practical recommendations to expand sustainability of research reactors are mentioned in Table 1.

Table 1: Practical recommendations to fulfill various aspects of sustainability in a research reactor

Factor	Practical Recommendations
Maintainability	• - Selecting proper distances among buildings • - Design maintenance and equipment hatch • - Using Underground routs • - Equipped repair stores • - Using proper vegetation
Durability	• - Classification of buildings • - Proper material selection • - Appropriate drainage systems • - Applying finite element methods for structural analysis • - Simplify the design • - Proper site selection • - Proper site layout
Resource efficiency	• - Reuse the produced heat in various systems • - Using natural resources • - Proper isolation of buildings • - Using recyclable materials • - Using roof top solar panels and • photovoltaic cells in administration buildings if applicable • - Using natural water circulation if applicable
Product Stewardship	• - Testing removals
Structural Robustness/ Reliability	• - Applying finite element methods for structural analysis • - Using proper standoff distances
Social Progress	• - People contribution in the design of complex • - Investigation of the neighborhoods
Risk Management/ Resilience	• - Considering views toward the site • - Measure various possible risks • - Proper site selection • - Applying passive defense considerations
Innovation	• - Applying all facilities and opportunities of the site and neighborhoods • - Using recyclable materials for various affairs • - Applying nontoxic materials
Human Health and Safety	• - Classification of systems, structures and components. • - Proper site layout • - Proper building height • - Local population demographics and distribution
Life Cycle Management	• - Having the future expansion ability
Environmental Regulation	• - Paying attention to nature of the site • - Paying attention to natural threats
Emission Reduction	• - Sewage and waste recycling • - Solar energy usage • - Natural ventilation usage

Conclusion

To wrap it up it should be mentioned that applying sustainable criteria in the design of a research reactor complex which contains radioactive material, can improve its environmental, economic and social aspects. This leads to a more safe and secure nuclear installation. In addition, it also results in society acceptance growth. The sustainability improvement recommendations should be practical and designers should apply all potential natural and man induced opportunities for their final goals. These practical recommendations can influence all the stages of a project. They can impact in site selection, site preparation, design, site layout construction and commissioning of a research reactor project.

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