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Sustainable Parameters for Residential Building Design in Kathmandu

By

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **" Sustainable Parameters for Residential Building Design in Kathmandu"** submitted by **Samisha Adhikari(076March016)** in partial fulfillment of the requirements for the degree of Masters in Architecture.

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DECLARATION

I hereby declare that the thesis entitled Sustainable Parameters for Residential Building Design In Kathmandu which is being submitted to the Department of Architecture, Pulchowk Campus, Institute of engineering, Tribhuvan University in partial fulfilment of the requirements for the degree of Masters in Architecture (M.Arch.) is a research work carried out by me, under the supervision of Prof. Dr. Sushil Bajracharya, between start date to completion date. I declare that the work is my own and has not been submitted for a degree of another University.

ABSTRACT

The industrial revolution has accelerated the modernization and growth of technology in the developed world and developing world. It has brought about the need to house humans for their sustenance and desire to expand their comfort to a new level. With the increase in economic development and economic status of people in developing countries, demands for architectural resources like land, buildings or building products, energy and other resources augments too. There is no proper system to check sustainable parameters in Nepal. This project is focused on to study upon environmental, social & economical sustainable parameters in national residential building context by analysis various sustainable parameters. Then, analysis of residential building with SVAGRIHA rating system of India because in Nepal there is lack of proper rating system manually upon these residence. This project also seek for explore on ecologically responsive architecture (ERAG) proposed by SONA.

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CHAPTER 1. INTRODUCTION

1.1 Background

Oxford dictionary explains sustainable means able to be sustain at a convinced rate or level. An inexperienced constructing is an outcome of a design philosophy which makes a specialty of increasing the efficiency of useful natural resource that can be use strength, air, water, and materials while lowering building effects on human health and the environment during the building's lifecycle, through better siting, design, construction, operation, maintenance and removal (Srinivas, 2015). Sustainability is the concept which promotes upon long term development through proper utilization of natural resources. Sustainable parameters of green building performance can be further classified into environmental, economic and social measures (Mishra, 2017).

Sustainability is defined by the World Commission on Environment and Development as assembly the desires of nowadays without adjusting upon human daily lifestyle and various activities on the potential of destiny generations to meet their own wishes. Sustainable building had been analyzed upon that type of building which totally incorporated; with the "whole building" approach to layout, creation, and operation (Thapa & Tiwari, 2020). Sustainable homes also are known as green buildings which has good approaches upon the various aspects of sustainability that gives on sides of various offer ideal environmental and monetary overall performance; increase efficiencies thereby saving electricity, water, and other assets; furnish satisfying, productive, and quality indoor spaces; use environmentally preferable materials; and educate building occupants about efficiency and conservation (Ramli & Masri, 2012).

Nepal is one of the least developed countries in the world located between two emerging economic giants of the present world - India and China. There is a nation with rich and vibrant history and blessed by nature in its diverse topographical features from the high mountain ranges of the Himalayas to the low-lying flat lands of Terai (Tuladhar, 2011).Also accord Tuladhar, Nepal government is short-term firefighting solutions rather than to focus on long-term sustainable plans and policy like lack of the government's policy and interest in the sustainable development in country context.

My national study area belongs to Kathmandu, Kathmandu is a historic city. The industrial revolution has accelerated the modernization and growth of technology in the developed

world and developing world. It has brought about the need to house humans for their sustenance and desire to expand their comfort to a new level (Tuladhar, 2011). With the increase in economic development and economic status of people in developing countries, demands for architectural resources like land, buildings or building products, energy, and other resources augments too (kim. & Rigdon, 2003). The issues of climate change have come to the forefront and have become topic of hot debate among scientist, researchers, policy makers and governments. Therefore, the need to maintain the fundamental ecological balance between nature and man-made environment, and sustainable building practice is emerging. Sustainable building design approach for mitigating the problems caused by the extensive use of toxic and environmentally unsustainable materials have resulted in finding newer approaches to design and construction of buildings (Tuladhar, 2011). In this project work main aim to study upon sustainable parameters in sustainable building in national and international context on environmental aspect to find upon how much these buildings are sustainable. Also, after SVAGRIHA analysis there is quantitative analysis on ERAG purposed by SONA & to draw some parameters for quantitative analysis of residential building of Kathmandu.

1.2 Need of the Research

Sustainability is all approximately the usage of the assets of nowadays correctly, in a manner that meets our personal wishes, however doesn't compromise the potential of others to fulfill their personal wishes inside the destiny in the future for coming days (Shakya, 2015). The United Nation Environment Program estimates that buildings consume about 40% of the world global energy, 25% of the global water, 40% of the global resources; buildings are also responsible of about 1/3 of greenhouse gas emissions of the whole planet also similar values were observed by studies performed by the U.S. Department of Energy (Asdrubali, Alessandro, & Schianoni, 2015). Sustainable development considers upon making building efficient without compromising upon functions. People are still moving towards concrete construction in the name of modernization and development (Thapa & Tiwari, 2020). While taking about Nepal, very few building had considered upon sustainable parameters while designing therefore it is necessary for researcher to make people know upon sustainability and sustainable parameters. Environment needs protection against ill effects of rapid construction (Mishra, 2017). Because of growing population and use of energy we have to choose upon

sustainable parameters. From this study, we would able to know on important factors of sustainable building and positive aspects: economic and environmental aspect than of normal building.

1.3 Rationale of the Research

The temperature of Nepal is warming at the rate faster than that of the global average (Bhusal, 2021). There are also other climatic elements are being changing drastically. There are consideration upon very few things upon sustainability. In Nepal, energy demand is more but the energy supply is less, country is facing the energy crisis and for the optimizing the energy demand, residential building consume large of energy for the daily use therefore it must initiate to reduce energy consumption, on various daily activities are been used upon it (Shakya, 2015). To reduce use of power call in present context to upcoming days also to future generation for and make balance between energy supply and call for, it's miles critical to take a look at upon sustainable parameters that gives concept upon why it's miles vital upon selection of sustainable parameters while designing residence in Kathmandu.

1.4 Problem Statement

In Nepal, there is a layout and construction of green homes are nevertheless taken into consideration to be now not so commonplace and most of the customers/builders are not privy to the effectiveness and performance of those kind of buildings (Mishra, 2017). That green/sustainable concept is familiar in international developing and developed country, although this concept is not much familiar in our country context. The influence of modern building construction technology over the locally available materials and techniques might be one the main reason for slow implementation of choosing sustainable building construction (Thapa & Tiwari, 2020). Also, there is no such strike building rules and regulations in our country context. So, might be that is a reasons why users of residence are less focused in sustainable parameters for building construction. Thus, we have support on existing sustainable parameters contains building and make people know upon sustainable residence construction. Study of sustainable parameters in national and international context could help people to understand more about outputs of sustainable building in more practical manner.

1.5 Research Objectives

In Nepali context sustainable practice is not common, there is less initiation on green building practice. Main aim of this research is to study upon sustainable building by comparing upon sustainable parameters. To study upon environmental, economical & social sustainable parameters upon residence building and check these building through SVAGRIHA rating system. After analyzed on these parameters, there is explore on ERAG which had been begun in early and had not continued till now.

Primary objectives:

1. To study upon sustainable parameters: environmental, economical & social aspect of residential building in national context.
2. To do SVAGRIHA rating system of residence of Kathmandu.
3. To explore on ecologically responsive architecture guide (ERAG) system purposed by SONA.

1.6 Validity of Research

Validity refers to how well an instrument has measured what it is intended to measure (BRM, n.d.). With over 70% of the world population projected to live in urban areas by 2030, the role of cities in sustainable development is gaining greater momentum (Komeily & Srinivasan, 2015). Sustainable city could only meets that future world population demand. Also according to Komeily Creating healthy and livable communities have become a priority in many regions, giving birth to several neighborhood sustainability assessment tools. In international context sustainable tools are in use however these tools are missing in Nepali context.

Sustainable tools gives ideas about green building, make people know about benefit of green building and promotes to use for their residence design. That research will show upon how much building are sustainable in the sense of environmental, economic & social aspects. Therefore, the research is valid since it fills the research gap and also will be helpful for future reference in context of Kathmandu.

1.7 Limitation of the study

Due to not available of proper rating system in our country context, the study building belongs to non-rated building of Nepal for case study. That means rating parameters are

not in use while studying sustainable parameters. As well as in this research limited national case study is done due to restricted time frame & there is restriction in sustainable parameters study.

CHAPTER 2. LITERATURE REVIEW

Literature review is done in order to understand and evaluate the existing level of knowledge and prior research done related to the topic. For this study, the literature review is done under the following study areas.

2.1 Sustainability

In latest years, sustainability idea has emerge as the not unusual interest of several disciplines. In context of architecture, Sustainability concept reflects Green architecture, development of architecture according to environmentally friendly (Ragheb & El-Shimy, 2015). Also, according to Amany Ragheba sustainability in case of building is to design, construct, operate and maintain buildings energy, water and new materials are utilized as well as limit the amounts of waste causing negative effects to health and environment generated and design environmentally sound and resource efficient buildings. There are three different dimensions of sustainability that are economy, environment and society.

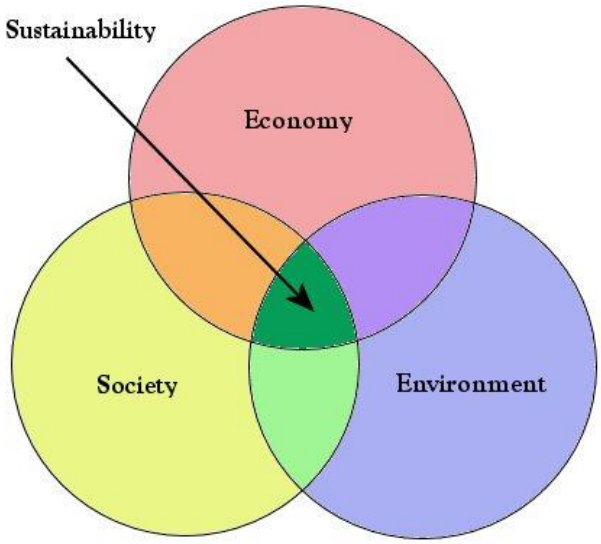


Figure 1: Sustainability pillar

(Parkin, 2003)

2.1.1 Environmental Sustainability

The priority for the nicely-being of the earth itself emerged in the Seventies, to start with targeted on natural resources and the human environment and later extended to the complex structures that guide existence on the planet for future use (Ruskin, 2002). The significance of the environmental size is evident by means of numerous feature the ecosphere offers: the "natural resources of the earth, together with the air, water, land, flower, fauna and herbal ecosystems" which "must be safeguarded for the benefit of present

and future generations (StockholmResilienceCentre, 2020)). Also according to Ruskin the public is concerned about human impacts on the atmosphere, land and water resources, the bioaccumulation of toxic substances, species loss and the degradation of ecosystems. Three broad criteria for ecological sustainability were described in 1990: renewable resources should provide a sustainable yield (the rate of harvest should not exceed the rate of regeneration); for non-renewable resources there should be equivalent development of renewable substitutes; waste generation should not exceed the assimilative capacity of the environment (Daly, 1990). Environmental measures focused on utilization of natural ecofriendly design.

Environmentally sustainability looks upon two aspects. First is the relatively new criterion of scale must now be added to the traditional criteria of allocation of resources and efficiency of use. Second, we must recognize that markets are almost invariably deficient as distributive mechanisms when natural resources are concerned (Daly H. , 1992). Environmental measures of an eco- pleasant building includes embodied power and carbon emission of the construction during production segment, strength intake at some stage in operational phase and recycling of substances all through dismantle section (Mishra, 2017). Ecologists and other biophysical scientists need to take more responsibility for leading the thinking on sustainable development and for seeing that efforts to achieve it are implemented promptly (Goodland, 1995). Additionally in keeping with Goodland ES it seeks to enhance human welfare with the aid of defensive the sources of uncooked materials used for human needs and ensuring that the sink for human wastes aren't handed, if you want to save you damage to people. Environmental sustainability measures mainly carries upon sustainable constructing from making plans segment to production phase to apply phase for users.

2.1.2 Economic Sustainability

Sustainability worries the specification of a fixed of movement to be taken by means of gift people so that it will no longer diminish the prospects of destiny persons to enjoy degree of consumption, wealth, utility, use for longer term approaches which gives higher life or welfare comparable of the various aspects to the ones enjoyed through gift people by using giving simpler for similarly uses facets (Bromley, 2008). Economic sustainability is the one of important pillar of sustainability is to pay concern upon economic performance by providing upon economic sustainability. That dimension seeks towards economical welfare for person for present and future scenario. According to Mpnbiot in recent years, the concept of doughnut economics has been developed by the British economist Kate Raworth to integrate social and environmental sustainability into economic thinking.

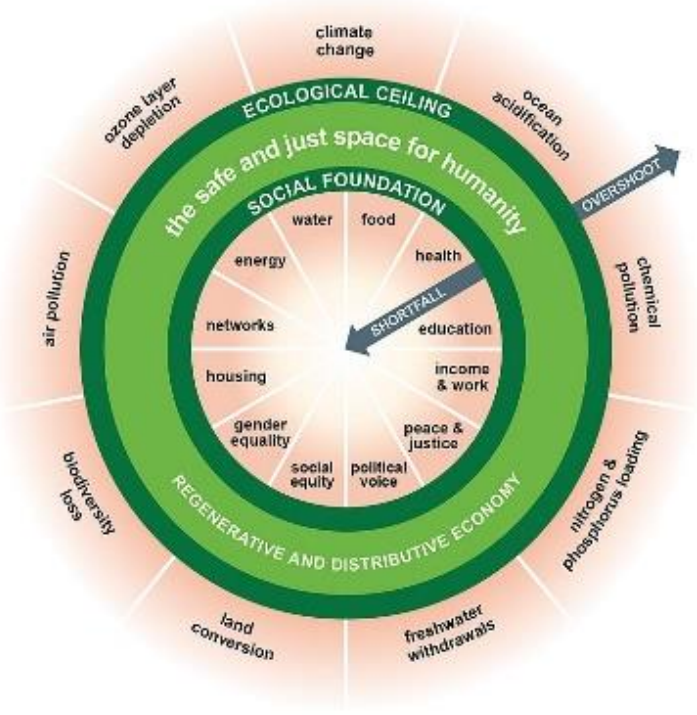


Figure 2: Doughnut Economics diagram

(Raworth, 2012)

Financial sustainability specializes in that portion of the herbal resource base that provides physical inputs, both renewable (e.g. forests) and exhaustible (e.g. minerals), into the manufacturing technique. Eco- Friendly buildings are said to be energy efficient which not only help to use the renewable energy sources but also save the certain monthly operational and maintenance cost (Mishra, 2017). Economic sustainability often tied to profitability has long been a regularly considered area of impact in product development, while environmental and social sustainability have not (McDonough, 2002). However, growing awareness of contemporary issues such as resource depletion, the circular economy and corporate social responsibility has caused various organizations to consider becoming more fully sustainable in their products, services, or operating practices, while

maintaining desirable economic performance (Bermejo, 2014). In case of economic sustainability many parameters of sustainable have to look upon it.

2.1.3 Social Sustainability

The idea of "social sustainability" in this technique encompasses such topics as: needed things for society which is required to live and work with in society such as social values, social equity, livability, fitness equity, community improvement, social capital, social assist; also there should be human rights, labor rights, location making, social duty, social justice, cultural competence, community resilience, community friendly resources and human model (McDonough, 2002). Sustainability have to give equal justice to all category of social beings. These domains of social sustainability are all established upon the connection among the social and the herbal, with the "ecological area" described as human embeddedness within the surroundings. In these terms, social sustainability encompasses all human activities (James, 2015). Fundamentally important though social sustainability is, environmental sustainability or maintenance of life-support systems is a prerequisite for social sustainability promptly (Goodland, 1995). Also, according to Goodland, poverty reduction has to come from qualitative development, from redistribution and sharing, from population stability, and from community sodality, rather than from throughput growth. All parameters are linked with each other for development.

In that breakdown, the concept of "monetary sustainability" specializes in the portion of natural sources that provide physical inputs for financial manufacturing, including each renewable and exhaustible inputs. The concept of "environmental sustainability" adds greater emphasis on the "life support systems," just like the atmosphere or soil that has to be maintained for economic production or human life to even occur. In contrast, social sustainability focuses on the human effects of economic systems, and so the category includes attempts to eradicate poverty and hunger, additionally on combat inequality (Goodland, 1995).

The sustainable improvement literature definitely advocates a triple-backside-line approach to sustainability (monetary, environmental, social sustainability). Because these three elements are intrinsically linked, decisions regarding anybody of them is best made within the context of all three elements together. The multi-objective optimization literature provides ways for the tradeoffs between interconnected objectives to be characterized, which lays the underside work for creating sustainability decisions while considering all

three sustainability elements together. Various work has been done that begins to link multi-objective optimization tools to the wants of sustainable design, yet the value of characterizing the sustainability space and using it for deciding in sustainable design has not been explored (Mattson, 2015). Economic, environmental and social sustainability are like pillar for all sustainability concept combination of these measures in proper way gives better sustainable society.

2.2 History of Sustainability

The Industrial Revolution added notable advances in generation like railroads, present day cities, and factories which all relied on electrical resources like oil and coal. These improvements all got here with rate: overpopulation, pollutants, disease. In reaction to those negative effects, a movement focused on sustainability and environmental protection grew (Rachelson, 2018). Historical development of sustainability concept are as follows:

Date	Events
1892	John Muir is usually called "the Father of National Parks." Muir is sometimes known for his work co-founding the Sierra Club in 1892.At the time, the Sierra Club was meant for lovers of the skin. Style of their early work focused on shielding Yosemite Park.
1901	In 1901, President Theodore Roosevelt became president. He was heavily influenced by naturalist. In the course of his presidency, he created the U. S. Forest provider and established one hundred fifty national forests, fifty-one federal chook reserves, four countrywide game reserves, five countrywide parks, and eighty one national monuments.
1949	After war II, the U.N. held the very first conservation conference. The U.N. Scientific Conference at the Conservation and usage of sources happened in 1949. Many experts from around the world gathered to debate how to conserve resources like land, water, wildlife, and energy.
1955	Congress enacted the pollution Act in 1955. This act simply focused on researching the results of pollution and didn't include other items for the govt. Or companies to influence.

Date	Events
1969	The country wide Environmental coverage Act (NEPA) changed into set up in 1969, as an effects of the developing sustainability movement. NEPA calls for all government federal companies to perform environmental tests and environmental effect statements.
1970	The National Environmental Policy Act (NEPA) was established in 1969, as a results of the growing sustainability movement. NEPA calls for all governmental federal agencies to perform environmental check and environmental impact statements.
1972	The Clean Water Act, administered by the EPA, was passed in 1972. Its focuses are on preventing pollution, improving wastewater treatment, and protecting the wetlands. In the same year, the U.N. held their Conference on the Human Environment. As a results of the conference, the U.N. Environment Programmer (UNEP) was formed.
1987	The Clean Water Act, administered by the EPA, was passed in 1972. Its focuses are on preventing pollution, improving wastewater treatment, and protecting the wetlands. In the same year, the U.N. held their Conference on the Human Environment. After the 1949 U.N. As a results of the conference, the U.N. Environment Programmer (UNEP) was formed.
1993	The evolution of "green brands" begin.
2015	The U.N. General Assembly published their Sustainable Development Goals. The goals are set to be carried out with the aid of the year 2030. Several of the 17 goals, like "Goal 6: Clean Water and Sanitation" and "Goal 7: Affordable and Clean Energy" focus on environmental sustainability issues (Rachelson, 2018).

2.3 Sustainable Architecture

Sustainable architecture is supposed to cut back the impact of the built environment on human health and so the natural environment by efficiently using energy, water, and other resources, protecting occupant health and improving employee productivity and Reducing waste, pollution and environmental degradation (Srinivas, 2015).

Figure 3: Sustainable building

(Vincent callebaut solent news, 2011)

Sustainable architecture promotes upon efficiently use of natural resources. Sustainable and eco-friendly architecture is one of the most aims that humans for creating an improved life have made because the ultimate model for all their activities. For this reason, moving towards a greener architecture is well-thought-out the most goal of the current architecture of our time (Mohammadjavad, 2014). A movement in architectural and building circles geared toward creating structures that are occupant and environmentally friendly. Criteria like sustainability, energy efficiency and healthfulness are considered. Also consisting to Srinivas, Sustainable design refers to such characteristics as a lowering of demands on the environment as a result of certain building characteristics: Low energy usage; reduced water usage; carbon neutral (i.e. no CO2 emissions result from property operations – either directly, or indirectly).Green or sustainable, constructing is that the practice of making and use healthier and greater useful resource efficient models of creation, upkeep, operation, protection and demolition (Roy, 2008). By lowering on energy demand green building provides heathier living comfort for user.

2.4 Green Architecture

Green architecture, or green design, is an approach to assembling that minimizes harmful effects on human health and therefore the environment (Ragheb & El-Shimy, 2015).The "green" architect attempts to guard air, water and earth by choosing constructing substance and various type of material of building construction, maintenance on building materials and production practices on green building design (Roy, 2008). Green architecture considers upon human beings health and considers upon giving better life for living beings. Green architecture defines an understanding of environment-friendly architecture under all classifications, and contains some universal consent (Burcu, 2015), it going to have of these characteristics:

Figure 4: Green Architecture

(Architectural digist, 2022)

1. Ventilation systems designed for efficient heating and cooling
2. Energy-efficient lighting and appliances
3. Water-saving plumbing fixtures
4. Landscapes planned to maximize passive solar power
5. Minimal harm to the natural habitat
6. Alternate power sources like alternative energy or wind generation
7. Non-synthetic, non-toxic materials
8. Locally-obtained woods and stone
9. Responsibly-harvested woods Adaptive reuse of older buildings
10. Use of recycled architectural salvage
11. Efficient use of space (Burcu, 2015)

While most green buildings don't have all of those features, the best goal of green architecture is to be fully sustainable.

2.4.1 Green Roof

Serve several functions for a constructing, like soaking rainwater, imparting insulation, developing a habitat for flora and fauna, growing benevolence and lowering pressure (Vandermeulen & Verspecht, 2011). Green roof is one of sustainable parameters comes under environmental sustainability. There are two types of green roof:

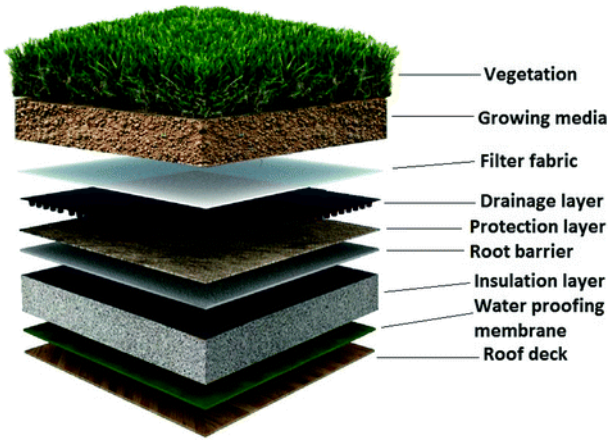


Figure 5: Green Roof

(Researchgate.net)

1. Intensive roofs, which are thicker, with a minimum depth of 12.8 cm, and may support a wider variety of plants but are heavier and need more maintenance.

2. Extensive roofs, which are shallow, ranging in depth from 2 cm to 12.7 cm, lighter than intensive green roofs, and require minimal maintenance (Volder & Dvorak, 2014).

The term green roof might also be used to indicate roofs that use some sort of green technology, like a cool roof, a roof with solar thermal collectors or photovoltaic panels also mentioned as eco-roofs, vegetated roofs, living roofs, green roofs (Wilmers F. , 1991).

2.4.2 Green Walls

Also referred to as vertical greenery is actually introducing plants onto the building façade. Comparing to green roof, green walls can cover more exposed hard surfaces within the the built environment where skyscrapers are the predominant building style (Gregory, 2003). Green wall is most popular in high rise buildings. According to (Ken, 2008) if a skyscraper has a plant ratio of one to seven, and then the façade area is equivalent to almost three times the area. So, if the building is protected thirds of the façade, this have contributed to doubling the amplify of flower on site. So a skyscraper can become green, thus increasing the organic mass on the positioning (Wilmers, 1990).

Figure 6: Green wall on skyscraper

(Greendiary.com,2021)

There are three types of Green Walls:

1. Wall-climbing Green wall is that the quite common and traditional green walls method. Although it's a time consuming process, climbing plants can cover the walls of building naturally. Sometimes they're grown upwards with the assistance of a trellis or other supporting systems.

2. Hanging-down Green Wall is also another popular approach for inexperienced walls. It can easily form an entire vertical green belt on a multi-story building through planting at every story compare to the wall-climbing type (Wilmers, 1990).

3. Module Green Wall is that the latest concept compared to the previous two types. It calls for more complicated layout and planning considerations earlier than vertical system can come to region. It's also probably the most expensive green walls method (Jonathan, 2003).

2.5 Green Building Benefit

Green building isn't an easy development trend, it's an approach to building suited to the demands of its time, whose relevance and importance will only still increase:

1. Comfort: Because a well-designed passive solar home or building is extremely energy efficient, it's freed from drafts. Extra sunlight from the south windows makes it more cheerful and pleasant within the winter than a standard house. Green buildings are comfortable in both summer and winter helps to balance thermal comfort.
2. Economy: If addressed at the planning stage, passive solar construction doesn't must cost quite conventional construction, and it can economize on fuel bills (kats, 2003).
3. Aesthetics Passive solar buildings can have a traditional appearance on the surface, and also the passive solar features make them bright and pleasant inside (Ragheb, Shimy, & Ragheb, 2015).
4. Environmentally responsible: Passive solar homes can significantly cut use of heating fuel and electricity used for lighting. If passive cooling techniques are used in the layout, summer expenses may be reduced as nicely (Woolley, 2006).

2.6 Living Architecture

Residing structure make a specialty of these processes, integrating ecological functions into the buildings to trap, shop and filter out water, purify air and procedure other vitamins. Living Architecture also addresses biophilia, the documented health benefits associated with being in touch with living systems in the built environment (Harrell, 2008). Reasons for doing had been the increase of insulation (keep cool in summer time and preserve cold out in winter), improved aesthetics, progressed indoor and outdoor climate, lessen (Sheweka & Magdv, 2011).

Figure 7: Living Architecture

(Kadvacorp, 2022)

2.7 Sustainable parameters

2.7.1 Sustainable parameters

There are six main relevant features widely used to measure upon sustainable parameters in building. These parameters as follows:

1. Site and surroundings
2. Energy efficiency and renewable energy use
3. Water consumption
4. Indoor environmental quality
5. Materials use and management
6. Integrated design approach

(Mishra, 2017)

2.7.2 Site and surroundings

Sustainable architecture is the usage of design techniques that reduce the bad environmental effect from a built surrounding. Following study has been done through traditional building.

1. Site planning

• With row neighborhood buildings

• Developed with max open spaces

• Courtyards & streets

2. Average land coverage:

• 6mx9m = 54 sq m

• < 2 anna plot

• Use min urban land

• With high population density

• Min 6 person/house

3. Encourage all urban facility in walking distance

• Market, primary school, medical shop, temple etc

• No need of any vehicles

• Which reduce pollution

• Saves surrounding environment

4. Planned site with services

• Street, alley, water supply, sanitation, etc.

5. Min heat island effect:

• Non reflectivity of light & heat: From roof of building Paved surface of open spaces.

• Green environment friendly planning.

(Bajracharya S. B., 2020)

2.7.3 Materials use and management

Material conservation can be ensured in the building sector by designing buildings that contribute to the lower use of building materials, and by choosing ecological building materials (Alparslan, 2010). Green constructing substances typically bring about decreased upkeep and replacement prices over the lifestyles of the constructing, preserve electricity and enhance occupant health and productivity. Green building should be reusable and should be environmentally friendly. Green building materials can be selected with the aid of evaluating characteristics consisting of reused and recycled content material with non or low off-gassing harmful air emissions, low toxicity, sustainably and unexpectedly

renewable harvested materials, excessive recyclability, sturdies, longevity and neighborhood product. (Cullen & J., 2010).

	STRATEGIES	METHODS
MATERIAL CONSERVATION (MC)	Building design with reduced use of materials (MC1)	Reducing the surface of building shell in the design (MC1.1)
		Use of simple geometric figures in the design (MC1.2)
		Designing buildings with efficient use of interior spaces (MC1.3)
		Reuse of existing buildings and infrastructure by renewal (MC1.4)
	Selection of ecological materials (MC2)	Selection of durable building systems and materials requiring less maintenance (MC2.1)
		Selection of reusable, recycled and recyclable building materials that contain recycled materials in packaging (MC2.2)
		Selection of natural building materials (MC2.3)
		Selection of local and regional building materials (MC2.4)

Figure 8: Strategies and methods for material conservation

(Alparslan, 2010), (Çelebi, 2007), (Gültekin, 2011)

2.7.4 Water consumption

The use of water begins at the construction phase of the building and continues throughout the use of the building (Vickers, 2001). Water is the key element of building construction, proper consumption of water leads to meet the building's one sustainable parameter that is water conservation. In the building sector, water economies can be made by decreasing water consumption, reusing water and using water without contamination materials (Alparslan, 2010).

	STRATEGIES	METHODS
WATER CONSERVATION (WC)	Decreasing water consumption (WC1)	Planning landscape that uses water efficiently and requires less maintenance (WC1.1)
		Using plants that are drought-tolerant and require less water (WC1.2)
		Using facilities with less water consumption (WC1.3)
	Re-use of water (WC2)	Reusing waste water by clarification (WC2.1)
		Using rainwater collecting facilities (WC2.2)
		Making arrangements that prevent water from mixing with ground water (WC2.3)
	Use of water without contamination (WC3)	Lower use of toxic pesticides (WC3.1)
		Using cleaning materials which do not cause contamination (WC3.2)

Figure 9: Strategies and methods for water conservation

(Alparslan, 2010), (Çelebi, 2007), (Gültekin, 2011)

2.7.5 Energy efficiency and renewable energy use

Energy consumption begins at the production section and maintains for the duration of the section of production and use of the constructing; in the constructing quarter, power conservation can be ensured by way of using renewable power resources, with the aid of thinking about hodily situatins of the location under have a look at, by means of designing strength-efficient constructing forms, by deciding onstrngth- efficient building shells and finally by designing power-efficient panorama building(Vickers, 2001). Energy efficiency in building belongs to both active and passive means of sustainable energy.

	STRATEGIES	METHODS
ENERGY CONSERVATION (EC)	Use of renewable energy resources (EC1)	Using solar cells in electricity production (EC1.1)
		Using solar collectors for heating water (EC1.2)
		Using passive solar systems (EC1.3)
		Using wind energy in air-conditioning and cooling (EC1.4)
		Using daylight for lighting (EC1.5)
		Using geothermal energy for heating and cooling (EC1.6)
		Using energy-efficient systems and instruments (EC1.7)
	Considering physical environmental conditions (EC2)	Effective positioning of the building (EC2.1)
		Choosing suitable area for building location (EC2.2)
	Design of energy-efficient building forms (EC3)	Using simple geometric figures in the design (EC3.1)
		Designing structures with effective use of interior spaces (EC3.2)
		Increasing solar gain by widening south-oriented zones (EC3.3)
	Selection of energy-efficient building shells (EC4)	Preventing heat loss by choosing proper insulation materials (EC4.1)
		Using high-performance floor coverings and glass (EC4.2)
	Energy-efficient landscape design (EC5)	Using plants for heating and cooling (EC5.1)
		Using green roof applications (EC5.2)
		Using renewable landscape plans (EC5.3)

Figure 10: Strategies and methods for energy conservation

(Alparslan, 2010), (Çelebi, 2007), (Gültekin, 2011)

2.7.6 Indoor environmental quality

The basic objective of the building sector is to create artificial environments with due regard for the safety, health, physiological needs, and productivity of the users (Davis, 1981). In these environments, people and different dwelling and non-dwelling and non-living organism need to percentage common spaces. In the building sector, the design of livable environments can be ensured by conserving natural environments, designing ecological cities, taking into consideration human health, and raising awareness about ecology (Vickers, 2001).

	STRATEGIES	METHODS
DESIGN OF LIVEABLE ENVIRONMENTS (DLE)	Conservation of natural environments (DLE1)	Conservation of current plant cover and aquatic and terrestrial living creatures (DLE1.1)
		Conservation of the topographic structure (DLE1.2)
		Conservation of underground and aboveground water levels (DLE1.3)
		Conservation of natural resources and natural living spaces (DLE1.4)
		Restoration of damaged ecosystems (DLE1.5)
		Repair and reuse of the current structure and infrastructure (DLE1.6)
		Building materials detrimental to natural balance should be avoided at the production phase (DLE1.7)
	Design of ecological cities (DLE2)	Prevention of pollution (visual, noise, air, soil) (DLE2.1)
		Development multi-functional designs (DLE2.2)
		Decreasing use of automobiles by building roads for pedestrians and bicycles only in the area around the building (DLE2.3)
	Design for human health (DLE3)	Using water-based natural materials in interior spaces (DLE3.1)
		Using naturally-dried preservative-free wood in interior spaces (DLE3.2)
		Using adequate amount of sub-basement and water tables on the walls to prevent dampness (DLE3.3)
		Providing for adequate movement and quality of air in interior spaces (DLE3.4)
	Raising ecology awareness (DLE4)	Developing methods to help the society gain ecological experience in buildings (DLE4.1)
		Implementing research and development studies and developing curricula in educational institutions (DLE4.2)
		Organizing ecology and environment seminars for all segments of society (DLE4.3)

Figure 11: Strategies and methods for design of livable environments

(Alparslan, 2010), (Çelebi, 2007), (Gültekin, 2011)

2.7.7 Integrated design approach

Integrated design approaches indicates for integration of building design with other modern techniques to make building easily functional. These integrated approaches are some are computer based software.

2.8 Sustainable building life cycle

This examine taken into consideration eco- pleasant constructing creation in the context of sustainable development. A building includes four essential phases as layout, production, operation and preservation and demolition. As given in determine, sustainable constructing method changing the system that motive pollutants, non-renewable useful resource utilization into utilization of aid-efficient products and processes useful for surroundings and society at some stage in the phase of pre-building, constructing, constructing and put up-constructing measures (Mishra, 2017).

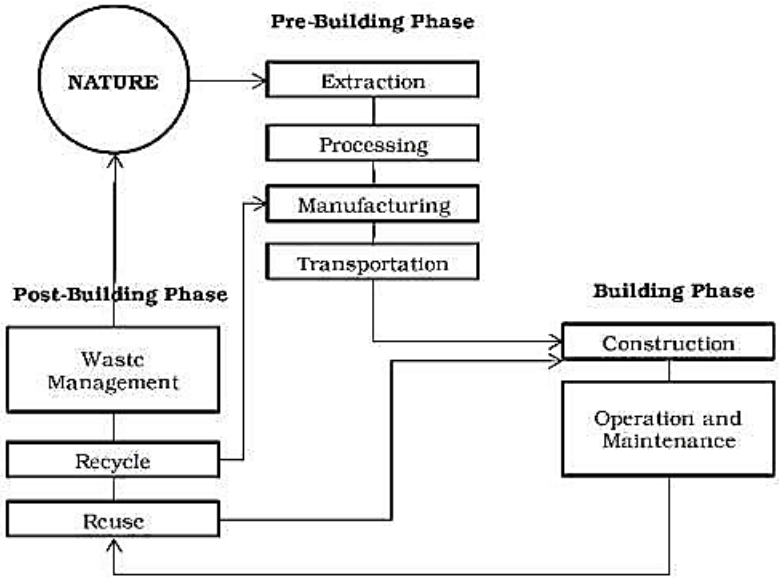


Figure 12: The sustainable building life cycle

2.9 Embodied Energy and Carbon Emission of Building Materials

The embodied energy is the energy consumed by all the processes associated with the production of a product from the acquisition of natural resources to the product delivery (Mishra, 2017). This includes the mining and production of substances and equipment, the delivery of substances and the executive features. As a rule of thumb, embodied energy is a reasonable indicator of the overall environmental impact of building materials, assemblies or systems (Kumar & Buddhi, 2012).

S.No.	Material	Embodied Energy (MJ/kg)	CO_2 emission (kg / kg)
1	Aggregate	0.10	0.005
2	Concrete	0.95	0.13
3	Brick	3.00	0.22
4	Soil	0.45	0.023
5	Glass	15.00	0.85
6	Aluminum	155.00	0.24
7	Steel	24.40	1.77
8	Plastics	80.50	
9	Timber	8.50	0.46
10	Lime	5.50	0.74
11	Cement	4.60	0.83
12	Sand	0.10	0.005
13	Ceramics	10.00	0.65

Figure 13: Embodied Energy per unit mass and CO2 emission of Building Materials

2.10 U- Value of Surfaces of a building

Thermal transmittance, additionally known as U-value, is the price of transfer of warmth through a shape (which may be a single material or a composite), divided via the difference in temperature across that shape (Mishra, 2017). The units of measurement are W/m²K. Thermal transmittance takes heat loss due to conduction, convection and radiation into account (Lymath, n.d).

2.11 Sustainable development goals

Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all (SustainableDevelopmentGoals, 2015). The "2030 schedule for Sustainable development" changed development finalized during for the duration of United nations Sustainable development Summit in September 2015. The Sustainable development goals adopted by the UN Member States are 17 thematic areas that define a roadmap for sustainable improvement till 2030. Sustainable development goals(SDCs) 11 has focused on sustainable cities and communities. The aim of goal 11 is "Make cities and human settlements inclusive, safe, resilient and sustainable." SDG 11 is a dedicated goal that focuses on cities and human settlements and is built around urban sustainability. Sustainable goals 11 targets are

11.1 Housing

11.2 Transport

11.3 Planning

11.4 Heritage

Figure 14: SDG 11

(Introducing a new Global Goal for Cities and Human Settlements, 2015)

11.5 Vulnerability

11.6 Environment

11.7 Public Spaces

11.a Urban-Rural Areas

11.b Integrated Policies

11.c Governmental Capacities

2.11.1 Need of Urban sustainable goals

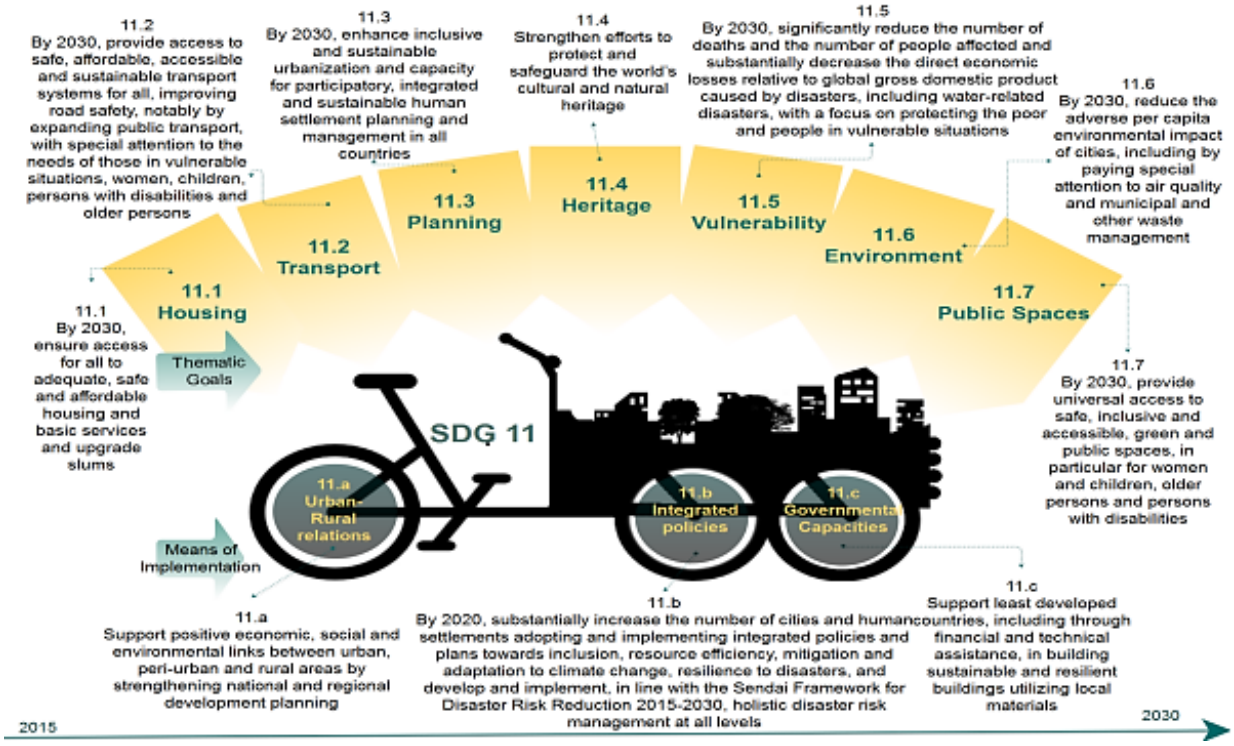


Figure 15: Sustainable development goals image

(SustainableDevelopmentGoals, 2015)

1. Increase in Urban Areas

   • In 2050, the urban population is anticipated to attain 6.5 billion.

   • In 1990, there were 10 towns with 10 million human or more; through 2014, the variety of mega-town rose to 28 and become anticipated to attain 33 by way of 2018.

2. Increase in Urban Areas in Developing Countries

   • In coming many years, ninety percent of urban expansion could be within the grawing international.

   • In the future, 9 out of 10 mega-cities will be in the developing world Energy Consumption by the cities/urban areas.

- Cities occupy just 3 percent of the Earth's land but account for 60 to 80 percent of energy consumption and at least 70 percent of carbon emissions Economic Role of the cities/urban areas.
- They generate approximately 80 percentage of the global GDP.
- The SDG 11 aims to include local and regional perspectives in the SDG.
- Local governments are generally pioneers in sustainable urban development
- Local governments can develop practical solutions to challenges that have proven to be problematic and divisive for national governments.
- The increase in responsibility for the local governments due to increase in urban areas, has often not been matched by consistent financial and institutional support from national government (Unitednationdevelopmentprogram, 2016).

2.11.2 Importance of the Urban Sustainable Development Goal

1. Giving voice to local and subnational governments at the United Nations
   - Integration of sustainable urban development into the global framework for action, and upscaling the effect that local and subnational governments can have in making contributions to the achievement of the SDGs.
   - Supporting local governments in taking actions that cover multiple targets and cut across thematic areas: poverty measure at the urban level, safety in mobility in urban areas, and urban consumption and waste etc. have been officially identified within the SDG framework.
   - The local and subnational governments are more likely to see their access to development funds and support from other levels of government increase because of the high-profile of the SDG.
2. Promoting Sustainability in Global Context
   - SDG offers a shared narrative of sustainable improvement and assist guide the pulic's understanding of complex demanding situations.
   - Unite the global community and mobilize stakeholders.
   - Support long-term approaches towards sustainable development.
   - Define responsibilities and foster accountability.

- Promote integrated thinking and put to rest the policies being pursued in a disintegrated manner by different level of authorities (Unitednationdevelopmentprogram, 2016).

2.11.3 New Urban Agenda (NUA)

The New Urban Agenda was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador, on 20 October 2016 (unhabitat, 2016). The New Urban Agenda is an action-oriented document that mobilizes Member States, local authorities and other key stakeholders to drive sustainable urban development at the local level. The implementation of the New Urban schedule contributes to the localization of the 2030 time table for it's in an integrated way and to the filfillment of the Sustainable development goals and targets, which include Goal eleven of making town and human settlements inclusive, safe, resilient and sustainable.

2.11.4 Efforts for the implementation of the SDGs in Nepal

In Nepal, SDGs agreed a proposed set of 17 SDGs with 169 targets on a broad range of sustainable development issues for post2015 till 2030. SDGs have replaced the MDGs. SDGs are built on the MDGs covering a wider range of sustainable development issues beyond those encompassed in the MDGs. SDGs and their targets, the enabling policy environment and existing institutions for their operationalization in Nepal,

The SDG 11 targets include achieving the following by 2030:

1. Access for all to adequate, safe and affordable housing and basic services, and upgrade slums
2. Access to safe, affordable, accessible and sustainable transport systems for all, and improve road safety, notably by expanding public transport
3. Inclusive and sustainable urbanization,
4. Safeguard the cultural and natural heritage
5. Significantly reduce the economic losses relative to GDP caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
6. Reduce the adverse per capita environmental impact of cities, including air quality and municipal and other waste management

7. Provide universal access to safe, inclusive and accessible green and public spaces, in particular for women and children, older persons and persons with disabilities.

2.12 GRIHA

Nepali context did not have rating system, for rating sustainable constructing I had selected upon GRIHA rating machine due to the fact this rating system belong to India which matches with regional context of Nepal also I had selected SVAGIHA which matches with area of case study residence.

Green Rating for Integrated Habitat Assessment that addresses various concerns of green buildings through the design, construction and operations phase of any building in order to ensure minimal negative impact on the environment by using philosophy of five 'R's i.e. recycle, reuse, reduce, refuse and reinvent (Wanjiru, 2019). Griha is national Rating System for Green Buildings proposed by Ministry of New and Renewable Energy (MNRE) in 2007. I had studied upon water management & occupant comfort.

2.12.1 Water management

Table 1: GRIHA water management criteria

3.Water Management	11 (Possible point)
i.Water Demand Reduction	3
ii.Wastewater Treatment	3
iii.Rainwater Management	5

(Wanjiru, 2019)

Water management includes following points:-

i. Reduce the overall water demand.

ii. Promote grey water and black water segregation and further treat them onsite. to reduce dependency on fresh water.

iii. Manage rainwater efficiently such that post-construction storm water run-off does not exceed the pre-construction run-off.

iv. Evaluate both the quality and quantity of water available for becoming self-sufficient.

2.12.2 Occupant comfort

Table 2: GRIHA criteria occupant comfort

7.Occupant Comfort(OC)	12 (Possible point)
i.Visual Comfort	4
ii.Thermal and Acoustic Comfort	2
iii.Maintaing Good IAQ	6

(Wanjiru, 2019)

Occupant comfort includes following points:-

i. Ensure that visual comfort (daylighting and artificial lighting) is provided to the building occupants.

ii. Ensure that occupants of the building are thermally and acoustically comfortable to benefit their health and well-being, and ascertain improved performance.

iii. Encourage design and monitoring of ventilation systems such that the indoor air quality meets minimum requirement as recommended by the relevant standards.

According to building type and area covered GRIHA has various variations. Variations of GRIHA rating system are as follows:

1. SVAGRIHA Pre-Certification
2. SVAGRIHA
    a. SVAGRIHA V3 >> projects with built up area 100 m2 ≤ x ≤ 2500 m2
    b. SVAGRIHA V2.2 >> projects which are less than 2500 sq m built-up area >> except for a factory building
3. GRIHA Pre-Certification >> new construction projects >> built up area more than 2500 m
4. GRIHA for Affordable Housing
5. GRIHA for Existing Building Rating >> built-up area greater than 2,500 sq. m
6. GRIHA for Existing Day Schools
7. GRIHA for Large Developments
8. GRIHA FOR CITIES
9. GRIHA Water Positive Certification

My study belongs project containing are less than 2500 sq.m. So had had done literature study of SVAGRIHA.

2.12.3 SVAGRIHA

SVAGRIHA, an abbreviation for Simple Versatile Affordable GRIHA, was conceived to unfold out the concept of green homes and sustainability to small-scale stakeholders, that is,properties of tasks including bungalows and small offices. It was developed as a simple guidance to ramp up its adoption by means of well-known loads and further reduce the GHG emission as a result of small-scale structure. SVAGRIHA (Simple Versatile Affordable GRIHA) was jointly developed by GRIHA Council & TERI team (Naik, Salvi, & Pandhare, 2020).

1. The new version of SVAGRIHA furthers the dimension of this tool by appending an impact evaluation calculator. This online tool will guide the usersin direction of selecting appropriate layout strategies for his or her projects, primarily based on the site and climatic conditions. It's going to additionally assist them to perform qualitative and quantitative effect assessment of their tasks. Informed decisions during the initial stage of construction can help in minimizing the deleterious effects of the development on the environment (BTsquare, 2011). Types of Svagriha according to area allocation are as follows:
    a. SVAGRIHA V3 >> projects with built up area 100 m2 ≤ x ≤ 2500 m2
    b. SVAGRIHA V2.2 >> projects which are less than 2500 sq m built-up area >> except for a factory building (Wanjiru, 2019).

My study residence belongs to area less than 2500 sq.m. So I had studied upon SVAGRIHA V2.2.

2.12.4 Process of Svagriha rating

SVAGRIHA is a guidance-cum-rating system being developed for small standalone buildings like residences, commercial offices, motels, dispensaries, schools etc. and/or set of buildings with a cumulative built-up area of 2500 sq.m. Or less. Process of SVAGRIHA rating are as follows:

1. Registration

2. Online entry on SVAGRIHA by respected authority.

3. Evaluation/Review as consistent with SVAGRIHA by the project team

4. Finish online registration with necessary conditions.

5. Site Visit and supervised by ADaRSH

6. Evaluation

7. Award of Rating (SVAGRIHAmanual, 2011).

2.12.5 SVAGRIHA Rating Variations

Points Achieved	SVAGRIHA Rating
25-30	★
31-35	★★
36-40	★★★
41-45	★★★★
45-50	★★★★★

SVAGRIHA has 14 criteria. The 14 criteria under SVA GRIHA that has to be satisfied in any project for different ratings are put under 5 groups namely; 5 sub-groups-namely: Architecture and energy, water and waste, materials, landscape and Lifestyle. The total points that a project can achieve are 50The rating will be done on a 1–5-star scale.

2.12.6 GRIHA rating framework

Sub-Group	Maximum points	Minimum points to be achieved
Landscape	6	3
Architecture & Energy	21	11
Water & waste	11	6
Materials	8	4
Lifestyle	4	1

Figure 16: SVAGRIHA Sub-groups

(Srinidhi, Tufael, & Seka, 2020)

Criterion number	Criterion name	Points
1	Reduce exposed, hard paved surface on site and maintain native vegetation cover on site	6
2	Passive architectural design and systems	4
3	Good fenestration design for reducing direct heat gain and glare while maximising daylight penetration	6
4	Efficient artificial lighting system	2
5	Thermal efficiency of building envelope	2
6	Use of energy efficient appliances	3
7	Use of renewable energy on site	4
8	Reduction in building and landscape water demand	5
9	Rainwater harvesting	4
10	Generate resource from waste	2
11	Reduce embodied energy of building	4
12	Use of low-energy materials in interiors	4
13	Adoption of green Lifestyle	4
14	Innovation	2
Total		50

Sub-Group: LANDSCAPE

1. Criteria: Reduce exposed, hard paved surface on site and maintain native vegetation cover on site.

Table 3: Landscape category 1

Criterion no.	subdivision	Point allocated
1.	i. All trees in the perimeter zone shall be protected	02
	ii. The total number of trees on site before and after	02
	iii. All new trees anted on site will be native	02

Sub-Group: Architecture & Energy

2. Criteria: Passive architectural design and systems
   - Adopt of passive design measures
   - Use of low-energy or passive heating/cooling measures >> ensure overall energy consumption building >> ensuring good thermal comfort conditions for the occupants.

Table 4: Architecture & Energy category 1

Criterion no.	Criterion name	subdivision	Point allocated
2.	Passive architectural design and systems	i. Adopt a minimum of 2 passive design measures in building	02
		ii. Active, low-energy cooling/heating systems are installed in the building	02

3. Criteria: Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration
   - Design of openings >> direct heat gain through fenestration is minimized >> maximizing daylight penetration.

- Reduce the direct heat gain through fenestration >> ensuring good daylighting.

Table 5: Architecture & Energy category 2

Criterion no.	Criterion name	subdivision	Point allocated
3.	Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration	i. Reduce the overall insolation through the fenestration by 10%, 20%, 30%or more over the base case	01,02,03 (03)
		ii. More than 25%,50%, 70%, 90% of the total living area falls under daylight zones	Mandatory, 01,02,03 (03)

4. Criteria: Efficient artificial lighting system

Adoption of energy efficient artificial lighting systems (lamps/luminaires/ballasts etc.) >> to reduce the overall LPD (Lighting Power Density) below ECBC recommended levels.

Table 6: Architecture & Energy category 3

Criterion no.	Criterion name	subdivision	Point allocated
4.	Efficient artificial lighting system	Demonstrate decrease LPD ranges with the building layout in comparison to ECBC recommended LPD levels	02

5. Criteria: Thermal efficiency of building envelope

Table 7: Architecture & Energy category 4

Criterion no.	Criterion name	Subdivision	Point allocated
5.	Thermal efficiency of building envelope	i. When viewing the output in sq.ft./TR, the project should achieve sq.ft./TR higher than the prescribed thresholds.	1,1
		i. When viewing the output in w/sq.m., the project should achieve w/sq.m. lower than the prescribed thresholds.	

6. Criteria: Use of Energy Efficient Appliances

- The intent of this criterion is to promote the adoption of energy efficient appliances.

Table 8: Architecture & Energy category 5

Criterion no.	Criterion name	Subdivision	Point allocated
6.	Use of Energy Efficient Appliances	All the Air-conditioners, fans and geyser installed on site are 3-star,4-star,5-star BEE labelled (Bureau of Energy Efficiency; run by the Indian government under Ministry of Power	01,02,03(03)

7. Criteria: Use of renewable energy on site

- To promote the use of renewable energy; Renewable energy system for electricity generation
- Solar Water Heaters

Table 9: Architecture & Energy category 6

Criterion no.	Criterion name	Subdivision	Point allocated
7.	Use of renewable energy on site	i. Rated capacity of the renewable energy system installed on site conforms to or exceeds the thresholds[100-500m^2 Built up area >> 1KW (min. size of R.E.S to be installed)]	02
		i. Installed capacity of solar water heaters on site is equivalent to 50%, 75% or more of the daily hot water requirement [Hot water requirement for Residence :100 liters per day]	01,02(02)

8. Criteria: Reduction in building and landscape water demand
    - To reduce the overall water demand of the building through use of low-flow fixtures
    - To reduce the landscape water demand through the use of native species of flora and efficient irrigation systems

Table 10: Water & waste category 1

Criterion no.	Criterion name	Subdivision	Point allocated
8.	Reduction in building and landscape water demand	i. Reduce the total water requirement in the building by at least 25%,33%, 50% or more over the base case	01,02,03 (03)
		i. Reduce the total water requirement in the building by 25%, 50% or more over the base case(to reduce the landscape water demand through the use of native species of flora and efficient irrigation systems)	01,02 (02)

9. Criteria: Rainwater harvesting
    - Capture rainwater for use on site
    - To promote rainwater harvesting >> recharge into the ground water aquifer

Table 11: Water & waste category 2

Criterion no.	Criterion name	Subdivision	Point allocated
9.	Rainwater harvesting	i. The total rainwater harvesting potential for the project (from the roof only) is equivalent to at least 75% of the total	03

Criterion no.	Criterion name	Subdivision	Point allocated
		building water demand over 2 days	
		i. Rainwater is recharged into the ground water aquifer and has a filtration system installed	01

10. Criteria: Generate resource from waste

- Zero waste generation through adoption of requisite strategies

Table 12: Water & waste category 3

Criterion no.	Criterion name	Subdivision	Point allocated
10.	Generate resource from waste	i. Zero waste generation through adoption of requisite strategies. (adopt techniques on web page which help in recycling organic waste right into an aid)	02

11. Criteria: Reduce embodied energy of building

Table 13: Materials category 1

Criterion no.	Criterion name	Subdivision	Point allocated
11.	Reduce embodied energy of building	i. 100% of OPC is replaced by PPC (including building structure and	02

Criterion no.	Criterion name	Subdivision	Point allocated
		masonry and plaster mortar)	
		ii. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 5% or more over the base case	01
		iii. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 10% or more over the base case	

12. Criteria: Use of low-energy materials in interiors

Table 14: Material category 2

Criterion no.	Criterion name	Subdivision	Point allocated
12.	Use of low-energy materials in interiors	i. 70% of the flooring is low-energy	01
		ii. At least 70% of internal partitions/paneling/false ceiling/in-built furniture/ doors & window-panels & frames are low-energy	02

Criterion no.	Criterion name	Subdivision	Point allocated
		i. All interior paints are low-VOC and lead-free (including no paint/plain mortar finish/whitewash/lime mortar finish)	01

13. Criteria: Adoption of green lifestyle

- Adoption of green lifestyle
- Reduce the carbon footprint of occupants
- Equitable distribution of resources

Table 15: Lifestyle category 1

Criterion no.	Criterion name	Subdivision	Point allocated
13.	Adoption of Green Lifestyle	i. Built-up area meets the prescribed threshold [Residential: 12.5 sqm< X < 50 sqm]	01
		ii. Total expected distance travelled to basic services in a year is less than 2100 km (Residential= 7-11 services, 2100km)	01
		iii. Environmental awareness is created through panels/brochures/printouts etc. or Organic farming is carried out on site.	01

14. Criteria: Innovation

- Adopt strategies, independent of the previous 13 criterion, to make the project more sustainable
- Submit documents/narrative highlighting the measures adopted on site
- For each innovation – 1 point (maximum 2 points)

Table 16: Lifestyle category 2

Criterion no.	Criterion name	Subdivision	Point allocated
14.	Innovation	i. For each innovation (max. 2 points)	02

2.12.7 LEED rating system

LEED is Leadership in Energy and Environmental Design that includes a hard and fast of performance requirements used in the certification of commercial, institutional and othe building types in both the public and private sectors with the aim of selling healthy, durable and environmentally sound practices. Following are the objectives of LEED:

1. Establishing standards of measurement.
2. Promoting integrated design practices.
3. Recognizing environmental leadership in building industry.
4. To increase the awareness among users by specifying the benefits of green building (LEED, 2019).

There are various criteria in LEED. Additional criteria in latest version are as follows:-

1. Location and Transportation
2. Sustainable Sites
3. Water Efficiency
4. Energy and Atmosphere
5. Materials and Resources
6. Indoor Environmental Quality

7. Innovation and Design Process

8. Regional Priorities

9. Integrative Process

My thesis belongs to rating system for water & air so I had studied upon LEED's water efficiency & indoor environmental quality.

Water efficiency

Table 17: LEED water efficiency criteria

Water Efficiency	11 (Possible point)
i. Outdoor Water Use Reduction	Required
ii. Indoor Water Use Reduction	Required
iii. Building Level Water Metering	Required
iv. Outdoor Water Use Reduction	2
v. Indoor Water Use Reduction	6
vi. Cooling Tower Water Use	2
vii. Water Metering	1

Water efficiency explain upon following point:-

i. Reduce water consumption.

ii. Support water management and identify opportunities for additional water savings

iii. Consideration upon cooling tower.

Indoor environment

Table 18: LEED indoor environment

Indoor Environmental Quality (EQ)	16 (Possible point)
i.Minimum indoor air quality performance	Required
ii. Environmental tobacco smoke(ETS)control	Required
iii.Enhanced indoor air quality strategies	2
iv.Low emitting materials	3
v.Construction indoor air quality management plan	1
vi.Indoor air quality management	2
vii.Thermal Comfort	1
vii.Interior Lighting	2
viii.Daylight	3
ix.Quality Views	1
x.Acoustic Performance	1

Indoor environmental quality explain on following points:-

i. Contribute to the comfort and well-being of building occupants by establishing minimum standards for indoor air quality (IAQ).

ii. Prevent or minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke.

iii. Promote occupant's comfort, well-being, and productivity by improving indoor air quality.

iv. Reduce chemical contaminant's concentration that can damage air quality, human health, productivity, and the environment.

v. Establish better quality indoor air in the building after construction and during occupancy.

vi. Promote occupant's productivity, comfort, and well-being by providing quality thermal comfort.

vii. Connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight into the space.

viii. Give building occupants a connection to the natural outdoor environment by providing quality views.

2.13 Sustainable parameters concept

2.13.1 National Context

2.13.1.1 Nepal Building code (NBC)

NBC is designed with Mandatory Rules of Thumb (MRT) for reinforced concrete buildings with masonry infill and reinforced concrete building without masonry infill (DUDBC & NBC-202, 2015). This MRT addresses the precise requirements of those RC-framed buildings which have emerge as very common place with proprietor-developers, who even adopt the development of this form of building without employing professional designers (Mishra, 2017). There is restriction upon designer through column, floor height and also use of various other materials. The building code still doesn't mention any rules, regulations or policies about the sustainable/green houses in NBC205, 2015 even after the amendment of NBC -202, 1994. There is no such strong codes for building design. While on the other hand the financial status of public or government school might be one of the reason that drags it off from the path of sustainability (Thapa & Tiwari, 2020). There are some initiatives like through SONA (Society of Nepalese Architect) that had developed subcommittee to develop sustainable building guideline for Nepal. Also some municipalities like Dharan municipality had promoted green building through its bye-law and gives some reward points to client.

ERAG Rating system of SONA

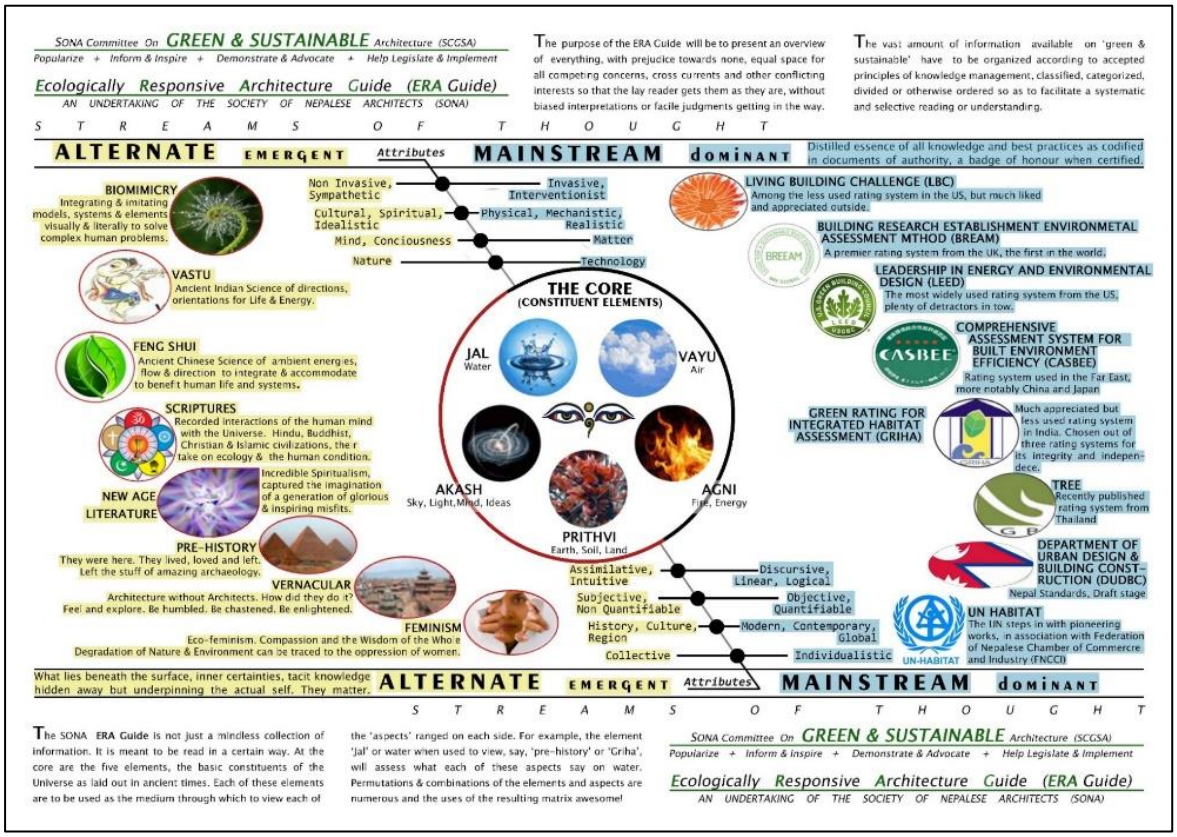


Figure 17: ERAG Diagram

(SONA, 2016)

ERAG is ecologically responsive architecture guide for Nepali context, which is initiated by Society of Nepalese Architects (SONA) by Past President Ar. Bibhuti Man Singh. ERAG's major objective is rating guideline for "For contextual sustainable building design in all the geographical regions within Nepal" (SONA, 2016). ERAG is started because international rating system has lengthy process, costly, intense documentation required. SONA came up with matrix of topics that comes under ERAG. It consist of three sections: the middle section or core, basic constituent of the universe were placed i.e. Jal, Vayu, Agni, Prithvi and Aakash. Each of these elements were to be used as the medium through which to view each of the 'aspects' ranged on each side (SONA, 2016).

- Example: the element 'Jal' or water when used to view 'Pre-history' and 'GRIHA', would assess what each of these aspects say on water.

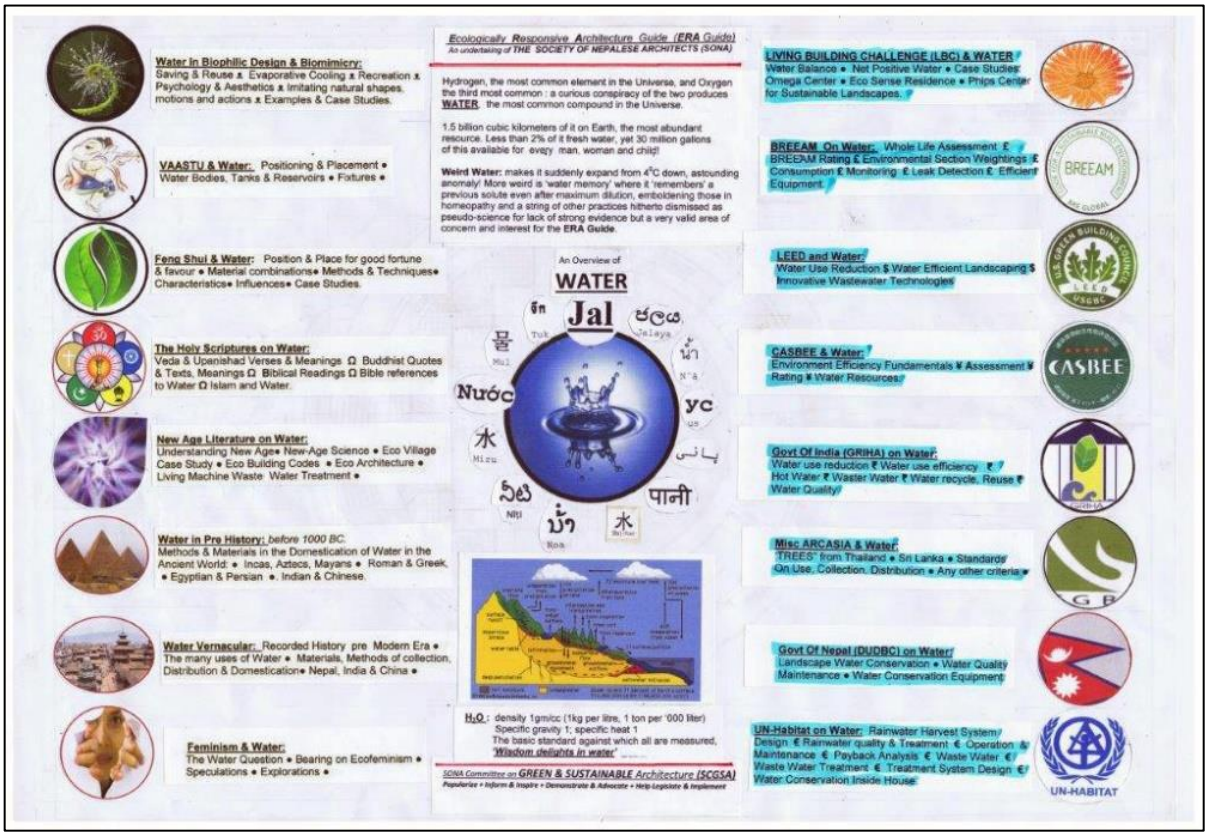


Figure 18: Relation of water with other element

(SONA, 2016)

Traditional Housing context inside Kathmandu

My study area belongs to Kathmandu. So I had studied upon traditional housing context in Kathmandu valley. Traditional architecture in Kathmandu valley is the outcome of centuries of optimization of material use, construction techniques and orientation (Upadyay, Yoshida, & Rijal, 2006). Kathmandu valley has traditional architecture which was developed with mud architecture as that of the ancient architecture of the world (Mishra, 2017). The materials used for those types of buildings are sundried brick, burnt brick, mud mortar, mud plaster, clay tile, timber and stone. The thick load bearing wall of 450 to 600 mm with built with multilayer of crimson Red brick (pakkiapa), Solar dried brick (kachi apa) and mud plaster positioned from outside to inside in external walls. These building constructed were sustainable (Bajaracharya, 2013). We can find buildings with reinforced concrete frames and unreinforced brick masonry infill in cement mortar within Kathmandu valley (Bajaracharya, 2013). The daily practices in maximum urban region for the development of residential and commercial complexes typically falls underneath this category. Indoor air temperatures were lower than outdoor air temperatures in summer whereas indoor air temperatures were higher than outdoor in winter in these traditional

buildings and saves minimum 10-20% energy for either heating or cooling both in summer and winter in traditional buildings than modern buildings of Kathmandu (Bajracharya, 2014).

2.14 Case study

2.14.1 Sustainable building construction in Kathmandu

Kathmandu valley was a sustainable place from environmental and ecological point of view until the modern era (Tuladhar, 2011). It was agriculturally self-sufficient and socially harmonious, bounded in a social hierarchy for a long period of time throughout the history that remained intact (Adhikari, 2008). The switch from agro based work and industry to service and business oriented work brought about change in lifestyle, the problems of urban management in the city is at a critical juncture as there is no proper monitoring and evaluation of the systems working in the city (Tuladhar, 2011). The change in lifestyle and welcoming of modern construction materials and techniques leads to unorganized urban growth. Kathmandu Valley is well popular for its increasing urbanization along with concrete infrastructures mushrooming all around the city (Mishra, 2017).

Now, also according Mishra to Inside the valley and in other parts of the country, construction of Eco- Friendly/ Sustainable houses are being increased more in humanitarian projects of INGOs and NGOs rather than in the private or public buildings. Similarly, the major activities done during the projects were assisting government in preparing policy frameworks to promote sustainable housing, Supporting three selected municipalities in promoting Green Homes, Stimulating demand for Green Homes components by strengthening supply chain, bridging SMEs and consumers through awareness building and promotional activities, building capacity of SMEs and creating green jobs for the urban poor, developing voluntary Green Labeling System.

My project study area belongs to Kathmandu valley, which is highly populated with dense settlement and rapidly increasing urbanization. The urbanization rate of the country is 3.62%. Meanwhile, Kathmandu valley has most huge demographic profile. The population growth rate of the valley is 4.35%, making it one of the highest growing urban agglomerate is South Asia (Shakya, Bajracharya, & Bajracharya, 2015). These are the sign which display the requirement and importance of the environmental pleasant buildings inside the city which would offer balance among the energy wanted and whole lifestyles of the building (Mishra, 2017).

2.14.2 In Regional context (India)

For regional study I had selected a residential building of India i.e., Samruddhi House, located in Surat, India with area 430 sq.m. This residence had been designed by Ar. Vishal Shah, Ar. Vishal Desai. According to Architect Samrudhhi is a House nested in Surat city's lately developed suburban residential neighborhood. Samruddhi, a Gujarati word meaning prosperity, is a house for a family of three prospering generations with a mutual inclination towards having a 'Home' that feels 'Homely' (AanganArchitects, 2021). Sustainable features of residence:

Figure 19: Samruddhi Residence

(Hana Abdel,2021)

1. Site planning and building planning

Site planning was done with in consideration of climatic element like existing temperature of Surat. So maximum ground area had been covered and make balance with internal courtyard inside building. That gives more open indoor space as well as helps in thermal comfort. Also a double-height courtyard in the residence, as a source of Natural light and air, along with it being a cohesive family space in living room.

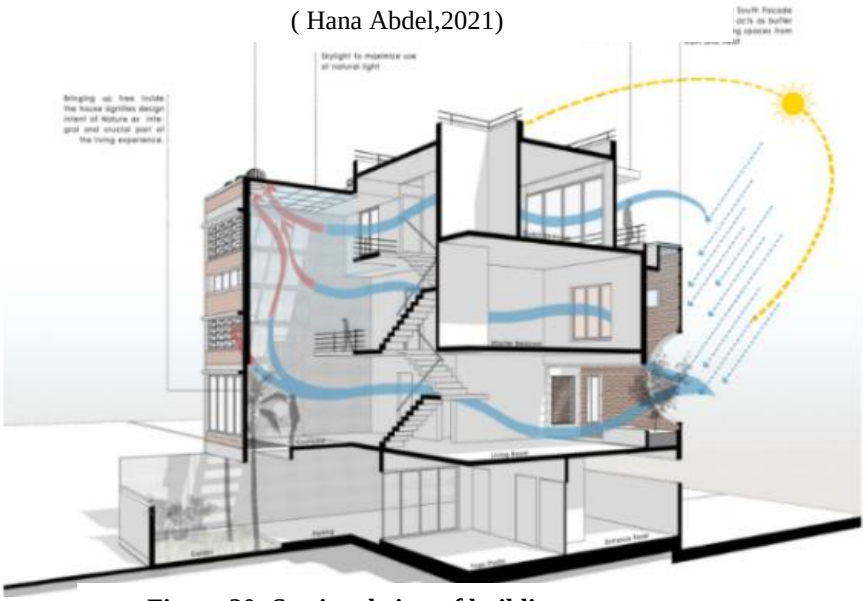


Figure 20: Sectional view of building

(Hana Abdel, 2021)

2. Passive design strategies

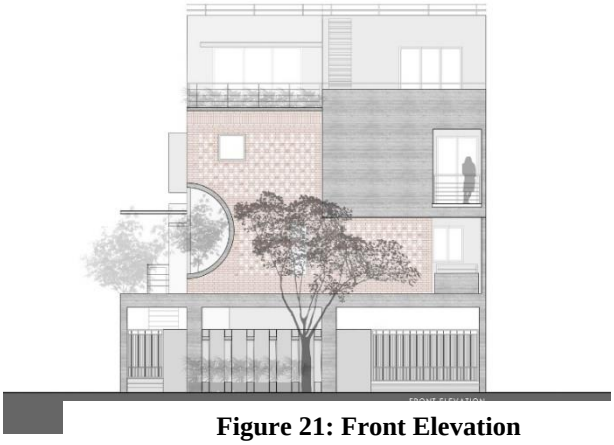


Figure 21: Front Elevation

Hana Abdel, 2021

Passive design strategy is one of major element of this residence (AanganArchitects, 2021)**.** To use stack effect in building Southwest side had been opened and as shown in section there is interchange of air in building. The cool air enters from west corner and passes to open courtyard and warm air passes through top opening.

Figure 22: Opening on south west corner

3. Building's element design

Brick display presenting favored privatizes, ventilation in addition to passive cooling for the southern façade. The association additionally prioritizes privatizes as a challenge in arranging personal and semi-private areas across the courtroom. That provides thermal comfort.

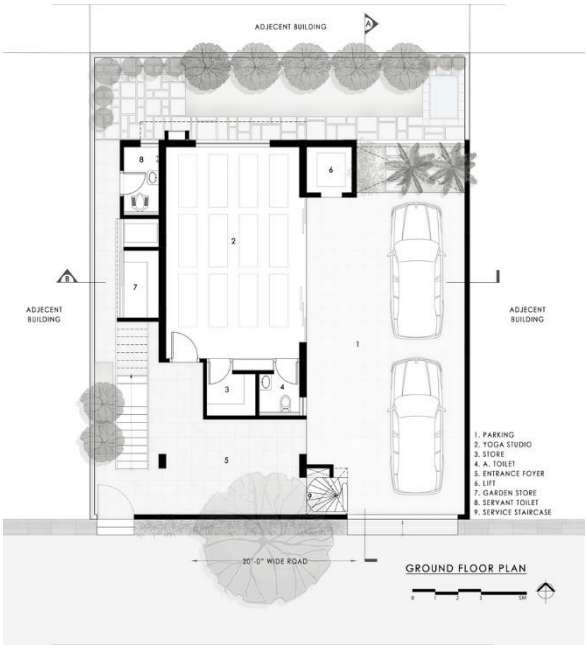


Figure 23: Open floor plan

2.14.3 India 'sustainable building- KOZHIKODE, INDIA

For regional case study, I had selected one sustainable building 'The wall of being Residence' of KOZHIKODE, INDIA. The client's personality embraces a modern lifestyle, at the same time are very nostalgic about their ancestral village of the central Malabar region (Abdel, 2020). Focuses upon vernacular architecture.

- Location:
  KOZHIKODE, INDIA
- Established in 2020 A.D

Figure 24: The wall of being residence

(Archdaily, 2020)

- Building typology: Residence
- Architect:
  Muhammed Ashiqe, Rumna K. P.
- Frame Structure with vernacular style

Features of The wall of being Residence are as follows:

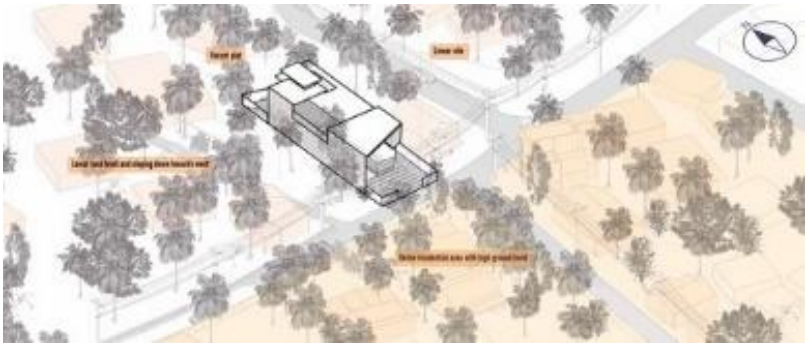


Figure 25: Master plan of kerela

(Archdaily, 2020)

Site and surrounding

Site selection (access to road**)**

- The residence stands at a y - junction in a dense residential neighborhood of Kozhikode, a coastal city in the south Indian state of Kerala.
- Site is located in dense urban area.

Availability of basic infrastructure

Basic infrastructure refers to main railways, roads, canals, harbors and docks, the electromagnetic telegraph, drainage, dikes and land reclamation (Torrisi & Gianpiero , 2009). That mainly indicates for water supply, sanitary system, teli-communications.

- Public vehicle are easily available within walking distance.
- Water supply pipelines and sanitary systems are connected with site.
- There is available of electricity and internet facility.

Figure 26: Landscape design in existing landform

(Archdaily, 2020)

Preserve and protect landscape during construction

- Existing site is flat and designed according to flat condition. Design to include existing site features
- Because crowed neighborhood a solution to ensure privacy, an inward-looking plan was adopted from which the idea of an abutting wall was conceived.
- Abutting wall –"The wall of being", plays as a canvas depicting one's roots and cultural background, from which the three-dimensional volume of the house emerges (Abdel, 2020).

Figure 27: Vertical louvered for privacy
(Archdaily, 2020)

Heat Island Effect, Green Roof

- Heat island effect is less on Kerala residence there is indoor water body and open courtyard with tree to balance indoor temperature.

2.14.4 Energy and environment

Climate Responsive Building Design

- Orientation of building is north south, morning suns lies in ground floor bedroom
- Kitchen has mostly occupied in east which catches the mornings sun, these rooms have been planned to receive the early morning sun, thus minimizing artificial lighting requirements

Figure 28: Open corridor
(Archdaily, 2020)

- Kerala belongs to hot climate, to balance the thermal comfort water element and open courtyard had been provided. Also, there is open North-south direction open

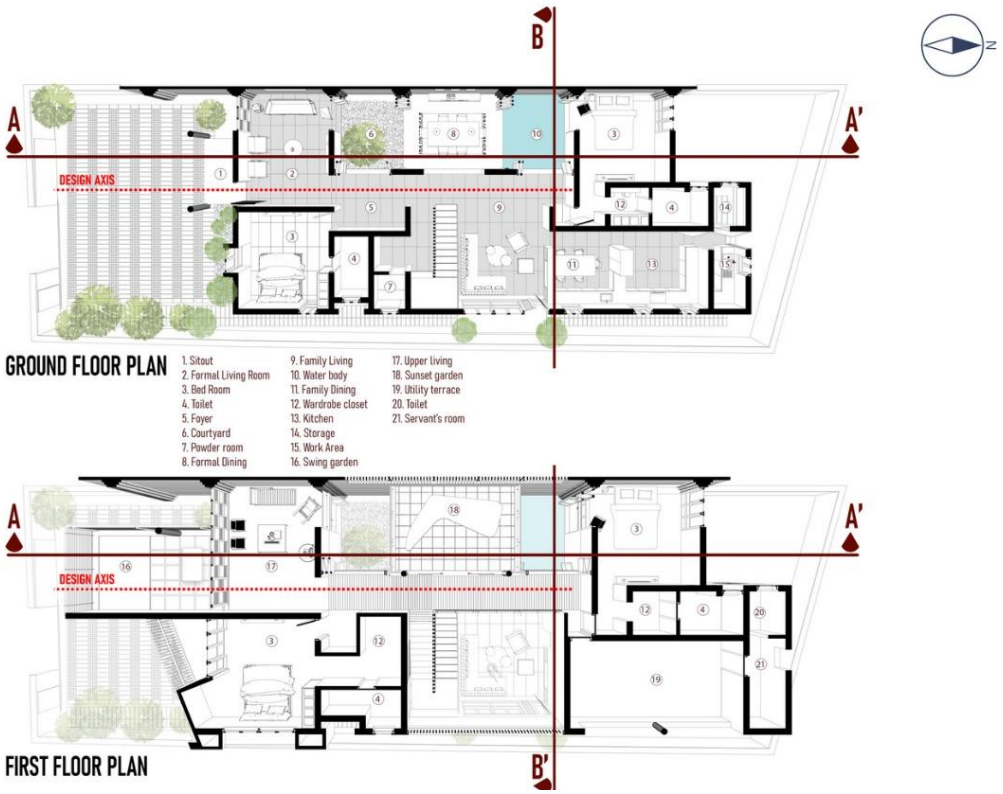


Figure 29: Floor plan of Kerala residence

(Archdaily, 2020)

corridor had been provided to balance indoor thermal comfort.

Passive Design to reduce the conventional energy demand (Day-lighting)

- Orientation of building its gives direct natural lights.
- Open floor plans gives on ground and upper floor gives passes of lights.
- All rooms have cross ventilation to provide cooling requirements for summer.
- For cooling window with louvered opening had been provide.

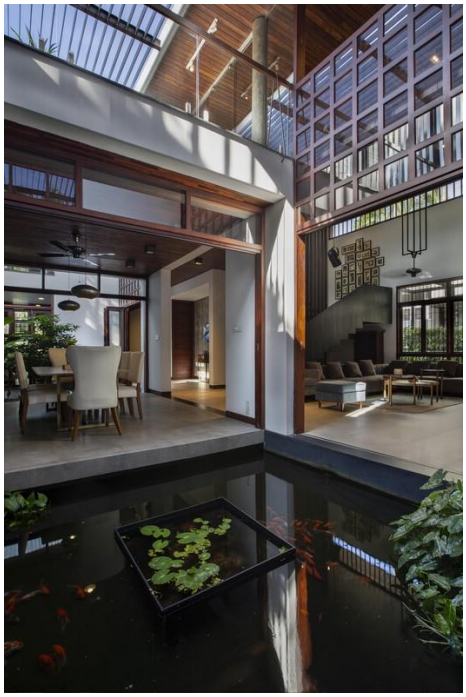


Figure 30: Water element of Kerala Residence
(Archdaily, 2020)

Figure 31: Courtyard design
(Archdaily, 2020)

Energy Efficient Lighting

- Natural lighting had been prioritized, in interior, kitchen study areas.
- Considered upon to maximum shadow cast in building in summer time.

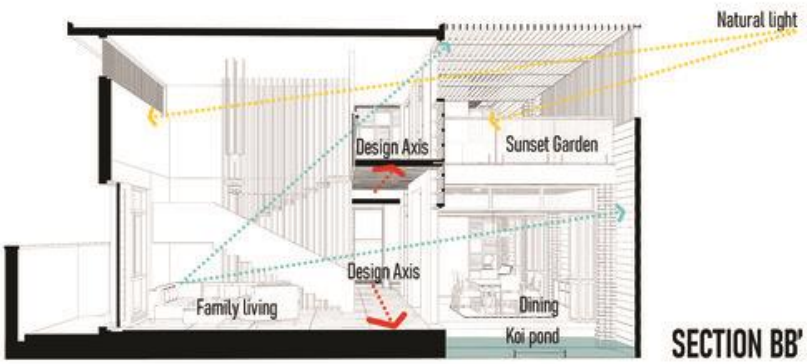


Figure 32: Natural lighting in building
(Archdaily, 2020)

Reduce air Pollution during construction

- Air pollution has been reduced at phase of construction by choosing of less embodied energy containing materials.

Roof Treatment

- For roof treatment from solar radiation horizontal pergolas had been provided.

Figure 34: Wooden ceiling for thermal insulation
(Archdaily, 2020)

Figure 33: Horizontal pergola
(Archdaily, 2020)

2.14.5 Water efficiency

Use of Water Efficient Equipment

- Water efficient equipment has been used in case of kitchen and bathroom.

Ground Water Recharge

- Maximum landscape in soft-scape that allows for ground water recharge.
- As shown in picture, permeable flooring has been provided which allows to pass the water to ground.

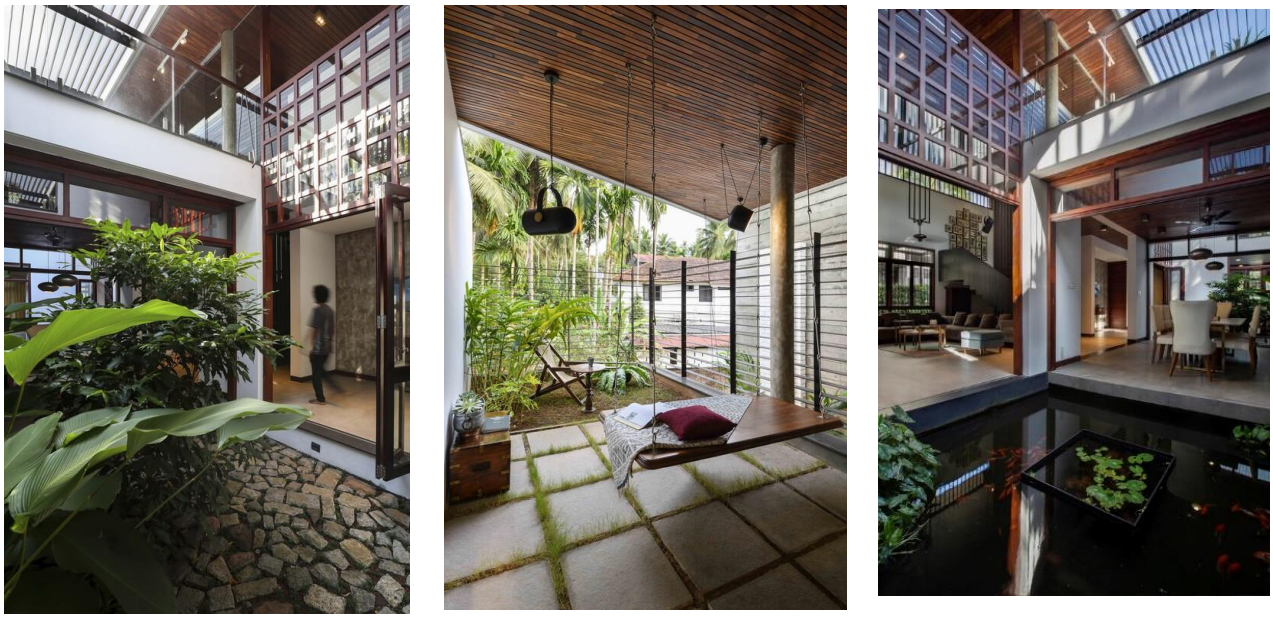


Figure 35: Permeable flooring

(Archdaily, 2020)

2.14.6 Building materials

Low embodied energy material

- Floorings : marble, wooden flooring are used
- Wooden cladding had been provided
- Brick and concrete facing in wall without plaster.

Figure 36: Wooden cladding

(Archdaily, 2020)

Figure 37: Wooden flooring & cladding in roof

(Archdaily, 2020)

Green materials (Materials with Low Environmental Impact)

- Brick exposed both externally and internally, no plaster and paint in the wall which reduced cost, harmfulness in the environment
- Openings are wooden frame window which helps in thermal balance
- Floorings is done through laminated wood and screeding which provides thermal comfort as well as for low environmental impact.

Figure 38: Wooden flooring & in staircase
(Archdaily, 2020)

- For roofing in interior wooden cladding is done
- Lighting fixtures like LED light is used which consume less energy; longer life time
- Modern materials like tile, marble are been provided.

2.14.7 In International context

Hinterland in Alexandria

Residence design of Northern Western coast Hinterland in Alexandria. It's miles characterized by way of extended fairly heat season and quick barely wet temperature iciness, favorable for thermophilic biological spectrum. Precipitation falls mainly for the duration of less warm season from autumn to spring.

1. Localized Indigenous Knowledge (IK)

Futher to IK, development specialist treasure this neighborhood expertise, finding it extraordinarily useful in fixing complicated problems of health, agriculture, training and the environment, each in developed and developing countries. (Ragheb & El-Shimy, 2015). Major IK concepts applied are as follows:

I. Courtyard. The comforts offered by a courtyard-air, light, privacy, security, and tranquility - provides the shadows are properties nearly universally desired in human housing.

II. Thickness of stone walls.

The partitions are designed to provide insulation, daylight filters via boom wall thickness (40-50cm).

III Roof.

Roof treatment is done by using environmental favorable techniques.

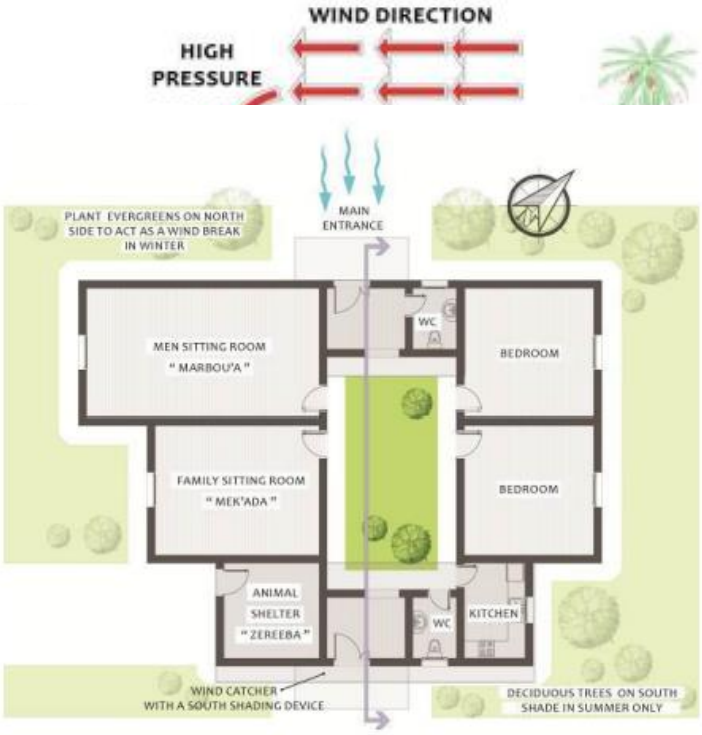


Figure 40: House plan

(Ragheb, 2013)

IV. Narrow openings.

Small openings and excessive from the ground to prevent the entry of heat during the day for the interior and hold them for the night time.

2. Features were considered to optimize the integration of passive design strategies.

Constructing orientation determines the amount of solar radiation it gets. In addition to different elements including. Evergreen timber have been planted on north aspect to behave as wind ruin in wintry weather, while deciduous trees on south facet to coloration in summer season handiest.

I. Courtyard design.

The vital courtyard lets in areas for relaxation and interaction of occupants preserving their activities faraway from acquaintances further to passive cooling strategies. It achieves enough daylight penetration, reduces solar warmth and promotes cooling breezes even as preserving out warm and dusty wind.

II. Sun angles and Shadings.

The design doesn't oversize the amount of south-side windows as oversizing can lead to overheating. Ideal proportions for an overhang are calculated by latitude (Alexandria, 31.2000° N).The overhang is large enough to block summer sun, but doesn't block sun in winter (Ragheb & El-Shimy, 2015).

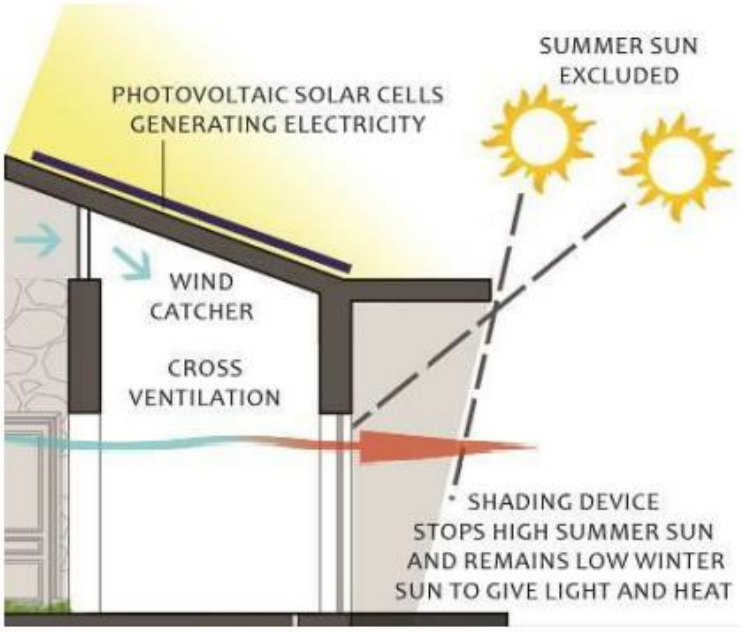


Figure 41: South horizontal overhangs

(Ragheb, 2013)

I. Thermal Mass.

Thicker wall had been provided to control for heat loss.

II. Construction Materials.

Walls: Solid 8" Masonry wall which could be

Double wall for maximizing thermal mass.

III. Rain water harvesting is highly considered.

IV. Aquifer Water. Well pumps are built to be used for extracting water from an underground source (Ragheb & El-Shimy, 2015).

2.14.8 SVAGRIHA rated

Plot No. 25, Zed Earth Villa

For SVA GRIHA rated case study, I had selected one sustainable building 'Zed earth vlla' of Bengaluru, Karnataka, INDIA.

- Location: Bengaluru, Karnataka, INDIA
- Building typology: Residence
- Site area: 560 Sq. m.
- Built up area: 290 Sq. m.

Figure 42: Zed Earth Villa

(Biodiversity Conservation India Ltd., n.d.)

- Typology : Residential
- SVA GRIHA rating : 5 star
- Architect: Biodiversity Conservation India Ltd., Bengaluru
- Frame Structure with vernacular style

  Strategies are as follows:

Landscape

- Almost 70% of the total open area on site is soft paved and/or shaded under trees.
- Native trees have been planted on site.

Energy

- Fenestrations and floor plan layouts have been designed to facilitate natural ventilation through all spaces.
- About 88% of total living area falls under daylight zone.
- Fenestration design of the villa reduces the direct incident heat penetration by about 38%, compared to SVAGRIHA base case for Bengaluru.
- Lighting power density is 4.78 W/sq.m. and thermal efficiency of the project is 289.82 sq.ft./TR (26.93 sq.m./TR), which is 5% better than the SVAGRIHA base case for Bengaluru.
- Solar photovoltaic panels of size 1.4 kWp and solar water heater of 150 lpd capacity have been installed on the villa.
- All air-conditioning systems, fans and geysers comply with BEE 5-star efficiencies.

Water and waste

- Use of low-flow fixtures reduces the building water demand by almost 74% compared to SVAGRIHA base case.
- Rainwater storage tank of 1500 litre capacity has been installed on site to capture and utilize rainwater.
- Organic Kitchen waste is converted into manure through the use of "Dailydump's Khamba".

Materials

- Use of hollow concrete blocks helps in reducing the embodied energy of the building by about 40% compared to SVAGRIHA base case.
- Use of low-VOC and lead free paints helps in maintaining good indoor air quality.
- Over 70% of interior finishes are low-energy like bamboo flooring, rough local granite etc.

Lifestyle

- There is provision for basic amenities like grocery store, pharmacy etc. within the campus.
- Each Villa has a Retainer's room for accommodation of service staff.
- Each Villa has a kitchen garden and brochures to promote environmental awareness (Biodiversity Conservation India Ltd., n.d.).

Residence in CR Park, New Delhi

- Location: New Delhi, INDIA
- Building typology: Residence
- Built up area : 8100 sq ft
- Typology : Residential
- SVA GRIHA rating : 5 star
- Architect: Biodiversity Conservation India Ltd., Bengaluru
- Frame Structure

  The following strategies were adopted to reduce the building impact on the natural environment:

Figure 43: CR park residence New Delhi

Landscape

•Green wall with cross ventilation

• Native trees have been planted on site.

Energy

- That includes low energy electronics, LED lights, and motion sensors.

Water and waste

- Water recycling, rainwater harvesting systems, and ultra-low-flow water fixtures. The rainwater storage tank is connected to the recharge pit, which ensures that all the water is either consumed or recharged back into the earth.

Figure 44: Interior of CR park residence

Materials

- The design, based on principles of green architecture, is punctured with fenestrations to reduce heat gain, and incorporates materials such as fly ash bricks, ACC bricks for walls, vermiculite insulation, earthen pots, and green roof for insulation.

Lifestyle

- Though the costs of constructing an environmentally sustainable house may initially be marginally higher, but the owner's return on investment will more than make up for the costs incurred by saving energy (Biodiversity Conservation India Ltd., n.d.).

CHAPTER 3. Research Methodology

3.1 Conceptual framework

This research falls under post-positivist paradigms. According to the post-positivist paradigm believes that reality can be measured, which is believes as truth but not absolute. This research talks about evidences based facts on case study. Ontological claim talks that post-positivist paradigm talk approximately facts however best imperfectly and probabilistic, on this studies by using case study method information might be identified via direct field remark. For epistemology, post-positivist paradigm talks about finding probable truth, facts of research where case study with analysis and observation will be done to meet research purpose.

Qualitative methods & Case study for study. Qualitative methods will be carried out by open ended interview of architect and owner of case study building. Qualitative research is multi-method in attention, involving an interpretive, naturalistic approach to its subject rely, because of this qualitative researchers observe things for their herbal settings, attempting to make sense of, or interpret, phenomena in phrases of the meanings human beings carry to them (Uprety, 2021). Case study method will be carried out by selecting of multiple case study of national levels. That international case study is done on international context and regional context. Case study methods is done by emphasizing the study of a phenomenon within its real-world context, the case study method favors the collection of data in natural settings, compared with relying on "derived" data (Bromey, 1986). Field based case study will carried out to know the sustainable parameters of national and international context on based of environmental, economic & social aspect of sustainability. That case study provides about actual facts of site. That gives ideas about sustainable parameters in design on existing context. According to (Uprety, 2021) a case study is an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident. In this research boundary are the existing sustainable parameters of Kathmandu building & context is case study site. Case study will be carried out to review to build theoretical perception on sustainable parameters by literature review and interview. Also, in this research building will be rated by SVA GRIHA rating system on known upon how much building is green. For objective to explore on ERAG, I will do 20 numbers of questionnaire

survey, from architects practicing green. From this I will be familiar about architect perception upon national building design guideline.

Research methodology includes various sequential steps to find out result of given problem on a specific content. This research will be done through study of non-rated residential buildings by case study analysis and methodology will be:

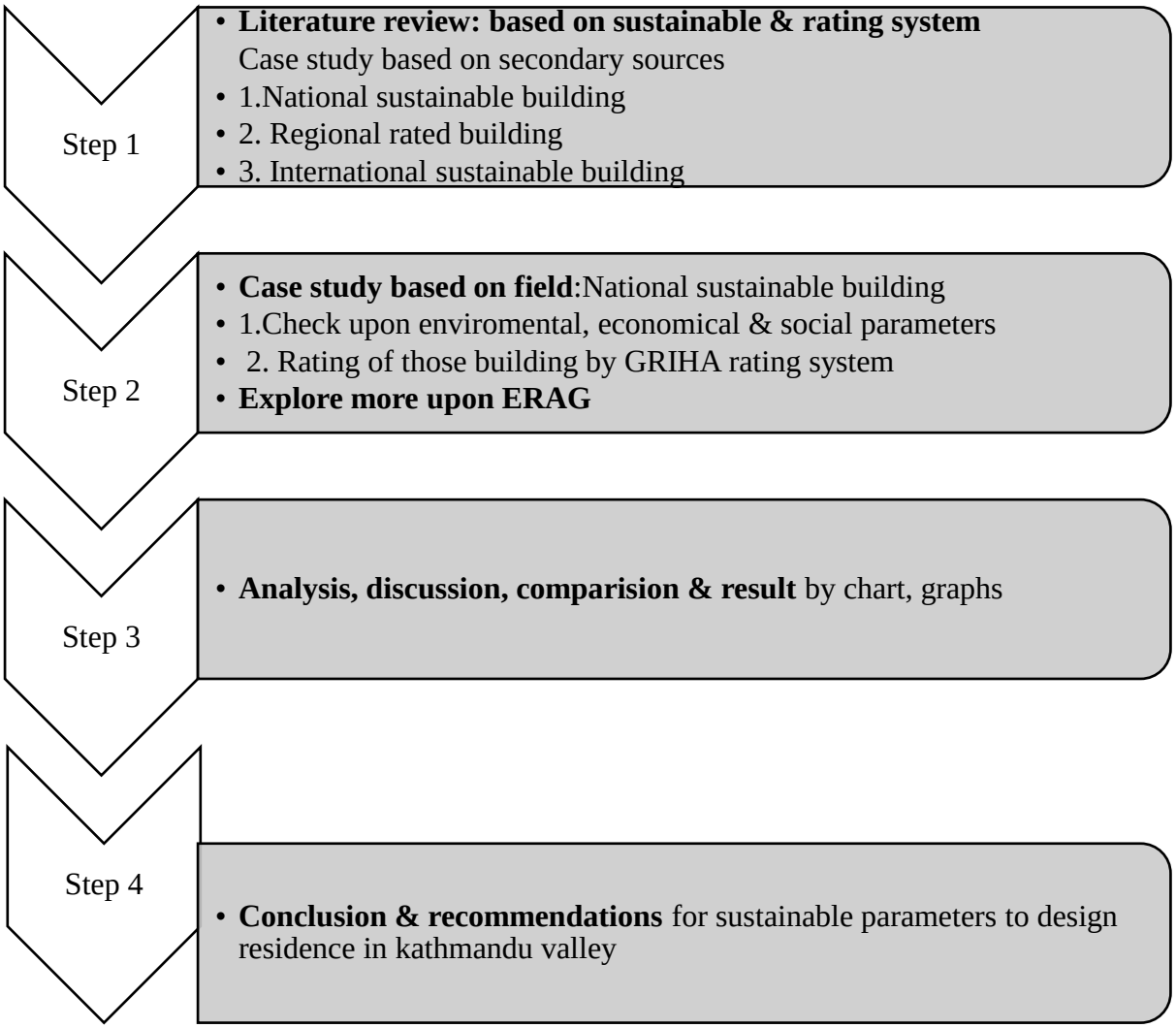


Figure 45: Research methodology

3.2 Literature review

Literature review is one of important part of my thesis. Literature review is survey of various information that gives conceptual ideas of research. Mainly, literature review is being decided by objectives I am going to do. Literature review gives ideas of following features:-

1. sustainable buildings

2. sustainable parameters
3. Rating system that can be used in international level,
4. Initiatives done in Nepal
5. Case study of international, regional sustainable building & on SVAGRIHA rated building of India

3.3 Case study on

Case study is done on sustainable residence of Kathmandu valley.

3.3.1 Sustainable residence of Kathmandu valley

1. Mato Ghar
2. Sura building
3. Nirpal residence
4. Hamro mato ghar

These are the building which follows sustainable parameters, mainly these residence are considered passive design techniques while designing building.

3.3.2 Analyzed with sustainable parameters

Sustainable parameters for case study is separated by literature review study and also referred by international & regional case study.

Environmental sustainable parameters

A. Site and surrounding

1. Site selection(access to road)
2. Availability of basic infrastructure
3. Preserve and protect landscape during construction
4. Design to include existing site features
5. Heat Island Effect, Green Roof

B. Energy and environment

1. Climate Responsive Building Design
2. Use of Renewable Energy
3. Efficient Heating/Cooling Equipment
4. Passive Design to reduce the conventional energy demand (Day-lighting)
5. Energy Efficient Lighting
6. Solar Water Heating and lighting (Solar Water Heating)
7. Use of Less Energy consuming equipment (Solar-power energy)

8. Reduce air Pollution during construction
9. Roof Treatment

C. Water efficiency

1. Use of Water Efficient Equipment
2. Rain Water Harvesting
3. Ground Water Recharge
4. Septic Tank / Waste water treatment technology (Waste Water Treatment)
5. Storm water design with Proper Drainage System (Protection from heavy rain/storm water design)

D. Building materials

1. Low embodied energy material
2. Availability of materials
3. Use of recycled materials
4. Green materials (Materials with Low Environmental Impact)
5. Reuse of materials on site (Reuse of materials)
6. Reduction in waste during construction
7. Promotion of local material

E. **Operation & Maintains cost**

Economical sustainable parameters

F. Economical parameters

1. In design phase
2. In Operation phase
3. Reuse of material after demolition

Social sustainable parameters

3.3.3 Analyzed with SVAGRIHA rating system

GRIHA is the green rating system, which is followed in India; due to lack of proper rating system in our country, GRIHA is selected because of regional context wise similar. Following are the points being analyzed by manually.

1. Landscape
2. Architecture & energy
3. Water & waste

4. Material
5. Lifestyle

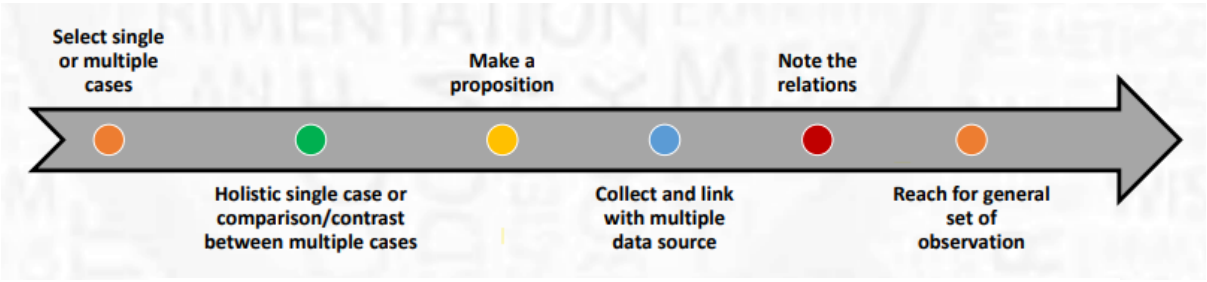
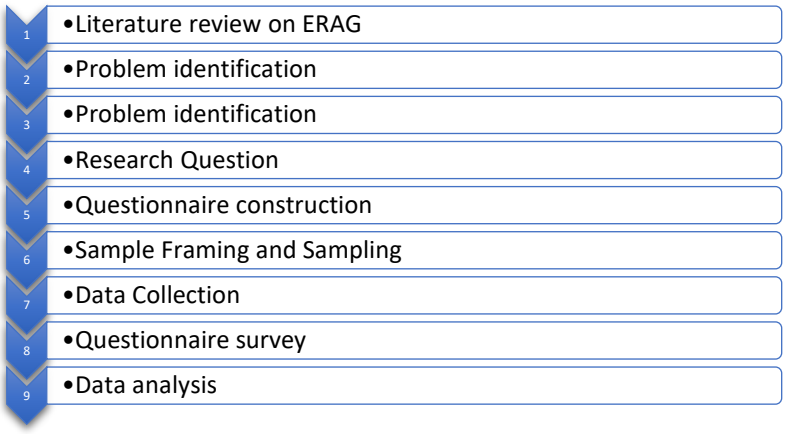


Figure 46: Method of case study

(Uprety, 2021)

3.4 Explore more upon ERAG

To explore upon ERAG, done by questionnaire survey. Structured questionnaire survey is used to know architects perceptions On ERAG. The steps to carry out the research are mentioned below:



3.4.1 Sample Framing and Sampling

A sample can be defined as a group with a relatively smaller number of people selected from a population for investigation purposes. The members of the sample are called as participants or respondents. A sample is defined as a finite part of population whose characteristics and experiences are studied so as to gain the information about the entire population (Wilumila, n.d.). Sampling is the process of drawing sample from whole population size, from which required data can be collected. This research comes under probabilistic sampling where population (numbers of architects) are being decided, according to their practice of work. The sample taken will be based those Architects working in sustainable field.

Sample size calculation

Maximum margin of error (€) = 5%

Confidence level= 95%

So,

z= 1.960

The number of architect are roughly 60 numbers.

So,

$$n = \frac{Nz^2P(1-P)}{(N-1)*e^2 + z^2*P(1-P)}$$

Therefore,

n= 20.28=20

3.4.2 Questionnaire Construction

A quantitative questionnaire will be designed to obtain the answers to evaluate the perception of architects upon ERA guideline & know how we can make ERAG in quantifying way. The major focus will be to address the questions that can withdraw the desirable objectives on "To explore on ecologically responsive architecture guide (ERAG) system purposed by SONA." Initially, ERAG based literature review is done to find out the variables for questionnaire which gives research questions. On ERAG literature review studied upon history, background, tangible, in-tangible aspects, Pachatato & Panchatato's element. Also, to make quantifying rating system through ERAG analyzed upon various aspects like International rating system LEED, GRIHA, parts of GRIHA had been studied.

The analysis is done in various base of information regarding history of ERAG, reasons to not continue of ERAG, survey upon how ERAG can be quantified & deciding upon how much rating can be done upon water & air element based on energy & environment. In reason not to continue of ERAG explain upon options: - Not familiar, technically not feasible, financially not feasible, Not required, Can't be quantified. In questionnaire explain about ERAG can be quantified is explain upon options: - Providing rating number, adding quantified sub points, providing knowledge on ERAG. Rating system based on air & water gives the points upon rating least 1 to highest 5, according to indicators & points architects have to gives points on questionnaire survey.

3.4.3 Data collection

Data will be collected primarily from the questionnaire and interview among the selected architect which is further processed to give suitable output. Primary source of data include information collected and processed directly by the researcher, such as observations, surveys, interviews, and focus groups. Also, the information is gathered from official

sources including books, journals, and articles and so on. This research is carried out by direct questionnaire method. The information's are gathered from the below-listed sources:

- Literature Review
- Questionnaire and Interviews

3.4.4 Field Operationalization

In this research closed-ended questions will be prepared for questionnaire survey. All the structured questions are been prepared. The structured questionnaires will be transferred in the KOBO toolbox to operationalize in the field and later will be deployed and collected through KOBO collect which is a free open-source tool for mobile data collection based on the selection of building as per convenience. The detailed information of survey includes selected option of architect.

3.4.5 Data Analysis

All the raw data will be collected in the KOBO TOOLBOX software instantly after the questionnaire survey is conducted. Further, the statistical analysis will be done using the SPSS statistical tool such that direct graphical comparisons can be made with the obtained results. SPSS refers to Software Package for Social Science, used for complex statistical data analysis to analyze survey data and provides a plethora of basic statistical functions which include frequencies, cross-tabulation, and bivariate statistics(Virginia tech, 2018). This technique is used to understand the relationship between dependent and interdependent variables that are stored in a data file and to compare events, groups.

3.5 Comparison with sustainable parameters

Comparison in between Mato ghar & Sura residence.

3.6 Comparison with rating system

Comparison in between Mato ghar & Sura residence.

3.7 Analysis, discussion & Result

3.8 Conclusion & recommendations

3.9 Research method

Research studies techniques are the strategies, tactics or strategies utilizes inside the series of facts or proof for analysis as a way to find new records or create better know how of a topic(The University of Newcastle, 2020). Research method gives ideas about which research process or methods using during studying. These methods are as follows:

1. Topic selection
2. Proposal finalization

According to research proposal: background, need, rationale of research, problem statement, research objectives, methodology validity, and limitation were drawn.

3. Literature review

Literature review will be done on following topic sustainability, history of sustainability, sustainable & green architecture, green building benefit, sustainable parameters, case study on traditional house, national & international context. After that sustainable parameters will be derived.

4. Sustainable parameters separation

Sustainable parameters will be separated by literature review

5. Case study of national and international context

For case study non-rated sustainable building will be selected because their absence of proper rating system in our country Nepal. Example: Mato ghar, surya building of Durbar marg, Nirpal residence.

6. Data Analysis

In data analysis sustainable parameter wise analysis will be done.

7. Finding and discussion
8. Conclusion

CHAPTER 4. CASE STUDIES

Case study is the major part of this research, based on case study findings, discussion & conclusion were drawn. Initially, interviews with sustainable designer architect taken then case study of sustainable residence of Kathmmandu valley was done.

4.1 Philosophy Architect Prabal Thapa on sustainable building

Architect Prabal Thapa incorporate sustainable design solutions in all projects, offering energy efficient and cost effective solutions for our clients. Placement and orientation of the constructing into the terrain, optimized production techniques and selection of suitable construction stuff form a key part of the making plan process. Passive design principles are incorporated to ensure the building to operate on minimum energy requirements (PrabalThapaArchitects, 2020). Landscaping is incorporated to actively facilitate the micro climate around the built. These are ensured through the selection of suitable plants and trees. Site works such as retaining walls and paving are selected to provide maximum water permeability for ground water recharge (PrabalThapaArchitects, 2020). At begging of mato Ghar design Architect Thapa had considered upon client demand and techniques of rammed earth as in required amount.

Architect Prabal Thapa mainly focused on 2 aspects of design to make building more sustainable. These are consideration of energy use at time of construction and another is energy required to sustain the building. At time of construction of building we have to consider on minimum earth movement at time of site preparation so that less energy would be consume. At time of construction Architect Thapa considers upon active and passive strategies in building. In case of Mato Ghar design in case of passive strategies he had considered upon orientation of building so that maximum sunlight enters in room so such south faced building has been chosen. Also, for minimum shadow cast he had played in height of building. Building has been south oriented and in sun zone staircase had been provided. Wall thickness had been done 14'' for thermal comfort inside building. In case of vegetation climate responsive i.e. local plant had been chose in case of landscaping and also for agricultural, vegetables production. For active strategies he had considered on sustainable element like formation of biogas, waste water treatment, solar panels and solar water heaters. In case of materials exposed bricks and concrete had been provided to save materials. Electrical and plumbing line are exposed to make work easily in time of

operation phase. Architect Thapa considered upon cross ventilation in each room and allows natural lighting in corridor of first floor through transparent sheet.

4.2 Philosophy Architect Bibhuti Man Singh on sustainable building

Bibhuti Man Singh is one of famous architect, considered for sustainable rating system for building. Considered upon sustainable features have to bring in building. In Nepal, there is lack of proper rating system. His concept is to bring qualitative analysis on building. That rating system have to considered upon design phase to construction phase. In other country context they have their own rating system. In case of Nepal, there is required of own rating system. So for both qualitative & quantitative analysis of building, he had think upon that analysis for Nepali context.

These parameters had been decided through literature review study and these parameters are been examine in site at time of case study. To know upon what are the parameters are been used, methods on installation ad advantages of these parameters selection. Also, these residence had been checked through SVA GRIHA rating system.

A. Site and surrounding

6. Site selection(access to road)
7. Availability of basic infrastructure
8. Preserve and protect landscape during construction
9. Design to include existing site features
10. Heat Island Effect, Green Roof

B. Energy and environment

10. Climate Responsive Building Design
11. Use of Renewable Energy
12. Efficient Heating/Cooling Equipment
13. Passive Design to reduce the conventional energy demand (Day-lighting)
14. Energy Efficient Lighting
15. Solar Water Heating and lighting (Solar Water Heating)
16. Use of Less Energy consuming equipment (Solar-power energy)
17. Reduce air Pollution during construction
18. Roof Treatment

C. Water efficiency

6. Use of Water Efficient Equipment
7. Rain Water Harvesting
8. Ground Water Recharge
9. Septic Tank / Waste water treatment technology (Waste Water Treatment)
10. Storm water design with Proper Drainage System (Protection from heavy rain/storm water design)

D. Building materials

8. Low embodied energy material
9. Availability of materials
10. Use of recycled materials
11. Green materials (Materials with Low Environmental Impact)
12. Reuse of materials on site (Reuse of materials)
13. Reduction in waste during construction
14. Promotion of local material

E. **Operation & Maintains cost**

F. Economical parameters

4. In design phase
5. In Operation phase
6. Reuse of material after demolition

G. Social parameters

H.SVA GRIHA Rating

4.3 Mato Ghar

One of sustainable building is Mato Ghar of Budhanilkantha, Kathmandu. Mato Ghar consists of various green features including the planning, construction technique, building materials, passive and active solar energy, bio gas and wastewater management, rain water

Figure 47: Mato Ghar

Google, 2022

harvesting and green spaces (Mishra, 2017). Features of Mato Ghar are as follows:

- Location: Budhanilkantha, Kathmandu
- Established in 2010A.D.
- Plinth area- 2263 sq ft
- Construction technology: Rammed earth
- Architect: Ar. Prabal Thapa
- Owner: Hemendra Bohora, harvard educated Environmental engineer (research on sustainable building practices)

❖ Sustainable Features of Mato Ghar are as follows:

4.3.1 Environmental parameters

Site and surrounding

Site selection (access to road)

- 1.4 km from Rudreshwor chowk bus stop Budhanilkantha road.
- Properly accessible via road through main road.
- Site is connected with 13' road

Availability of basic infrastructure

Basic infrastructure refers to main railways, roads, canals, harbors and docks, the electromagnetic telegraph, drainage, dikes and land reclamation (Torrisi & Gianpiero , 2009). That mainly indicates for water supply, sanitary system and tele-communications.

Figure 48: Road access to site
(Mishra, 2017)

- Public vehicle are easily available within walking distance.
- Water supply pipelines and sanitary systems are connected with site.
- There is available of electricity and internet facility.

Preserve and protect landscape during construction

- Building was built according to actual landform.
- There is uplift of west wing to not disturb in actual landform.
- In case of Landscape design considered upon existing natural form.

Figure 49: Natural form of Mato ghar

Design to include existing site features

- There is slightly contour difference in actual site condition, had been made accessible via stairs.
- Steps had been design with respect to site.
- Straight building toward south orientation.
- Considered on exiting tress, water resources.
- Considered on earth movement characters.

Figure 50: Landscape design in existing landform

Heat Island Effect, Green Roof

- Heat island effect is less on Mato ghar due to use of floor and roof finishing material
- Solar system had been used.

Energy and environment

Climate Responsive Building Design

- Orientation of building is south, east west elongated.
- Kitchen and toilets are mostly occupied in North where living room, bedroom are in south orientation which catches long term solar radiation.

Figure 51: Use of rammed earth techniques

Use of Renewable Energy

- Use of renewable building material like Rammed earth technology, which is sustainable material which produce less carbon at time of construction that harms less in environment.

Efficient Heating/Cooling Equipment

- Solar water heater is used.
- Solar panels are used for lighting purposes.
- Almost 90% of total electricity needs comes from solar power.
- Use of bamboo frame and straw mats for thermal comfort.

Figure 52: Solar photovoltaic panels

- Use of natural ventilation through roofing.

Figure 53: Natural ventilation through roof

Figure 54: Straw roof with bamboo rafter

Passive Design to reduce the conventional energy demand (Day-lighting)

- Orientation of building its gives direct natural lights.
- Open floor plans gives on ground and upper floor gives passes of lights
- All rooms have cross ventilation to provide cooling requirements for summer
- Selection of transparent materials for roofing which allows to passes of lights to interior corridor.
- According to NBC code 206:2015, 1/8th of room area is required for natural lighting, in case of Aama Ghar corridor total corridor portion had been provided by natural lights i.e. 100% opening for lighting and that is sufficient.

Figure 55: Skylight for porch

Energy Efficient Lighting

- Natural lighting had been prioritized, in interior, kitchen study areas.
- Northern and Southern wing get the afternoon sun all year round.
- Considered upon to minimize shadow cast in building.

Figure 56: Skylight of top floor

Solar Water Heating and lighting (Solar Water Heating)

- Solar panels generates 2.8 KW of electricity per second.
- All energy stored to inverters and channeled to appliances.
- Almost 90% of total electricity needs comes from solar power.
- Electricity from grid only used for car charging and pumping water.

Figure 57: Solar panels

Use of Less Energy consuming equipment (Solar-power energy)

- Solar panels are used as active strategies for energy.
- South oriented solar panels are provided.

Reduce air Pollution during construction

- Air pollution has been reduced at phase of construction by choosing of less embodied energy containing materials.
- According to site condition design had been done, for site making less energy had been used.

Roof Treatment

- CGI roof with air gap had been provided, then reflector insulator had been provided then straw mat, then bamboo had been provided.

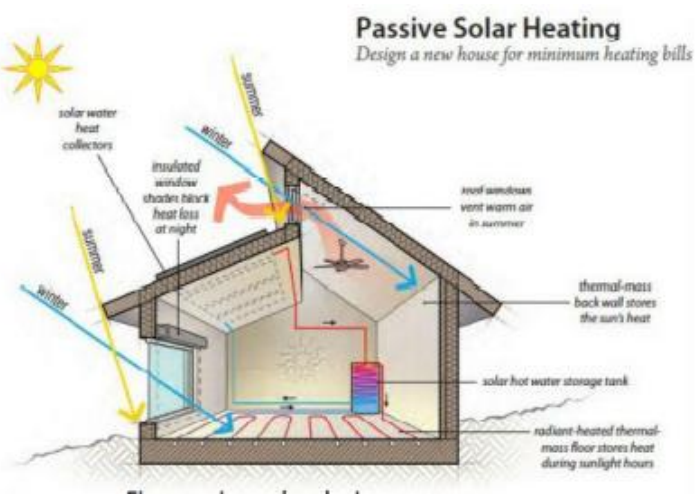


Figure 59: Section of mato ghar

(Mishra, 2017)

gure 58: Single side Aluminum foil

Water efficiency

Use of Water Efficient Equipment

- One of major priority considered by architect.
- Water efficient equipment like washing machine kitchen and bathroom.

Rain Water Harvesting

- There is approaches for rainwater harvesting through gutters from roof and treated for use of water for various purposes like cleaning, washing, irrigation in garden. Ground Water Recharge
- Maximum landscape is soft-scape that allows for ground water recharge. As shown in masterplan there is maximum green landscape, soft cape covers 60% of total site area. There is maximum soft-scape which are either water element or agricultural farm.

Figure 60: Gutter for rainwater harvesting

Septic Tank / Waste water treatment technology (Waste Water Treatment)

- There is separation of rain water, solid waste and grey water.
- Polluted water had not been directly passed to Natural River.

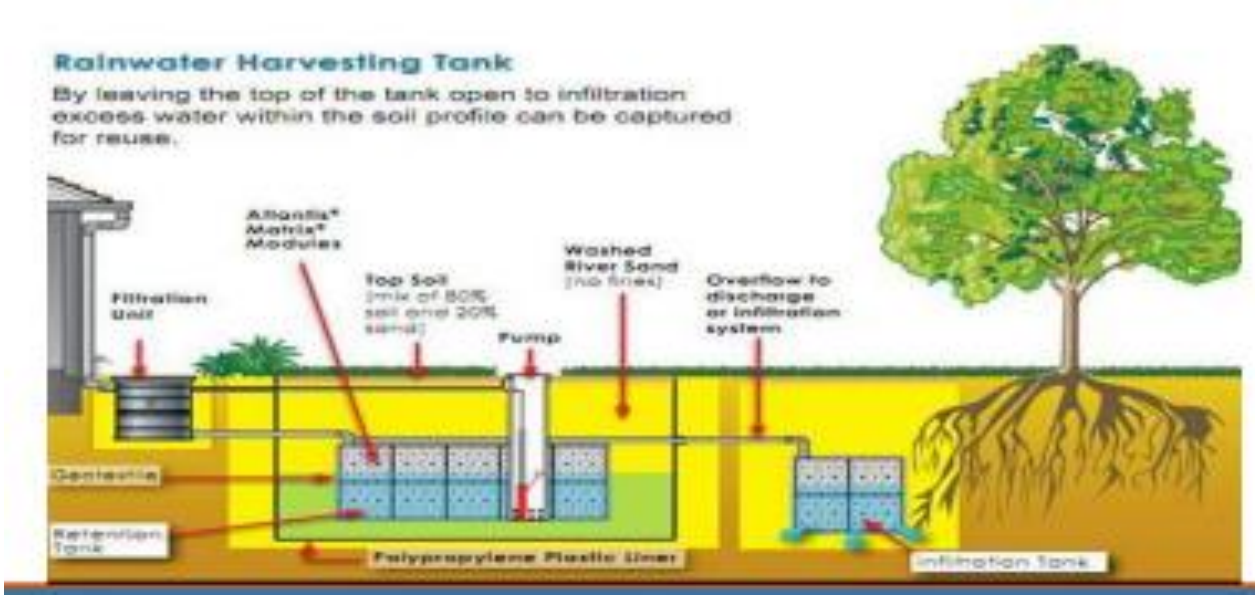


Figure 61: Water treatment plant

(architects, 2008)

Following are the steps involved in waste water treatment:

1. The Primary Unit: The primary unit involves the sedimentation of wastewater and sludge, and their primary treatment in septic tanks.

2. The Secondary Unit: In this unit, both black and grey water is treated in a chambered Anaerobic Baffled Reactor (ABR).

3. The Tertiary Unit: The final unit involves aerobic/anaerobic treatment inside Horizontally Planted Gravel Filters (HPGF) that reduces colors and odors.

- After tertiary treatment, the vegetables/garden plants absorb phosphorus and nitrogen. The clean water is used for flushing of bathroom and gardening, as a consequence, reducing the use/ requirement of sparkling water.
- After tertiary treatment, the vegetables/garden plants absorb phosphorus and nitrogen(Bhandari, n.d.).

Building materials

Low embodied energy material

- Landscape Floorings: Soft cape with flag stone.
- Indoor flooring: Tile flooring.
- Embodied energy of concrete, brick, timber is respectively 0.95 MJ/Kg, 3 MJ/Kg and 8.5 MJ/Kg.
- Wall: rammed earth, exposed concrete bands brick facing walls and somewhere plastered.

Figure 63: Mud exposed wall

Availability of materials

- Locally available material are used like slate flooring outdoor areas.
- Bamboo as rafter, straw mats as thermal insulating material are being used.

Use of recycled materials

- Not much considered on recycled materials

Figure 64: Roofing skylight

Green materials (Materials with Low Environmental Impact)

- Brick exposed both externally and internally, no plaster and paint in the wall which reduced cost, harmfulness in the environment.

- Openings aluminum frame double glazed glass panels which is environmental friendly.
- Floorings is done through clay tile, laminated wood which provides thermal comfort as well as for low environmental impact.
- Roof: straw mats, bamboo rafter being used.
- Lighting fixtures like LED light is used which consume less energy; longer life time.
- Sanitary fixtures: normal fixtures are used which are easily available in the market, exposed of sanitary fixtures.
- The open plumbing and electrical systems reduce the cost of concealing these features.

Figure 66: Open sanitary pipeline

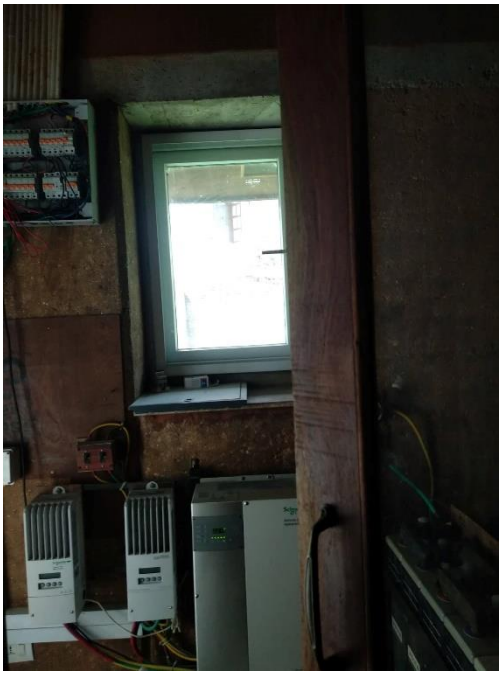


Figure 65: Open electrical pipeline

Operation & maintenance cost

- Other maintains are similar of modern building like external paints, change of material.
- Invertor maintains cost is high.
- Rid bed maintains is high and not easy.

4.3.2 Economical parameters

In design phase

- For design sustainable features had been considered which is initially high in construction which had been minimized by simple design.

Figure 67: Simple in exterior form

In Operation phase

- For building no external heating and cooling is required.
- Sufficient for summer and winter.

Reuse of material after demolition

- Used mud, bamboo, straw are reusable.

Social parameters

- At time of construction, rammed earth technique is labor intensive.
- Less effects to environment effect (U vale Wall: 0.76 (wall thickness 18"), Floor: 0.5, Roof: 0.3) (Mishra, 2017).

4.3.3 SVA GRIHA Rating

Sub-group: Landscaping

Criteria: Reduce exposed, hard paved surface on site and maintain native vegetation cover on site.

Figure 68: Stone slate as hardscape

Figure 69: Green garden

Table 19: Mato Ghar landscape category 1

Criterion no.	subdivision	Point allocated	Point Achieved	Remarks
1.	i. All trees in the perimeter zone shall be protected	02	02	• All tress are being protected • All trees are planted after planning of building.
	i. The total number of trees on site before and after construction	02	02	
	iii. All new trees planted on site will be native	02	02	

Sub-Group: Architecture & Energy

Criteria: Passive architectural design and systems

- Adopt of passive design measures

- Use of low-energy or passive heating/cooling measures >> ensure overall energy consumption building >> ensuring good thermal comfort conditions for the occupants.

Figure 70: Passive cooling technique for roof

Figure 71: Roof cooling natural ventilation

Table 20: Mato ghar Architecture & Energy category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
2.	Passive architectural design and systems	i. Adopt a minimum of 2 passive design measures in building	02	02	• Roof cooling techniques & rammed earth techniques. • Floor to ceiling windows openings.
		ii. Active, low-energy cooling/heating systems are installed in the building	02	01	

Criteria: Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration

- Design of openings >> direct heat gain through fenestration is minimized >> maximizing daylight penetration.

- Reduce the direct heat gain through fenestration >> ensuring good daylighting.

Figure 73: Mato Ghar long window

Figure 72: Mato ghar Ceiling opening

Table 21: Mato ghar Architecture & Energy category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
3.	Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration	i. Reduce the overall insolation through the fenestration by 10%, 20%, 30% or more over the base case	01,02,03 (03)	01	• Use of see through boundary wall. • Use of window from floor to ceiling.
		ii. More than 25%,50%, 70%, 90% of the total living area falls under	Mandatory, 01,02,03 (03)	03	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		daylight zones			

Criteria: Efficient artificial lighting system

- Adoption of energy efficient artificial lighting systems (lamps/luminaires/ballasts etc.) >> to reduce the overall LPD (Lighting Power Density) below ECBC recommended levels.

Figure 74: Use of CFL bulb

Table 22: Mato ghar Architecture & Energy category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
4.	Efficient artificial lighting system	Demonstrate lower LPD levels in the building design as compared to ECBC recommended LPD levels	02	01	• Use of CFL, LED bulbs.

Criteria: Thermal efficiency of building envelope

Table 23: Mato ghar Architecture & Energy category 4

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
5.	Thermal efficiency of building envelope	When viewing the output in sq.ft./TR, the project should achieve	1,1 (02)	01	• Use of rammed earth thick wall, sun dried brick

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		sq.ft./TR higher than the prescribed thresholds.			which helps to reduce indoor temperature.

Criteria: Use of Energy Efficient Appliances

- The intent of this criterion is to promote the adoption of energy efficient appliances.

Table 24: Mato ghar Architecture & Energy category 5

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
6.	Use of Energy Efficient Appliances	All the Air-conditioners, fans and geyser installed on site are 3-star,4-star,5-star BEE labelled (Bureau of Energy Efficiency; run by the Indian government under Ministry of Power	01,02,03(03)	01	• Use of normal market available fan.

Criteria: Use of renewable energy on site

- To promote the use of renewable energy; Renewable energy system for electricity generation.
- Solar Water Heaters.

Table 25: Mato ghar Architecture & Energy category 6

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
7.	Use of renewable energy on site	i. Rated capacity of the renewable energy system installed on site conforms to or exceeds the thresholds[100-500m^2 Built up area >> 1KW	02	02	• Use of solar panels and solar water heaters. • Solar water is sufficient for daily activities.
		i. Installed capacity of solar water heaters on site is equivalent to 50%, 75% or more of the daily hot water requirement [Hot water requirement for Residence :100 liters per day]	01,02(02)	02	

Sub-Group: Water & Waste

Criteria: Reduction in building and landscape water demand

- To reduce the overall water demand of the building through use of low-flow fixtures.
- To reduce the landscape water demand through the use of native species of flora and efficient irrigation systems.

Table 26: Mato ghar Water & waste category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
8.	Reduction in building and landscape water demand	i. Reduce the total water requirement in the building by at least 25%, 33%, 50% or more over the base case.	01,02,03 (03)	03	• Water efficient equipment. • Landscape maximum area is soft cape.
		ii. Reduce the total water requirement in the building by 25%, 50% or more over the base case(to reduce the landscape water demand through the use of native species of flora and efficient irrigation systems).	01,02 (02)	02	

Criteria: Rainwater harvesting

- Capture rainwater for use on site.
- To promote rainwater harvesting >> recharge into the ground water aquifer.

Figure 75: Rainwater collecting pond

Table 27: Mato ghar Water & waste category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
9.	Rainwater harvesting	i. The total rainwater harvesting potential for the project (from the roof only) is equivalent to at least 75% of the total building water demand over 2 days	03	02	• Rainwater harvesting through roof. • Rainwater is used for ground water recharge.
		ii. Rainwater is recharged into the ground water aquifer and has a	01	01	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		filtration system installed			

Criteria: Generate resource from waste

- Zero waste generation through adoption of requisite strategies

Table 28: Mato ghar Water & waste category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
10.	Generate resource from waste	Zero waste generation through adoption of requisite strategies.	02	01	- Biogas production. - Separation of degradable and non-degradable wastage.

Sub-Group: Material

Criteria: Reduce embodied energy of building

Figure 77: Use of earth, cement plater

Figure 76: Use of timber, mud plaster

Table 29: Mato ghar Materials category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
11.	Reduce embodied energy of building	i. 100% of OPC is replaced by PPC (including building structure and masonry and plaster mortar)	02	1	• Less use of cemented structure. • Embodied energy of mud, bamboo is less. • Embodied energy of these material is less.
		ii. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 5% or more over the base case	01	1	
		iii. The overall embodied energy of the floor	02	2	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		slabs, roof slabs and walls is reduced by 10% or more over the base case			

Criteria: Use of low-energy materials in interiors

Table 30: Mato ghar Material category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
12.	Use of low-energy materials in interiors	i. 70% of the flooring is low-energy	01	01	• Parqueting and tile flooring. • Use of rammed earth wall. • Use of low VOC paints.
		ii. At least 70% of internal partitions/paneling/false ceiling/in-built furniture/ doors & window-panels & frames are low-energy	02	02	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		iii. All interior paints are low-VOC and lead-free (including no paint/plain mortar finish/white wash/lime mortar finish)	01	01	

Sub-Group: Lifestyle

Criteria: Adoption of green lifestyle

- Adoption of green lifestyle
- Reduce the carbon footprint of occupants
- Equitable distribution of resources

Figure 79: Mato ghar organic farming

Figure 78: Mato ghar organic fruit

Table 31: Mato ghar Lifestyle category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
13.	Adoption of Green Lifestyle	i. Built-up area meets the prescribed threshold a. [Residential : 12.5 sq.m< X < 50 sq.]	01	01	• Built up area around 50 cu.m • School, hospital, bus-stop re within walking distance. • Organic farming.
		ii. Total expected distance travelled to basic services in a year is less than 2100 km (Residential= 7-11 services, 2100km)	01	01	
		iii. Environmental awareness is created through panels/brochures/printouts etc. Or Organic farming is carried out on site.	01	01	

Criteria: Innovation

- Adopt strategies, independent of the previous 13 criterion, to make the project more sustainable
- Submit documents/narrative highlighting the measures adopted on site
- For each innovation – 1 point (maximum 2 points)

Table 32: Mato ghar Lifestyle category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
14.	Innovation	For each innovation (max. 2 points)	02	02	• Space in – out building. • Construction of rammed earth

4.4 Sura building

One of sustainable building is Sura building of Budhanilkantha, Kathmandu. Sura building consists of various green features including the planning, construction technique, building materials, passive and active solar energy, rain water harvesting & green features. Features of Sura building are as follows:

- Location: Durbarmarg, Kathmandu
- Established in 2008A.D.
- Construction technology: Modern techniques
- Architect: Ar. Prabal Thapa
- Owner: Riva Thapa

Figure 80: Sura building of Durbarmarg

❖ Sustainable Features of Sura building are as follows:

4.4.1 Environmental parameters

Site and surrounding

Site selection (access to road)

- Properly accessible via road through main road.
- Site is connected with 2 side road.

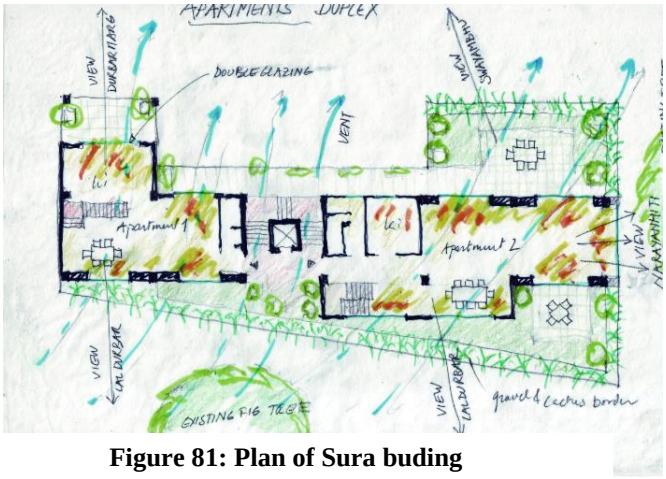


Figure 81: Plan of Sura buding

Availability of basic infrastructure

Basic infrastructure refers to main railways, roads, canals, harbors and docks, the electromagnetic telegraph, drainage, dikes and land reclamation (Torrisi & Gianpiero , 2009). That mainly indicates for water supply, sanitary system and tele-communications.

- Public vehicle are easily available within walking distance.
- Water supply pipelines and sanitary systems are connected with site.
- There is available of electricity and internet facility.

Preserve and protect landscape during construction

- Building was built according to actual landform.
- In case of Landscape design considered upon existing trees in south side.

Design to include existing site features

- There is slightly contour difference in actual site condition, had been made accessible via stairs.
- Basement plan, according to meet with actual land form.
- Considered on earth movement characters.

Figure 82: Section of Sura building

Heat Island Effect, Green Roof

- Heat island effect is less on Sura buiding due to use of green roof & vegetation.
- Solar system had been used.

Figure 83: Vegetation in staircase

Energy and environment

Climate Responsive Building Design

- Orientation of building is on south.
- Services area like stairs, restroom are centrally provided.

Use of Renewable Energy

- Use of renewable source like solar panels.

Efficient Heating/Cooling Equipment

- Solar water heater is used.
- Solar panels are used for lighting purposes.

Figure 84: Solar panels for heating & lighting

Passive Design to reduce the conventional energy demand (Day-lighting)

- Orientation of building its gives direct natural lights.
- Open floor plans gives on ground and upper floor gives passes of lights.
- All rooms have cross ventilation to provide cooling requirements for summer.
- Selection of transparent materials for roofing which allows to passes of lights to interior corridor.

Figure 85: Natural lighting

- According to NBC code 206:2015, 1/8th of room area is required for natural lighting, in case of Aama Ghar corridor total corridor portion had been provided by natural lights i.e. 100% opening for lighting and that is sufficient.

Energy Efficient Lighting

- Natural lighting had been prioritized, in interior, kitchen study areas.
- Considered upon to minimize shadow cast in building.

Figure 86: Plantation on terrace

Use of Less Energy consuming equipment (Solar-power energy)

- Solar panels are used as active strategies for energy.
- South oriented solar panels are provided.

Reduce air Pollution during construction

- Air pollution has been reduced at phase of construction by choosing of less embodied energy containing materials.
- According to site condition design had been done, for site making less energy had been used.

Roof Treatment

- Green roof, plantation had been provided.

Figure 87: Green roof of Sura building

Water efficiency

Use of Water Efficient Equipment

- One of major priority considered by architect.
- Water efficient equipment like washing machine, kitchen and bathroom.

Rain Water Harvesting

- There is approaches for rainwater harvesting through gutters from roof and treated for use of water for various purposes like cleaning, washing, irrigation in garden.

Septic Tank / Waste water treatment technology (Waste Water Treatment)

- There is separation of rain water, solid waste and grey water.

Figure 88: Steel horizontal & vertical element

Building materials

Low embodied energy material

- Landscape Floorings: Soft cape with flag stone.
- Vertical & horizontal steel are being used.
- Indoor flooring: Tile flooring, green roofing.
- Embodied energy of concrete, brick, steel is respectively 0.95 MJ/Kg, 3 MJ/Kg and 24.4 MJ/Kg.

Green materials (Materials with Low Environmental Impact)

- Brick exposed both externally and internally, no plaster and paint in the wall which reduced cost, harmfulness in the environment.
- Openings aluminum frame double glazed glass panels which is environmental friendly.
- Floorings is done through clay tile, laminated wood which provides thermal comfort as well as for low environmental impact.

Figure 89: Exposed concrete, wall without plaster

- Lighting fixtures like LED light is used which consume less energy; longer life time.

- Sanitary fixtures: normal fixtures are used which are easily available in the market, exposed of sanitary fixtures.
- The open plumbing and electrical systems reduce the cost of concealing these features.

Figure 90: Exposed brick & block

Operation & Maintains cost

- Other maintains are like external paints, change of material.
- Invertor maintains cost is high.

  Steel & glass required more maintains than other element.

4.4.2 Economical parameters

In design phase

- For design sustainable features had been considered which is initially high in construction which had been minimized by simple design.

In Operation phase

- For building no external heating and cooling is required.
- Sufficient for summer and winter.

Reuse of material after demolition

- Used of steel is reusable.

4.4.3 Social parameters

- At time of construction, locally available labor had been used.

❖ **SVA GRIHA** rating of Sura Building are as follows:

4.4.4 SVA GRIHA Rating

Sub-group: Landscaping

Criteria: Reduce exposed, hard paved surface on site and maintain native vegetation cover on site.

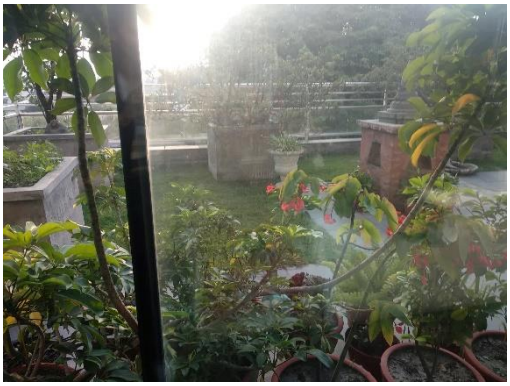


Figure 91: Roof garden

Figure 92: Plantation in parking

Table 33: Sura building landscape category 1

Criterion no.	subdivision	Point allocated	Point Achieved	Remarks
1.	i. All trees in the perimeter zone shall be protected	02	0	• All tress are being protected • All trees are planted after planning of building.
	ii. The total number of trees on site before and after construction	02	01	
	iii. All new trees planted on site will be native	02	02	

Sub-Group: Architecture & Energy

Criteria: Passive architectural design and systems

- Adopt of passive design measures
- Use of low-energy or passive heating/cooling measures >> ensure overall energy consumption building >> ensuring good thermal comfort conditions for the occupants.

Table 34: Sura Architecture & Energy category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
2.	Passive architectural design and systems	i. Adopt a minimum of 2 passive design measures in building	02	01	• Solar panels are being used. • Wall fan is used for some bedroom .
		ii. Active, low-energy cooling/heating systems are installed in the building.	02	01	

Criteria: Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration

- Design of openings >> direct heat gain through fenestration is minimized >> maximizing daylight penetration.
- Reduce the direct heat gain through fenestration >> ensuring good daylighting.

Figure 93: Vertical shading element

Table 35: Sura building Architecture & Energy category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
3.	Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration	i. Reduce the overall insolation through the fenestration by 10%, 20%, 30%or more over the base case	01,02,03 (03)	01	• Use of vertical steel element. • Use of window from floor to ceiling.
		ii. More than 25%,50%, 70%, 90% of the total living area falls under daylight zones	Mandatory, 01,02,03 (03)	01	

Criteria: Efficient artificial lighting system

- Adoption of energy efficient artificial lighting systems (lamps/luminaires/ballasts etc.) >> to reduce the overall LPD (Lighting Power Density) below ECBC recommended levels.

Table 36: Sura building Architecture & Energy category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
4.	Efficient artificial lighting system	Recommended LPD levels	02	01	• Use of CFL,LED bulbs.

Criteria: Thermal efficiency of building envelope

Table 37: Sura building Architecture & Energy category 4

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
5.	Thermal efficiency of building envelope	When viewing the output in sq.ft./TR, the project should achieve sq.ft./TR higher than the prescribed thresholds.	1,1 (02)	0	

Criteria: Use of Energy Efficient Appliances

- The intent of this criterion is to promote the adoption of energy efficient appliances.

Table 38: Sura building Architecture & Energy category 5

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
6.	Use of Energy Efficient Appliances	All the Air-conditioners, fans and geyser	01,02,03(03)	01	• Use of normal market

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		installed on site are 3-star,4-star,5-star BEE labelled (Bureau of Energy Efficiency; run by the Indian government under Ministry of Power			available fan.

Criteria: Use of renewable energy on site

- To promote the use of renewable energy; Renewable energy system for electricity generation.
- Solar Water Heaters.

Table 39: Sura building Architecture & Energy category 6

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
7.	Use of renewable energy on site	i. Rated capacity of the renewable energy system installed on site conforms to or exceeds the thresholds[100-500m^2 Built up area >> 1KW	02	01	• Use of solar panels and solar water heaters. • Solar water is sufficient for daily activities.
		i. Installed capacity of solar	01,02(02)	01	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		water heaters on site is equivalent to 50%, 75% or more of the daily hot water requirement [Hot water requirement for Residence :100 liters per day]			

Sub-Group: Water & Waste

Criteria: Reduction in building and landscape water demand

- To reduce the overall water demand of the building through use of low-flow fixtures.
- To reduce the landscape water demand through the use of native species of flora and efficient irrigation systems.

Table 40: Sura building Water & waste category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
8.	Reduction in building and landscape water demand	i. Reduce the total water requirement in the building by at least 25%, 33%, 50% or	01,02,03 (03)	01	• Water efficient equipment. • Balcony maximum area is soft cape.

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		more over the base case.			
		ii. Reduce the total water requirement in the building by 25%, 50% or more over the base case (to reduce the landscape water demand through the use of native species of flora and efficient irrigation systems).	01,02 (02)	02	

Criteria: Rainwater harvesting

- Capture rainwater for use on site.
- To promote rainwater harvesting >> recharge into the ground water aquifer.

Table 41: Sura building Water & waste category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
9.	Rainwater harvesting	i. The total rainwater harvesting potential for the project (from the roof only) is equivalent to at least 75% of the total building water demand over 2 days.	03	01	• Rainwater harvesting through roof. • Rainwater is used for ground water recharge.
		ii. Rainwater is recharged into the ground water aquifer and has a filtration system installed.	01	01	

Criteria: Generate resource from waste

- Zero waste generation through adoption of requisite strategies

Table 42: Sura building Water & waste category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
10.	Generate resource from waste	Zero waste generation through adoption of requisite strategies.	02	0	-No such initiations

Sub-Group: Material

Criteria: Reduce embodied energy of building.

Table 43: Sura building Materials category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
11.	Reduce embodied energy of building	i. 100% of OPC is replaced by PPC (including building structure and masonry and plaster mortar)	02	0	• Less use of cemented structure. • Exposed brick wall saves plaster and paints. • Embodied energy of these material is less.
		ii. The overall embodied energy of	01	1	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		the floor slabs, roof slabs and walls is reduced by 5% or more over the base case			
		iii. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 10% or more over the base case	02	2	

Criteria: Use of low-energy materials in interiors.

Table 44: Sura building Material category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
12.	Use of low-energy	i. 70% of the flooring is low-energy	01	01	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
	materials in interiors				• Parqueting and tile flooring. • Open floor plan. • Use of low VOC paints.
		ii. At least 70% of internal partitions/paneling/false ceiling/in-built furniture/ doors & window-panels & frames are low-energy	02	01	
		iii. All interior paints are low-VOC and lead-free (including no paint/plain mortar finish/white wash/lime mortar finish)	01	01	

Sub-Group: Lifestyle

Criteria: Adoption of green lifestyle

- Adoption of green lifestyle
- Reduce the carbon footprint of occupants
- Equitable distribution of resources

Table 45: Sura building Lifestyle category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
13.	Adoption of Green Lifestyle	i. Built-up area meets the prescribed threshold a. [Residential: 12.5 sqm< X < 50 sqm]	01	01	• School, hospital, bus-stop re within walking distance. • Organic farming.
		ii. Total expected distance travelled to basic services in a year is less than 2100 km (Residential= 7-11 services, 2100km)	01	01	
		iii. Environmental awareness is created through panels/brochures/printouts etc.or Organic farming is carried out on site.	01	01	

Criteria: Innovation

- Adopt strategies, independent of the previous 13 criterion, to make the project more sustainable
- Submit documents/narrative highlighting the measures adopted on site
- For each innovation – 1 point (maximum 2 points)

Table 46: Sura building

Lifestyle category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
14.	Innovation	For each innovation (max. 2 points)	02	0	• Space in – out building. • Construction of green roof.

4.5 Nirpal Residence

One of sustainable building is Nirpal residence of Kamal Pokhari, Kathmandu. Nirpal residence consists of various green features including the planning, construction technique, building materials, passive and active solar energy and wastewater management, rain water harvesting and green spaces. Features of Nirpal residence are as follows:

- Location: Kamal Pokhari, Kathmandu
- Established in 2019A.D.
- Plinth area- 1026.75 sq ft
- Construction technology: Rammed earth
- Architect: Ar. Nirpal Adhikari
- Owner: Ar. Nirpal Adhikari

Figure 94: Nirpal residence

❖ Sustainable Features of Mato Ghar are as follows:

4.5.1 Environmental parameters

Site and surrounding

Site selection (access to road)

- 400 m from Pashupati road.
- Properly accessible via road through main road.
- Site is connected with 13' road.

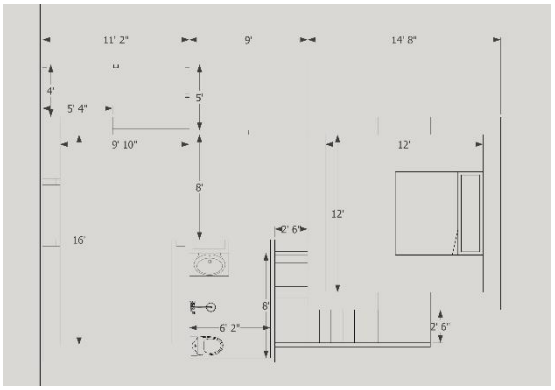


Figure 95: First Plan layout

Availability of basic infrastructure

Basic infrastructure refers to main railways, roads, canals, harbors and docks, the electromagnetic telegraph, drainage, dikes and land reclamation (Torrisi & Gianpiero , 2009). That mainly indicates for water supply, sanitary system and tele-communications.

- Public vehicle are easily available within walking distance.
- Water supply pipelines and sanitary systems are connected with site.
- There is available of electricity and internet facility.

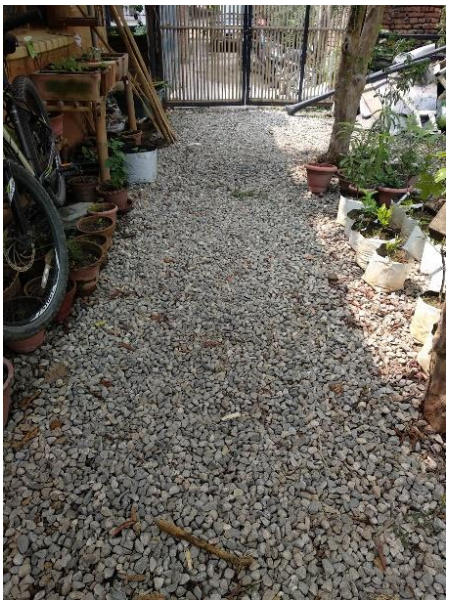


Figure 96: Natural form of Nirpal residence

Preserve and protect landscape during construction

- Building was built according to actual landform.
- In case of Landscape design considered upon existing natural form.

Design to include existing site features

- Topography of land is flat somewhere gentle slope.
- Existing site tress are being considered.
- Straight building toward south orientation.
- Considered on earth movement characters.

Heat Island Effect, Green Roof

- Heat island effect is less Nirpal residence due to use of floor and roof finishing material

Energy and environment

Climate Responsive Building Design

- Orientation of building is south.
- Kitchen and toilets are mostly occupied in North where living room, bedroom are in south orientation which catches long term solar radiation.

Use of Renewable Energy

- Use of renewable building material like Rammed earth technology, which is sustainable material which produce less carbon at time of construction that harms less in environment.

Passive Design to reduce the conventional energy demand (Day-lighting)

- Orientation of building its gives direct natural lights.
- Open floor plans gives on ground and upper floor gives passes of lights
- All rooms have cross ventilation to provide cooling requirements for summer
- Selection of transparent materials for roofing which allows to passes of lights to interior corridor.
- According to NBC code 206:2015, 1/8th of room area is required for natural lighting, in case of Aama Ghar corridor total corridor portion had been provided by natural lights i.e. 100% opening for lighting and that is sufficient.

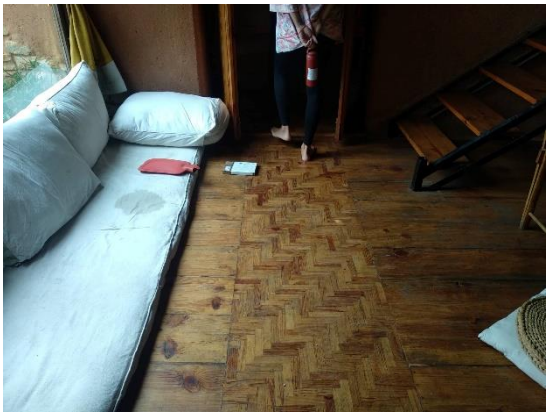


Figure 97: Sufficient Sunlight of Nirpal residence

Energy Efficient Lighting

- Natural lighting had been prioritized, in interior, kitchen study areas.
- Northern and Southern wing get the afternoon sun all year round.
- Considered upon to minimize shadow cast in building in south side.

Use of Less Energy consuming equipment (Solar-power energy)

- Solar panels are used as active strategies for energy.
- South oriented solar panels are provided.

Reduce air Pollution during construction

- Air pollution has been reduced at phase of construction by choosing of less embodied energy containing materials.
- According to site condition design had been done, for site making less energy had been used.

Roof Treatment

CGI roof with air gap had been provided, then reflector insulator had been provided then straw mat, then bamboo had been provided.

Water efficiency

Use of Water Efficient Equipment

- Water efficient equipment like washing machine kitchen and bathroom.

Building materials

Low embodied energy material

- Landscape Floorings: pebble flooring.
- Indoor flooring: Tile, parqueting flooring.
- Wall: rammed earth, exposed concrete bands brick facing walls and somewhere plastered.

Availability of materials

- Locally available material are used like slate flooring outdoor areas.
- Bamboo as rafter, straw mats as thermal insulating material are being used.

Figure 98: Tile flooring, bamboo rafters, straw mats in Nirpal residence

Use of recycled materials

- Not much considered on recycled materials.

Green materials (Materials with Low Environmental Impact)

- Openings aluminum frame double glazed glass panels which provides comfortable indoor environment.
- Floorings is done through clay tile, laminated wood which provides thermal comfort as well as for low environmental impact.
- Roof: straw mats, bamboo rafter being used.
- Lighting fixtures like LED light is used which consume less energy; longer life time.
- Sanitary fixtures: normal fixtures are used which are easily available in the market, exposed of sanitary fixtures.
- The open plumbing and electrical systems reduce the cost of concealing these features.

Operation & maintenance cost

- Other maintains are similar of modern building like external paints, change of material.
- Invertor maintains cost is high.

  Rid bed maintains is high and not easy.

4.5.2 Economical parameters

In design phase

- For design sustainable features had been considered which is initially high in construction which had been minimized by simple design, also there 40% of material cost & 60% of labor cost.

In Operation phase

- There is not much consideration on operation phase.

Reuse of material after demolition

- Used mud, bamboo, straw are reusable.

4.5.3 Social parameters

- At time of construction, rammed earth technique is labor intensive.
- Less effects to environment effect (U vale Wall: 0.76 (wall thickness 18"), Floor: 0.5, Roof: 0.3) (Mishra, 2017).

4.5.4 SVA GRIHA Rating

Sub-group: Landscaping

Criteria: Reduce exposed, hard paved surface on site and maintain native vegetation cover on site.

Table 47: Nirpal residence landscape category 1

Criterion no.	subdivision	Point allocated	Point Achieved	Remarks
1.	ii. All trees in the perimeter zone shall be protected	02	01	• All tress are being protected • All trees are planted after planning of building.
	iv. The total number of trees on site before and after	02	01	
	iv. All new trees planted on site will be native	02	02	

Sub-Group: Architecture & Energy

Criteria: Passive architectural design and systems

- Adopt of passive design measures
- Use of low-energy or passive heating/cooling measures >> ensure overall energy consumption building >> ensuring good thermal comfort conditions for the occupants.

Table 48: Nirpal residence Architecture & Energy category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
2.	Passive architectural design and systems	iii. Adopt a minimum of 2 passive design measures in building	02	02	• Roof cooling techniques & rammed earth techniques. • Floor to ceiling windows openings.
		iv. Active, low-energy cooling/heating systems are installed in the building	02	01	

Criteria: Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration

- Design of openings >> direct heat gain through fenestration is minimized >> maximizing daylight penetration.
- Reduce the direct heat gain through fenestration >> ensuring good daylighting.

Table 49: Nirpal residence Architecture & Energy category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
3.	Good fenestration design for reducing direct heat gain and glare while maximizing	iii. Reduce the overall insolation through the fenestration by 10%, 20%, 30%or	01,02,03 (03)	02	• Use of window from floor to ceiling.

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
	daylight penetration	more over the base case			
		iv. More than 25%,50%, 70%, 90% of the total living area falls under daylight zones	Mandatory, 01,02,03 (03)	01	

Criteria: Efficient artificial lighting system

- Adoption of energy efficient artificial lighting systems (lamps/luminaires/ballasts etc.) >> to reduce the overall LPD (Lighting Power Density) below ECBC recommended levels.

Table 50: Nirpal residence Architecture & Energy category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
4.	Efficient artificial lighting system	Recommended LPD levels	02	01	• Use of CFL, LED bulbs.

Criteria: Thermal efficiency of building envelope

Table 51: Nirpal residence Architecture & Energy category 4

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
5.	Thermal efficiency of building envelope	When viewing the output in sq.ft./TR, the project should achieve sq.ft./TR higher than the prescribed thresholds.	1,1 (02)	01	• Use of rammed earth thick wall which helps to reduce indoor temperature.

Criteria: Use of Energy Efficient Appliances

- The intent of this criterion is to promote the adoption of energy efficient appliances.

Table 52: Mato ghar Architecture & Energy category 5

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
6.	Use of Energy Efficient Appliances	All the Air-conditioners, fans and geyser installed on site are 3-star,4-star,5-star BEE labelled (Bureau of Energy Efficiency; run by the Indian	01,02,03(03)	01	• Use of normal market available fan.

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		government under Ministry of Power			

Criteria: Use of renewable energy on site

- To promote the use of renewable energy; Renewable energy system for electricity generation.
- Solar Water Heaters.

Table 53: Nirpal residence Architecture & Energy category 6

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
7.	Use of renewable energy on site	i. Rated capacity of the renewable energy system installed on site conforms to or exceeds the thresholds[100-500m^2 Built up area >> 1KW	02	02	• Use of solar panels and solar water heaters. • Solar water is sufficient for daily activities.
		v. Installed capacity of solar water heaters on site is equivalent to 50%, 75% or more of the daily hot water requirement [Hot water requirement for	01,02(02)	02	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		Residence :100 liters per day]			

Sub-Group: Water & Waste

Criteria: Reduction in building and landscape water demand

- To reduce the overall water demand of the building through use of low-flow fixtures.
- To reduce the landscape water demand through the use of native species of flora and efficient irrigation systems.

Table 54: Nirpal residence Water & waste category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
8.	Reduction in building and landscape water demand	i. Reduce the total water requirement in the building by at least 25%, 33%, 50% or more over the base case.	01,02,03 (03)	02	• Water efficient equipment. • Landscape maximum area is soft cape.
		iii. Reduce the total water requirement in the building by 25%, 50% or more over the	01,02 (02)	02	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		base case(to reduce the landscape water demand through the use of native species of flora and efficient irrigation systems).			

Criteria: Rainwater harvesting

- Capture rainwater for use on site.
- To promote rainwater harvesting >> recharge into the ground water aquifer.

Table 55: Nirpal residence Water & waste category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
9.	Rainwater harvesting	ii. The total rainwater harvesting potential for the project (from the roof only) is equivalent to at least 75% of the total building	03	02	• Rainwater harvesting through roof. • Rainwater is used for ground water recharge.

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		water demand over 2 days			
		iii. Rainwater is recharged into the ground water aquifer and has a filtration system installed	01	01	

Criteria: Generate resource from waste

- Zero waste generation through adoption of requisite strategies

Table 56: Nirpal residence Water & waste category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
10.	Generate resource from waste	Zero waste generation through adoption of requisite strategies.	02	01	- Biogas production. - Separation of degradable and non-degradable wastage.

Sub-Group: Material

Criteria: Reduce embodied energy of building

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
11.	Reduce embodied energy of building	iv. 100% of OPC is replaced by PPC (including building structure and masonry and plaster mortar)	02	01	• Less use of cemented structure. • Embodied energy of mud, bamboo is less. • Embodied energy of these material is less.
		v. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 5% or more over the base case	01	01	
		vi. The overall embodied	02	01	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		energy of the floor slabs, roof slabs and walls is reduced by 10% or more over the base case			

Criteria: Use of low-energy materials in interiors

Table 57: Nirpal residence Material category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
12.	Use of low-energy materials in interiors	iv. 70% of the flooring is low-energy	01	01	• Parqueting and tile flooring. • Use of rammed earth wall.
		v. At least 70% of internal partitions/paneling/false ceiling/in-built furniture/ doors & window-panels &	02	0	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		frames are low-energy			
		vi. All interior paints are low-VOC and lead-free (including no paint/plain mortar finish/white wash/lime mortar finish)	01	01	

Sub-Group: Lifestyle

Criteria: Adoption of green lifestyle

- Adoption of green lifestyle
- Reduce the carbon footprint of occupants
- Equitable distribution of resources

Table 58: Nirpal residence Lifestyle category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
13.	Adoption of Green Lifestyle	iv. Built-up area meets the prescribed threshold	01	01	• Built up area

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		a. [Residential: 12.5 sqm< X < 50 sqm]			around 50 cu.m • School, hospital, bus-stop re within walking distance. • Organic farming.
		v. Total expected distance travelled to basic services in a year is less than 2100 km (Residential= 7-11 services, 2100km)	01	01	
		vi. Environmental awareness is created through panels/brochures/printouts etc. or Organic farming is carried out on site.	01	01	

Criteria: Innovation

- Adopt strategies, independent of the previous 13 criterion, to make the project more sustainable
- Submit documents/narrative highlighting the measures adopted on site
- For each innovation – 1 point (maximum 2 points)

Table 59: Nirpal residence Lifestyle category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
14.	Innovation	For each innovation (max. 2 points)	02	01	• Space in – out building. • Construction of rammed earth

4.6 Hamro Mato Ghar

One of sustainable building is Hamro Mato Ghar of Thaiba, Godawari. Hamro Mato Ghar consists of various green features including in the planning, construction technique, building materials, passive and active solar energy, bio gas and wastewater management, rain water harvesting and green spaces. Features of Hamro Mato Ghar are as follows:

Figure 99: Hamro Ghar elevation

- Location: Thaiba, Lalitpur
- Established in 2018A.D.
- Site area-16,428 Sq. Ft.
- Plinth area- 1800 sq. ft.
- Construction technology: Rammed earth
- Architect: Ar. Saurab Shrestha
- Owner: Basanta Shrestha

❖ Sustainable Features of Hamro Mato Ghar are as follows:

4.6.1 Environmental parameters

Site and surrounding

Site selection (access to road)

- 8 km from Satdobato road.
- Properly accessible via road through main road.

- Site is connected with 13' road.

Availability of basic infrastructure

Basic infrastructure refers to main railways, roads, canals, harbors and docks, the electromagnetic telegraph, drainage, dikes and land reclamation (Torrisi & Gianpiero , 2009). That mainly indicates for water supply, sanitary system and tele-communications.

- Public vehicle are easily available within walking distance.
- Water supply pipelines and sanitary systems are connected with site.
- There is available of electricity and internet facility.

Preserve and protect landscape during construction

- Building was built according to actual landform.
- There is building in top area & in lower part gardening with vegetation had been provided.
- In case of Landscape design considered upon existing natural form.

Figure 100: Landscape of Hamro Mato ghar

Design to include existing site features

- There is slightly contour difference in actual site condition, had been made accessible via ramps.
- Straight building toward south orientation.
- Considered on exiting tress, water resources.
- Considered on earth movement characters.

Figure 101: Walkway of Hamro Mato ghar

Heat Island Effect, Green Roof

- Heat island effect is less on Hamro Mato ghar due to use of floor and roof finishing material

Energy and environment

Climate Responsive Building Design

- Orientation of building is south, east west elongated.
- Kitchen is provided in east side and toilets is on center so that maximum sunlight lies in bedroom & Kitchen.

Use of Renewable Energy

- Use of renewable building material like Rammed earth technology, which is sustainable material which produce less carbon at time of construction that harms less in environment.

Figure 103: Roof garden

Passive Design to reduce the conventional energy demand (Day-lighting)

- Orientation of building its gives direct natural lights.
- All rooms have cross ventilation to provide cooling requirements for summer.
- Selection of transparent materials for roofing which allows to passes of lights to interior corridor.

Figure 104: Skylight of top floor

- According to NBC code 206:2015, 1/8th of room area is required for natural lighting, in case of Aama Ghar corridor total corridor portion had been provided by natural lights i.e. 100% opening for lighting and that is sufficient.

Figure 105: Natural lighting in kitchen

Energy Efficient Lighting

- Natural lighting had been prioritized, kitchen study areas.
- Northern and Southern wing get the afternoon sun all year round.

Reduce air Pollution during construction

- Air pollution has been reduced at phase of construction by choosing of less embodied energy containing materials.
- According to site condition design had been done, for site making less energy had been used.

Roof Treatment

- Jhingati tile with air gap had been provided, then reflector insulator had been provided then straw mat, then bamboo had been provided.

Water efficiency

Use of Water Efficient Equipment

- Water efficiency had been less considered.

Figure 106: Gutter for rainwater harvesting

Rain Water Harvesting

- There is approaches for rainwater harvesting through gutters from roof and treated for use of water for various purposes like cleaning, washing, irrigation in garden. Ground Water Recharge.
- Maximum landscape is soft-scape that allows for ground water recharge.

Septic Tank / Waste water treatment technology (Waste Water Treatment)

- There is separation of rain water, solid waste and grey water.
- Polluted water had not been directly passed to Natural River.

Figure 107: Rainwater collection

Building materials

Low embodied energy material

- Landscape Floorings: Soft cape with flag stone.
- Indoor flooring: Tile flooring.
- Embodied energy of concrete, brick, timber is respectively 0.95 MJ/Kg, 3 MJ/Kg and 8.5 MJ/Kg.
- Wall: rammed earth, exposed concrete bands brick facing walls and somewhere plastered.

Availability of materials

- Locally available material are used like slate flooring outdoor areas.
- Bamboo as rafter, straw mats as thermal insulating material are being used.

Figure 108: Roof wooden planks

Use of recycled materials

- Not much considered on recycled materials.

Green materials (Materials with Low Environmental Impact)

- Brick exposed both externally and internally, no plaster and paint in the wall which reduced cost, harmfulness in the environment.
- Openings aluminum frame double glazed glass panels which is environmental friendly.
- Floorings is done through clay tile, laminated wood which provides thermal comfort as well as for low environmental impact.

Figure 109: Flooring in bathroom

- Roof: straw mats, bamboo rafter being used.
- Lighting fixtures like LED light is used which consume less energy; longer life time.
- Sanitary fixtures: normal fixtures are used which are easily available in the market, exposed of sanitary fixtures.
- The open plumbing and electrical systems reduce the cost of concealing these features.

Figure 111: Use of modern material

Figure 110: Use of straw mats

Operation & maintenance cost

- Other maintains are similar of modern building like external paints, change of material.

- Invertor maintains cost is high.
- Rid bed maintains is high and not easy.

4.6.2 Economical parameters

In design phase

- For design sustainable features had been considered which is initially high in construction which had been minimized by simple design.

In Operation phase

- For building no external heating and cooling is required.
- Sufficient for summer and winter.

Reuse of material after demolition

- Used mud, bamboo, straw are reusable.

4.6.3 Social parameters

- At time of construction, rammed earth technique is labor intensive.
- Less effects to environment effect (U vale Wall: 0.76 (wall thickness 18"), Floor: 0.5, Roof: 0.3) (Mishra, 2017).

4.6.4 SVA GRIHA Rating

Sub-group: Landscaping

Criteria: Reduce exposed, hard paved surface on site and maintain native vegetation cover on site.

Figure 112: Green landscape

Figure 113: Vegetation of Hamro mato ghar

Table 60: Hamro Mato Ghar landscape category 1

Criterion no.	subdivision	Point allocated	Point Achieved	Remarks
1.	iii. All trees in the perimeter zone shall be protected	02	02	• All tress are being protected • All trees are planted after planning of building.
	vi. The total number of trees on site before and after	02	02	
	v. All new trees planted on site will be native.	02	02	

Sub-Group: Architecture & Energy

Criteria: Passive architectural design and systems

- Adopt of passive design measures

- Use of low-energy or passive heating/cooling measures >> ensure overall energy consumption building >> ensuring good thermal comfort conditions for the occupants.


Figure 115: Roof cooling for passive cooling

Table 61: Hamro Mato Ghar Architecture & Energy category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
2.	Passive architectural design and systems	v. Adopt a minimum of 2 passive design measures in building	02	02	• Roof cooling techniques & rammed earth techniques. • Floor to ceiling windows openings.
		vi. Active, low-energy cooling/heating systems are installed in the building	02	01	

Criteria: Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration

- Design of openings >> direct heat gain through fenestration is minimized >> maximizing daylight penetration.
- Reduce the direct heat gain through fenestration >> ensuring good daylighting.

Figure 116: Use of see through boundary wall

Table 62: Hamro Mato Ghar Architecture & Energy category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
3.	Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration	v. Reduce the overall insolation through the fenestration by 10%, 20%, 30%or more over the base case	01,02,03 (03)	01	• Use of see through boundary wall. • Use of window from floor to ceiling.
		vi. More than 25%,50%, 70%, 90% of the total living area falls under daylight zones	Mandatory, 01,02,03 (03)	03	

Criteria: Efficient artificial lighting system

- Adoption of energy efficient artificial lighting systems (lamps/luminaires/ballasts etc.) >> to reduce the overall LPD (Lighting Power Density) below ECBC recommended levels.

Table 63: Hamro Mato Ghar Architecture & Energy category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
4.	Efficient artificial lighting system	Recommended LPD levels	02	01	• Use of CFL, LED bulbs.

Criteria: Thermal efficiency of building envelope

Table 64: Hamro Mato Ghar Architecture & Energy category 4

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
5.	Thermal efficiency of building envelope	When viewing the output in sq.ft./TR, the project should achieve sq.ft./TR higher than the prescribed thresholds.	1,1 (02)	01	• Use of rammed earth thick wall, sun dried brick which helps to reduce indoor temperature.

Criteria: Use of Energy Efficient Appliances

- The intent of this criterion is to promote the adoption of energy efficient appliances.

Table 65: Hamro Mato Ghar Architecture & Energy category 5

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
6.	Use of Energy Efficient Appliances	All the Air-conditioners, fans and geyser installed on site are 3-star,4-star,5-star BEE labelled (Bureau of Energy Efficiency; run by the Indian government under Ministry of Power	01,02,03(03)	01	• Use of normal market available fan.

Criteria: Use of renewable energy on site

- To promote the use of renewable energy; Renewable energy system for electricity generation.
- Solar Water Heaters.

Table 66: Hamro Mato Ghar Architecture & Energy category 6

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
7.	Use of renewable energy on site	7. Rated capacity of the renewable energy system installed on site conforms to or	02	1	• Use of solar panels and solar water heaters.

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		exceeds the thresholds[100-500m^2 Built up area >> 1KW			• Solar water is sufficient for daily activities.
		i. Installed capacity of solar water heaters on site is equivalent to 50%, 75% or more of the daily hot water requirement [Hot water requirement for Residence :100 liters per day]	01,02(02)	0	

Sub-Group: Water & Waste

Criteria: Reduction in building and landscape water demand

- To reduce the overall water demand of the building through use of low-flow fixtures.
- To reduce the landscape water demand through the use of native species of flora and efficient irrigation systems.

Table 67: Hamro Mato Ghar Water & waste category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
8.	Reduction in	i. Reduce the total water	01,02,03 (03)	02	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
	building and landscape water demand	requirement in the building by at least 25%, 33%, 50% or more over the base case.			• Water efficient equipment. • Landscape maximum area is soft cape.
		iv. Reduce the total water requirement in the building by 25%, 50% or more over the base case(to reduce the landscape water demand through the use of native species of flora and efficient irrigation systems).	01,02 (02)	01	

Criteria: Rainwater harvesting

- Capture rainwater for use on site.
- To promote rainwater harvesting >> recharge into the ground water aquifer.

Table 68: Hamro Mato Ghar Water & waste category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
9.	Rainwater harvesting	iii. The total rainwater harvesting potential for the project (from the roof only) is equivalent to at least 75% of the total building water demand over 2 days	03	01	• Rainwater harvesting through roof. • Rainwater is used for ground water recharge.
		iv. Rainwater is recharged into the ground water aquifer and has a filtration system installed	01	01	

Criteria: Generate resource from waste

- Zero waste generation through adoption of requisite strategies.

Table 69: Hamro Mato Ghar Water & waste category 3

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
10.	Generate resource from waste	Zero waste generation through adoption of requisite strategies.	02	01	- Biogas production. - Separation of degradable and non-degradable wastage.

Sub-Group: Material

Criteria: Reduce embodied energy of building.

Figure 117: Use of rammed earth, cement plater

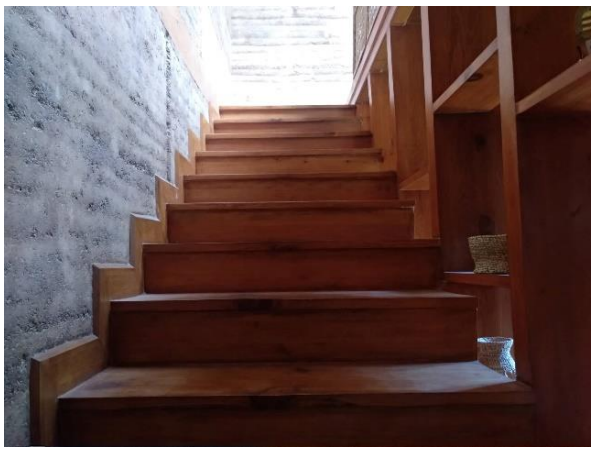


Figure 118: Use of timber, mud plaster

Table 70: Hamro Mato Ghar Materials category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
11.	Reduce embodied energy of building	vii. 100% of OPC is replaced by PPC (including	02	1	• Less use of cemented structure.

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		building structure and masonry and plaster mortar)			• Embodied energy of mud, bamboo is less. • Embodied energy of these material is less.
		viii. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 5% or more over the base case	01	1	
		ix. The overall embodied energy of the floor slabs, roof slabs and walls is reduced by 10% or more over	02	1	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		the base case			

Criteria: Use of low-energy materials in interiors

Table 71: Hamro Mato Ghar Material category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
12.	Use of low-energy materials in interiors	vii. 70% of the flooring is low-energy	01	01	• Parqueting and tile flooring. • Use of rammed earth wall. • Use of low VOC paints.
		viii. At least 70% of internal partitions/paneling/false ceiling/in-built furniture/ doors & window-panels & frames are low-energy	02	02	
		ix. All interior paints are low-VOC and lead-free	01	01	

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
		(including no paint/plain mortar finish/white wash/lime mortar finish)			

4.6.4.1 Sub-Group: Lifestyle

Criteria: Adoption of green lifestyle

- Adoption of green lifestyle.
- Reduce the carbon footprint of occupants.
- Equitable distribution of resources.

Figure 120: Mato ghar organic farming

Figure 119: Mato ghar organic fruit

Table 72: Hamro Mato Ghar Lifestyle category 1

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
13.	Adoption of Green Lifestyle	vii. Built-up area meets the prescribed threshold a. [Residential: 12.5 sqm< X < 50 sqm]	01	01	• Built up area around 50 cu.m • School, hospital, bus-stop re within walking distance. • Organic farming.
		viii. Total expected distance travelled to basic services in a year is less than 2100 km (Residential= 7-11 services, 2100km)	01	01	
		ix. Environmental awareness is created through panels/brochures/printouts etc. or Organic farming is carried out on site.	01	01	

Criteria: Innovation

- Adopt strategies, independent of the previous 13 criterion, to make the project more sustainable

- Submit documents/narrative highlighting the measures adopted on site
- For each innovation – 1 point (maximum 2 points)

Table 73: Hamro Mato Ghar Lifestyle category 2

Criterion no.	Criterion name	subdivision	Point allocated	Point achieved	Remarks
14.	Innovation	For each innovation (max. 2 points)	02	02	• Space in – out building. • Construction of rammed earth

CHAPTER 5. Comparison, Analysis and findings

5.1 Comparison and Analysis based on sustainable parameters

While comprising between these four building we found following parameters.

5.1.1 Site and Surrounding

Mato ghar, Budhanilkantha	**Sura building, Durbarmarg**	**Nirpal residence, kamalpokhari**	**Hamro mato ghar, Godawari**
• Building was built to actual natural landform • Existing topography considered ,consideration upon earth movement • Floor finish is use of low island effect.	• Building was built to actual land form • Besetment plan>>consideration upon design • Green roof & vegetation >reduce heat island effect	• Building was built to actual natural landform • Existing topography considered ,consideration upon earth movement	• Building was built to actual natural landform • Existing topography considered ,consideration upon earth movement

- ❖ All buildings had considered upon existing site by Mato ghar, Nirpal residence & Hamro mato ghar mainly focused on natural features and by Sura building consideration upon existing neighborhood, road condition.

5.1.2 Energy and Environment

Mato ghar, Budhanilkantha	Sura building, Durbarmarg	Nirpal residence, kamal pokhari	Hamro mato ghar, Godwari
• Building orientation is considered mostly • Bedroom, living room towards south & kitchen, bathroom towards north • Rammed earth technology is in use • Solar water heaters & panels are in used • Natural lighting & ventilation are used properly • Roof treatment for • Thermal comfort	• Building orientation is mostly • Services like stairs, restroom ae centrally provided. • Solar water heater is provided • Natural lighting is provided • Green roof with surrounding plantation	• Building orientation is considered mostly • Bedroom, living room towards south & kitchen towards east, bathroom towards center • Rammed earth, Bamboo construction technology • Solar water heaters & panels are in used • Natural lighting & ventilation are used properly • Roof treatment for • thermal comfort	• Building orientation is considered mostly • Bedroom, living room towards south & kitchen towards east, bathroom towards centre • Rammed earth technology is in use • Natural lighting & ventilation are used properly • Roof treatment for • thermal comfort

- ❖ Mato ghar, Hamro mato ghar & Nirpal residence had considered more environmental parameters than Sura building>> in case of solar energy use, roof treatment, reduction of air pollution during construction i.e, Mato ghar, Hamro mato ghar & Nirpal residence is more sustainable >>in environmental parameters.

5.1.3 Water efficiency

Mato ghar, Budhanilkantha	Sura building, Durbarmarg	Nirpal residence, kamal pokhari	Hamro mato ghar, Godwari
• Water efficient equipment>>washing machine • Rainwater harvesting>sufficient for cleaning, washing, gardening purpose • Gray & black water treatment	• Rainwater harvesting>not-sufficient • No such treatment for black water • Green roof with surrounding plantation	• Rainwater harvesting>sufficient for cleaning, washing, gardening purpose • Ground water recharge concept	• Rainwater harvesting>sufficient for cleaning, washing, gardening purpose • Gray & black water treatment • Ground water recharge concept

- ❖ Although all features of water efficiency had been attempted by Sura building which is not in sufficient amount: like in black & gray water treatment, maximum area is hardscape.
- ❖ There is no gray & black water treatment in Nirpal residence.

5.1.4 Building material

Mato ghar, Budhanilkantha	Sura building, Durbarmarg	Nirpal residence, kamal pokhari	Hamro mato ghar, Godwari
• Low embodied energy material being used like: rammed earth, sun dried brick, bamboo, exposed concrete without plaster and paints.	• Slate, exposed concrete, steel horizontal & vertical element are being used. • Flooring is used of clay tile, parqueting inside.	• Low embodied energy material being used like :rammed earth, sun dried brick, bamboo,	• Low embodied energy material being used like :rammed earth, sun dried brick, bamboo,

Mato ghar, Budhanilkantha	Sura building, Durbarmarg	Nirpal residence, kamal pokhari	Hamro mato ghar, Godwari
• Locally available material like straw mats used. • Plumbing & electrical system is exposed to reduce the concealing cost. • Normal sanitary fixtures being used. • Double glazed aluminum windows.	• Double glazed window.	exposed concrete without plaster and paints	exposed concrete without plaster and paints • Locally available material like straw mats used

❖ Mato ghar, , Nirpal residence, Hamro mato ghar had considered more features on material selection from planning to construction phase>>by considering upon locally available material, by checking importing distance whereas Sura building had considered upon modern material like steel as shading as well as elevation treatment element.

5.2 Findings of sustainable residence

5.2.1 Sustainable parameters

- Most of residence had focused on existing site conditions that is on actual topography of site that doesn't harm existing natural form.
- Energy efficient design had been prioritized through orientation, by both active and passive strategies like solar water heater and by planning of building (lighting, ventilation).
- Energy efficient and economic materials had been used like single panel reflectors, also in case of equipment solar panels are been used

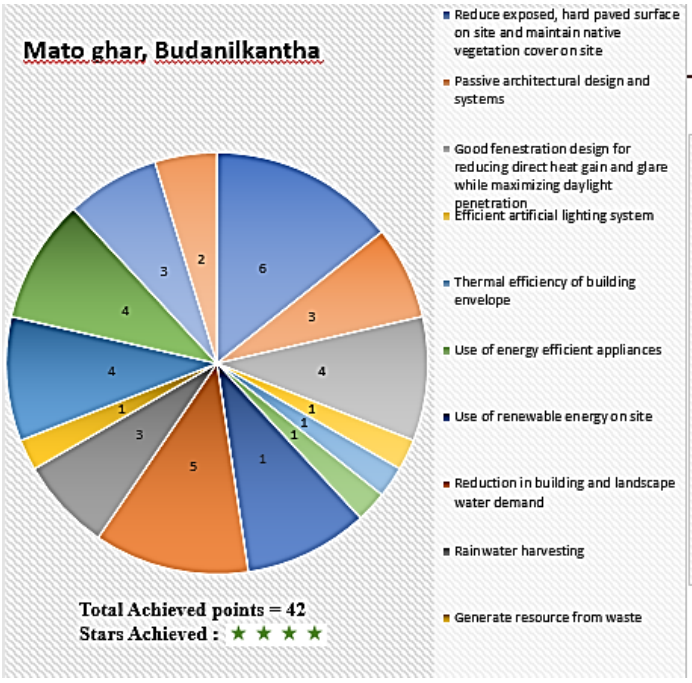
- Use of limited conventional building materials, which is the principles of an eco-friendly building.
- Vernacular material & modern materials both can be used to create sustainable architecture.
- Rating system gives ideas about how much building are efficient in same of sustainable building.

5.2.2 SVAGRIHA rating system

Findings of SVAGRIHA rating system are as follows:

Table 74: Comparison between four residences

s. n	Criterion Name	Points	Points Achieved (Mato ghar)	Points Achieved (Sura building)	Points Achieved (Nirpal resiiddence)	Points Achieved (Hamro mato ghar)
1	Reduce exposed, hard paved surface on site and maintain native vegetation cover on site	06	06	03	04	06
2	Passive architectural design and systems	04	03	02	03	03
3	Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration	06	04	02	03	04
4	Efficient artificial lighting system	02	01	01	01	01
5	Thermal efficiency of building envelope	02	01	0	01	01
6	Use of energy efficient appliances	03	01	01	01	01
7	Use of renewable energy on site	04	04	02	04	01
8	Reduction in building and landscape water demand	05	05	03	04	03
9	Rainwater harvesting	04	03	0	03	02
10	Generate resource from waste	02	01	0	01	01
11	Reduce embodied energy of building	04	04	03	03	03
12	Use of low-energy materials in interiors	04	04	03	02	04
13	Adoption of green lifestyle	04	03	03	03	03
14	Innovation	2	02	0	01	02
	TOTAL	50	42	23	34	35



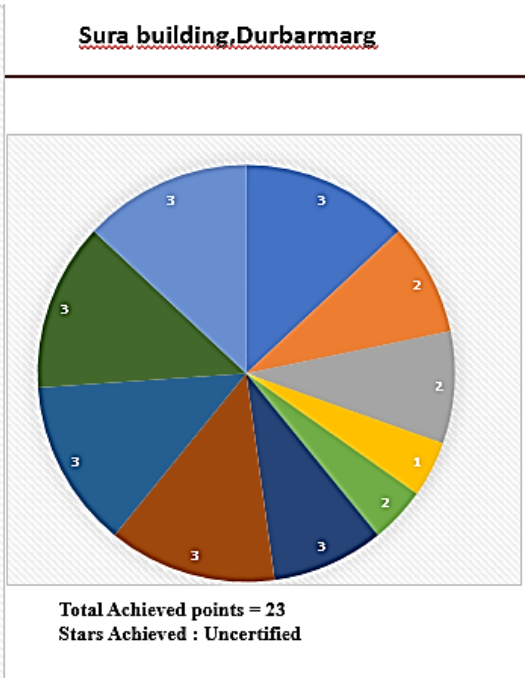


Figure 121: Comparison with Mato ghar & Sura building

Mato ghar has 4 star rating type which is manually rated which has 42 points & in case of Sura building it has uncertified with 23 points.

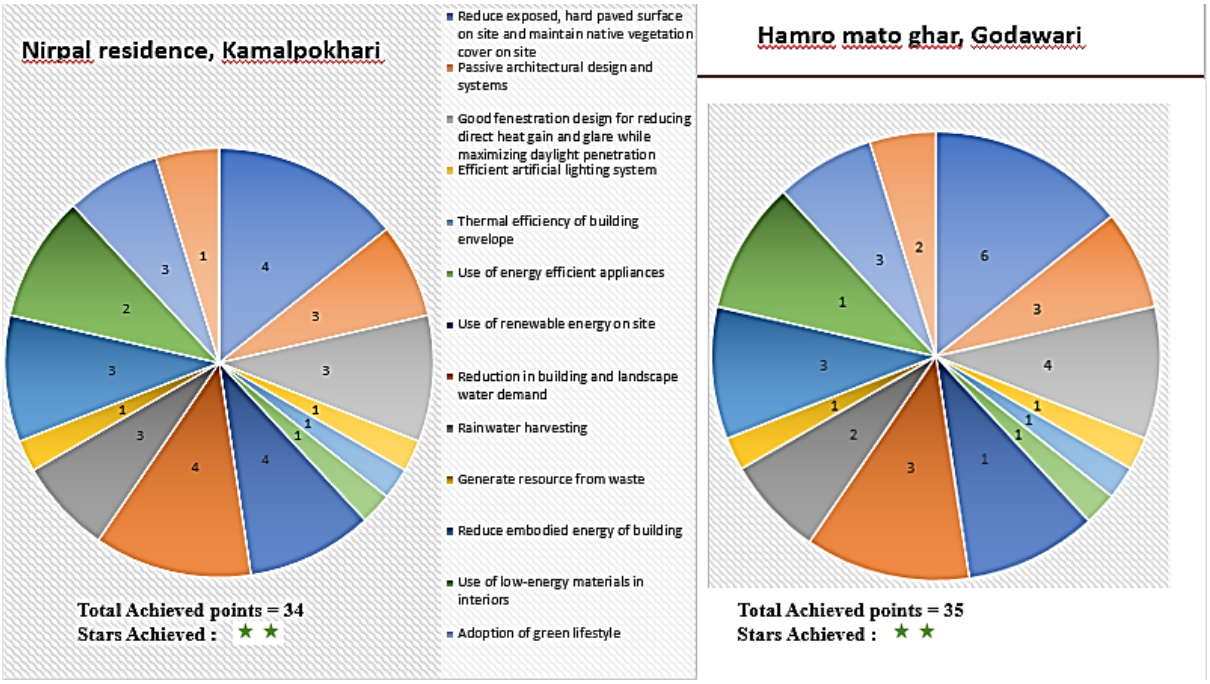


Figure 122: Comparison with Nirpal residence & Hamro mato ghar

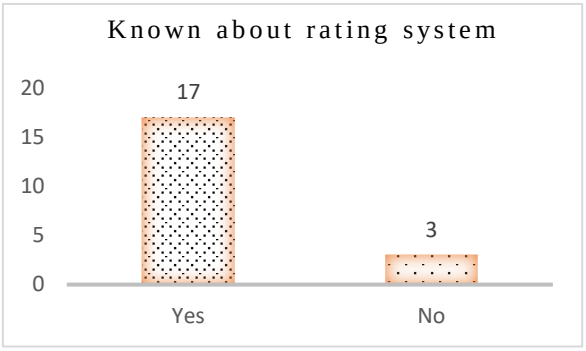
Nirpal residence has 2 star rating type which is manually rated which has 34 points & in case of Hamro mato ghar building it has 2 star rating with 35.Analysis based on ecologically responsive architecture guide (ERAG) purposed by SONA

ERAG is ecologically responsive architecture guideline which is proposed by SONA, which is not continued till now. For this I had done survey upon how ERAG can be continued. These points are decided according to element of Panchatato, I am looking upon water & air. Where water & air based element are being checked out on based with energy & environmental aspects In case of energy aspects, sub points are decided according to minimal energy consumption and maximizing energy conservation. In case of environmental aspects, sub points are being decided through how much water & air use affects towards environmental aspects.

5.2.3 Green building practice field

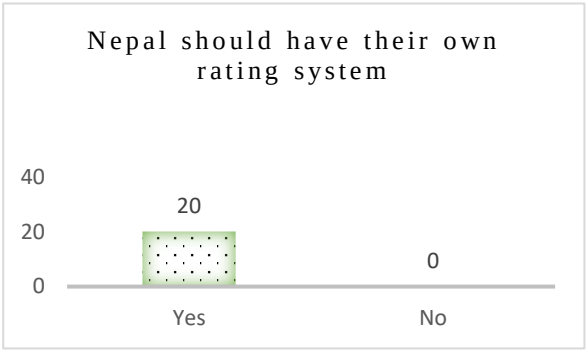
Known about building rating system

Out of the 20 surveyed Architects, 3 did not known about rating system. 17 of the architects are familiar with ERAG guideline. Most of Architects are familiar with ERAG guideline.



Nepal should have their own rating system

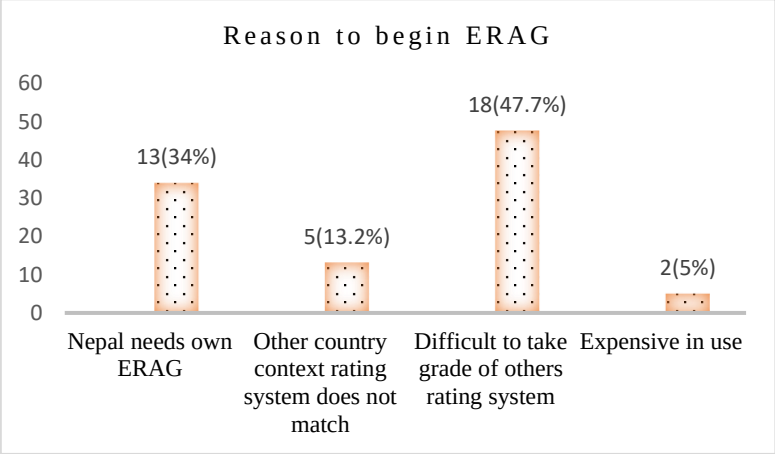
Among the surveys done in 20 Architect, all the architects agree with Nepal should have their own rating system.



5.2.4 Ecologically Responsive Architecture Guide (ERAG) guideline purposed by SONA

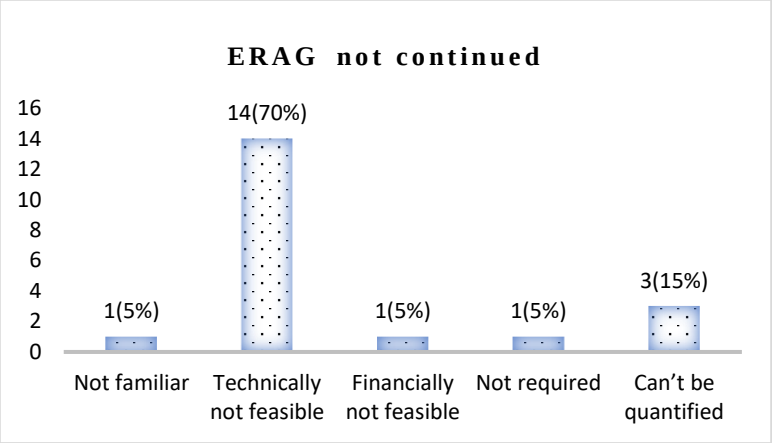
Reason to begin ERAG

Out of the 20 surveyed Architects, in reason to begin ERAG while proving multiple choice of selection 13 points comes under Nepal needs own ERAG, 5 points comes on other country context rating system does not match, 18 points comes on difficult to take grade of other rating system and 2 points shows agree to expensive in use option.



Reason to ERAG not continued

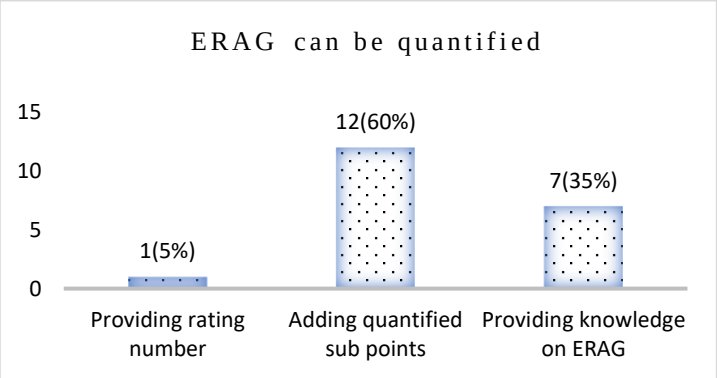
While doing reason to ERAG not continued survey with Architects, by proving single choice of selection, 1 is for not familiar, 14 is technically not feasible, 1 is of financially not feasible, 1 is of not require & 3 comes under cannot be quantified.



Here, from graphs it shown that most of architect aspect about technically not feasible is the major reason not continue of ERAG.

ERAG can be quantified

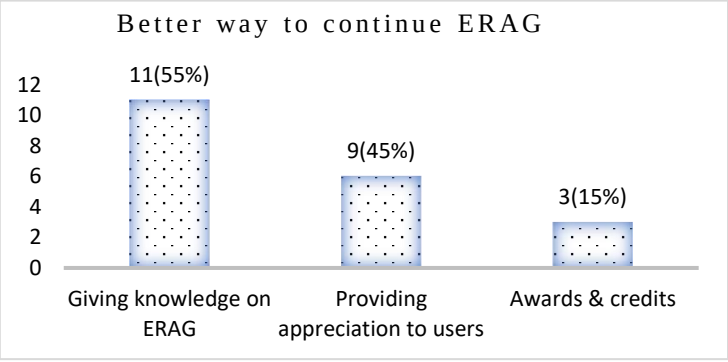
From the survey of how ERAG can be quantified, it was seen that 1 respondents Aspect about providing rating system, 12 talk aspects about adding quantified sub points, 7 aspect about providing knowledge on ERAG.



Most of people aspects about adding quantified sub points.

Better way to continue ERAG

From the survey of better way to continue ERAG, it was seen that 11 people aspects about giving knowledge on ERAG, 6 architect aspect upon providing appreciation to users and 3 aspects upon giving awards & credits.

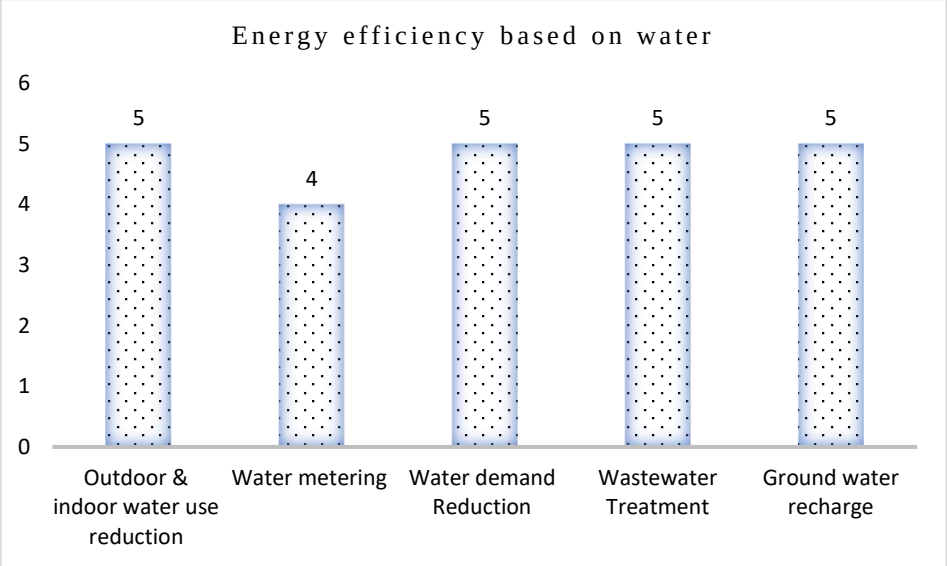


5.2.5 Energy & Environmental efficiency based on Water & air points comes under ERAG

Energy Efficiency based on water, rate out of 1-5

(Least=1, Highest=5)

In this sub point, water had been looked upon energy efficiency aspects, how much efficiency water had been used. While giving numbering to indicator 1-5, 1 is least & 5 is highest. As shown in table below 5 sub group had been decided & marking is done. For outdoor & indoor water use reduction indicator there is 5 point, for water metering indicator there is 4 point, for water demand Reduction there is 5 points, for wastewater treatment there 5 points & for ground water recharge there is 5 points. Most of architect had selected 5 points for 4 indicators.

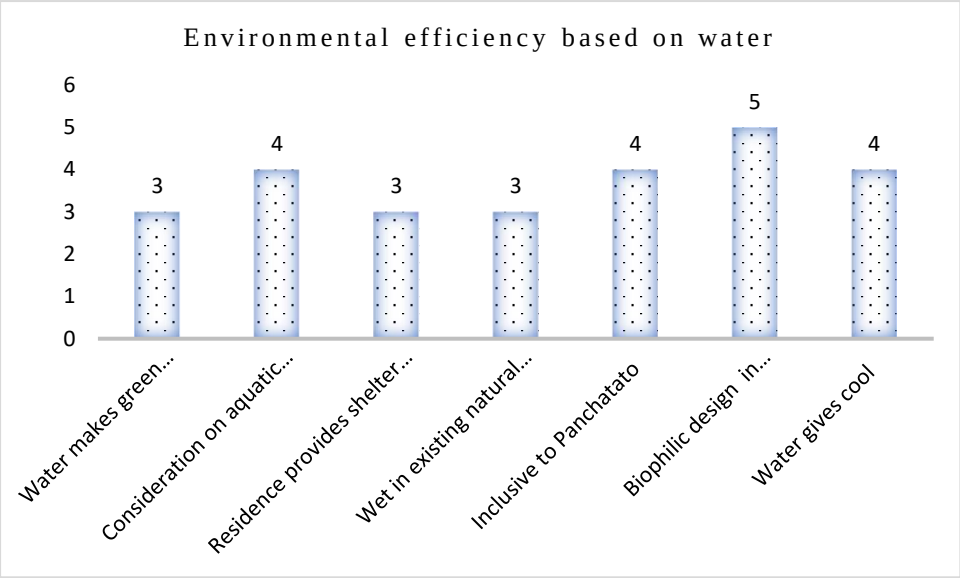


Environmental Efficiency based on water, rate out of 1-5

(Least=1, Highest=5)

In this sub point, water had been looked upon environmental efficiency aspects, how much efficiency water had been used. While giving numbering to indicator 1-5, 1 is least & 5 is highest. As shown in table below 7 sub group had been decided & marking is done. For Water makes green consideration in trees indicator there is 3 point, for Consideration on aquatic lifestyle indicator there is 4 point, for residence provides shelter to other species like birds there is 3 points, for wet in existing natural ground consideration upon soil living animals there is 5 points, for inclusive to Panchatato there is 5 points, for biophilic design

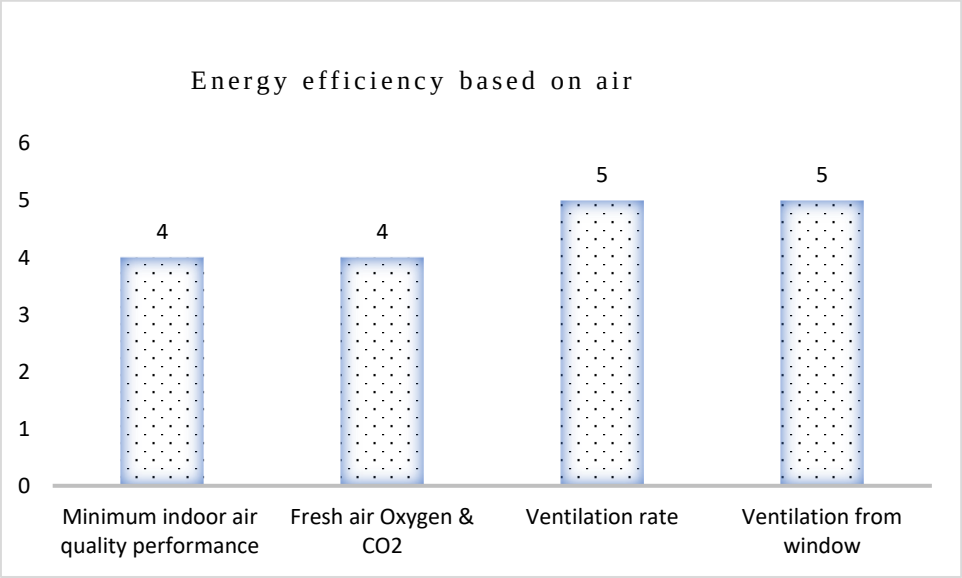
in residence there is 5 points & for Water gives cool there is 4 points. Most of architect had selected 5 points for biophilic design in residence indicator.



Energy Efficiency based on air, rate out of 1-5

(Least=1, Highest=5)

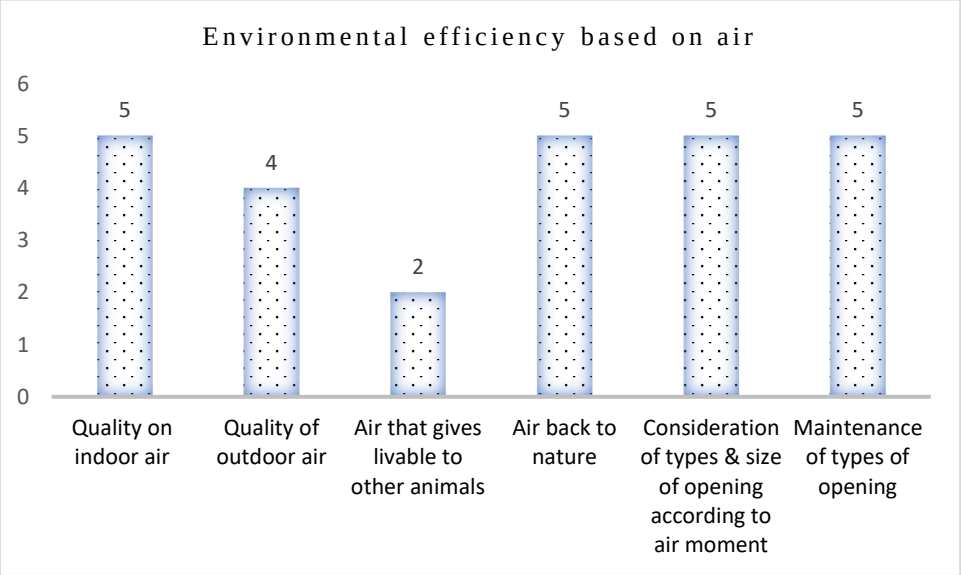
In this sub point, air had been looked upon energy efficiency aspects, how much efficiency air had been used. While giving numbering to indicator 1-5, 1 is least & 5 is highest. As shown in table below 4 sub group had been decided & marking is done. For Minimum indoor air quality performance indicator there is 4 point, for fresh air Oxygen & CO2 indicator there is 4 point, for ventilation rate there is 5 points & for ventilation from window there is 5 points. Most of architect had selected 5 points for ventilation rate & ventilation from window.



Environmental Efficiency based on air, rate out of 1-5

(Least=1, Highest=5)

In this sub point, air had been looked upon environmental efficiency aspects, how much efficiency air had been used. While giving numbering to indicator 1-5, 1 is least & 5 is highest. As shown in table below 6 sub group had been decided & marking is done. For Quality on indoor air indicator there is 5 point, for quality of outdoor air indicator there is 4 point, for Air that gives livable to other animals there is 2 points, for Air back to nature there is 5 points, for Consideration of types & size of opening according to air moment there is 5 points & for maintenance of types of opening there is 4 points. There is only 2 points for Air that gives livable to other animal's indicator.



5.3 Findings of ERAG

- There are many architects; are familiar with rating system
- Survey, all architects belief on Nepal need own ERAG.
- ERAG can be quantified by adding sub points upon it.
- Most of architect belief upon Nepal need own ERAG because it is difficult to take grade of other rating system.
- The main reason of ERAG not continued is technically not feasible.

5.3.1 Energy Efficiency based on water, rate out of 1-5

S.No.	Indicators	Points
a.	Outdoor & indoor water use reduction	5
b.	Water metering	4
c.	Water demand Reduction	5
d.	Wastewater Treatment	5
e.	Ground water recharge	5

- While looking upon energy efficiency based on water, most of Architects gives water demand reduction, wastewater treatment, ground water recharge, these are most prioritize points.

5.3.2 Environmental Efficiency based on water, rate out of 1-5

S.No.	Indicators	Points
a.	Water makes green consideration in trees	3
b.	Consideration on aquatic lifestyle	4
c.	Residence provides shelter to other species like birds	3
d.	Wet in existing natural ground consideration upon soil living animals	3
e.	Inclusive to Panchatato	4
f.	Biophilic design in residence	5
g.	Water gives cool	4

- According to survey, environmental efficiency based on environmental parameters had been prioritize upon biophilic design in residence design, that is natural things have to priotised in have to considered highest point in ERAG guideline.

5.3.3 Energy Efficiency based on air, rate out of 1-5

S.no.	Indicators	Points
a.	Minimum indoor air quality performance	4
b.	Fresh air Oxygen & CO2	4
c.	Ventilation rate	5

S.no.	Indicators	Points
d.	Ventilation from window	5

- Ventilation rate & ventilation from window are highest scored indicators of energy efficiency based on year, there should be fulfill on minimum requirement upon sufficient ventilation.

5.3.4 Environmental Efficiency based on air, rate out of 1-5

S.no.	Indicators	Points
a.	Quality on indoor air	5
b.	Quality of outdoor air	4
c.	Air that gives livable to other animals	2
d.	Air back to nature	5
e.	Consideration of types & size of opening according to air moment	5
f.	Maintenance of types of opening	5
g.	Inclusive to Panchatato	5

- According to survey, environmental efficiency based on environmental parameters had been prioritize upon quality on indoor air, used air should give back to nature, consideration of type & size of opening according to air moment, maintenance of types of opening & inclusive to Panchatato.

CHAPTER 6. Conclusion and Recommendations

6.1 Conclusion

Conclusion are drawn from three objectives listed above. The conclusion of study are as follows:-

The first objective of study was to study upon sustainable parameters: environmental, economical & social aspect of residential building in national context. I had studied upon 4 sustainable residence, according to four major points of sustainable parameters we can conclude that site and surrounding plays important role in case of sustainability from points on site selection, availability of basic infrastructure, preserve & protect landscaping during construction, consideration upon existing features how these parameters are used determines level of sustainability. Energy & environmental efficiency had been carried out by both active and passive strategies like climate Responsive Building Design, use of Renewable Energy, Efficient Heating/Cooling Equipment, Passive Design to reduce the conventional energy demand (Day-lighting), Solar Water Heating and lighting (Solar Water Heating) & other parameters also decides such as Reduce air Pollution during construction. Water efficiency is major element have to consider which includes use of water efficient equipment, rain water harvesting, waste water treatment technology. Material means use of materials as in required amount with low embodied energy, recycled material, reuse of material & promotion of local material. Utilization of these factors like site and surrounding, energy and environment, material efficiency, water consumption gives most sustainable building as looking from four residential buildings.

The second objective is do SVAGRIHA rating system of residence of Kathmandu. SVAGRIHA rating system was chosen to analyze upon sustainable parameters, there was study of 14 criteria & 5 subgroup like landscape, architecture & energy, water & waste, material, lifestyle points. After case study upon four residence Mato ghar, Sura building, Nirpal residence, Hamro mato ghar; analysis based on from that studied we found that Mato ghar has more SVARIHA points, as well as Mato ghar has more sustainable parameters, which has high points on landscape aspect like promotion of soft scape in landscaping, design based on existing natural form & in energy conservation aspect.

The third objective of study was to explore on ecologically responsive architecture guide (ERAG) system purposed by SONA. Quantitative analysis was done with 20 sustainable practicing architects to find out perspective of architect upon ERAG. While looking upon

energy efficiency based on water, most of Architects gives water demand reduction, wastewater treatment, ground water recharge, these are most prioritize points. According to survey, environmental efficiency based on environmental parameters had been prioritize upon biophilic design in residence design, that is natural things have to prioritized in have to considered highest point in ERAG guideline. Ventilation rate & ventilation from window are highest scored indicators of energy efficiency based on year, there should be fulfill on minimum requirement upon sufficient ventilation. According to survey, environmental efficiency based on environmental parameters had been prioritize upon quality on indoor air, used air should give back to nature, consideration of type & size of opening according to air moment, maintenance of types of opening & inclusive to Panchatato. From which it is found that, quantifying ERAG is best option to continue ERAG, from which water & air based parameters are being decided for point giving aspect which can be used to quantify residence of Kathmandu.

6.2 Recommendations

Based on the findings of the research, following recommendations are suggested. As findings are obtained through case study method & quantitative analysis, questionnaire surveys done in with 20 sustainable practicing architect. For case study four sustainable residence had been selected which is considered as sustainable buildings. The recommendation are drawn from views of the researcher.

There is limitation of timeframe in my research I have selected four sustainable residence, for future study that can be done through more numbers of sustainable residence. More numbers of residence could give more ideas about sustainability. Environmental, economic and social parameters can be explored in broad way.

Mato ghar had followed more sustainable parameters points, which has high points on site & surrounding aspect like in focused on natural features, site existing context, in energy conservation aspect active & passive strategies had been considered, in building material there is use of locally available material and low embodied material, in water efficiency there is treatment of black & gray water treatment and use of water efficiency equipment; these sustainable parameters can be used for residential building for further design.

There are five elements of Panchatato, for ERAG guideline where I had looked water & air; selection of other three elements could be better for ERAG rating analysis. For future to explore more on ERAG in quantitative way earth, fire and space parameters can be used, that gives ideas about quantify parameters upon other three elements also.

For continue of ERAG; SONA have to make some quantify points & have to strictly apply. If quantify points adding on ERAG that could use for quantify on residential building.

From my research it is found that, in Nepal there is required of quantifying tool to check sustainability in building for that either form SONA or from government of Nepal have to take initiated.

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ANNEX

Annex A: Questionnaire survey

Annex B: Findings of ERAG

Annex C: KOBO Data collection

Annex D: Article of IOE-GC

Annex A: Questionnaire survey

Annex A: Questionnaire survey

This questionnaire survey is quantitative type of survey based on Masters in Architecture thesis project of title "Sustainable Parameters of Residential Building Design in Kathmandu." These questions are based on sustainable rating system and Ecologically Responsive Architecture guide (ERAG).

Full name:

Gender:

a. Male
b. Female
c. Others

Profession:

a. Professor/Lecturer
b. Architect/ Engineer/ Engineer expert
c. Stakeholder
d. Others

Green building practice field

1. Do you know what do you mean by building rating system?
a. Yes
b. No
2. Are you familiar with any of following green rating system?
a. LEED
b. BREEM
c. GRIHA
d. CASBEE
e. OTHERS
f. None

3. Do you think Nepal should have their own rating system?
a. Yes
b. No

4. In your opinion what is the advantage of rating system?
a. Environmental benefit
b. Response to climate change
c. Sustainable lifecycle
d. All of above

5. In your opinion what is the disadvantage of rating system?
a. Expensive
b. Technical issue

c. Material available
d. All of above

6. Are you familiar with Ecologically Responsive Architecture Guide (ERAG) guideline purposed by SONA?
a. Yes
b. No

7. What do you know about history of ERAG?
…….
…….
…….
8. Reason to begin ERAG?
a. Nepal needs own ERAG
b. Other country context rating system does not match
c. Difficult to take grade of others rating system
d. Expensive in use

9. Why ERAG is not continued?
a. Not familiar
b. Technically not feasible
c. Financially not feasible
d. Not required
e. Can't be quantified

10. How ERAG can be quantified?
a. Providing rating number
b. Adding quantified sub points
c. Providing knowledge on ERAG

11. What is the better way to continue ERAG?
a. Giving knowledge on ERAG
b. Providing appreciation to users
c. Awards & credits

In this project, I had studied upon water & air for rating which can be used in ERAG. These questions are based on water & air rating system looks upon energy & environmental parameter.

12. According to you, Energy Efficiency based on water, rate out of 1-5?
*1-Least; 5-Highest

Annex B: Findings of ERAG

Annex B: Findings of ERAG

S.No.	Indicators	Points
a.	Outdoor & indoor water use reduction	
b.	Water metering	
c.	Water demand Reduction	
d.	Wastewater Treatment	
e.	Ground water recharge	

13. According to you, Environmental Efficiency based on water, rate for 1-5?
    *1-Least; 5-Highest

S.No.	Indicators	Points
a.	Water makes green consideration in trees	
b.	Consideration on aquatic lifestyle	
c.	Residence provides shelter to other species like birds	
d.	Wet in existing natural ground consideration upon soil living animals	
e.	Inclusive to Panchatato	
f.	Biophilic design in residence	
g.	Water gives cool	

14. According to you, Energy Efficiency based on air, rate out of 1-5?
    *1-Least; 5-Highest

S.no.	Indicators	Points
a.	Minimum indoor air quality performance	
b.	Fresh air Oxygen & CO2	
c.	Ventilation rate	
d.	Ventilation from window	

15. According to you, Environmental Efficiency based on air, rate out of 1-5?
    *1-Least; 5-Highest

S.no.	Indicators	Points
a.	Quality on indoor air	

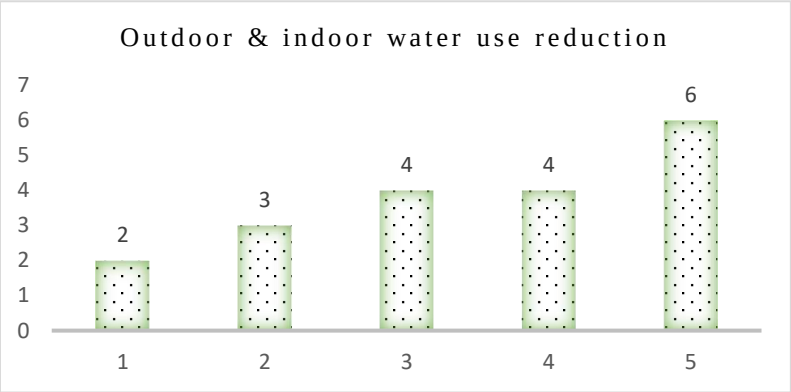
S.no.	Indicators	Points
b.	Quality of outdoor air	
c.	Air that gives livable to other animals	
d.	Air back to nature	
e.	Consideration of types & size of opening according to air moment	
f.	Maintenance of types of opening	
g.	Inclusive to Panchatato	

Energy & Environmental efficiency based on Water & air points comes under ERAG

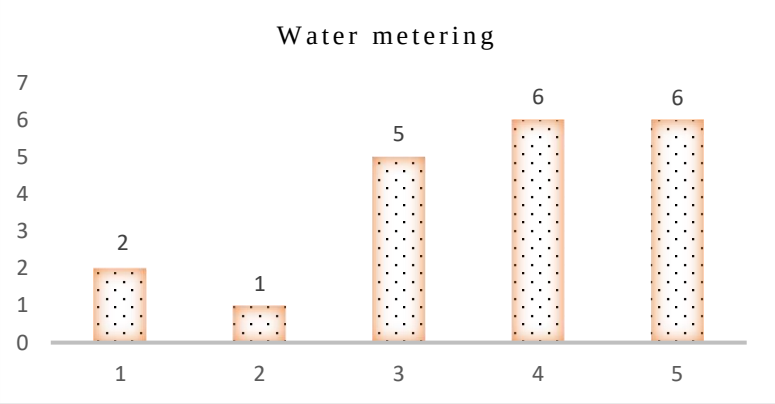
Energy Efficiency based on water, rate out of 1-5

(Least=1, Highest=5)

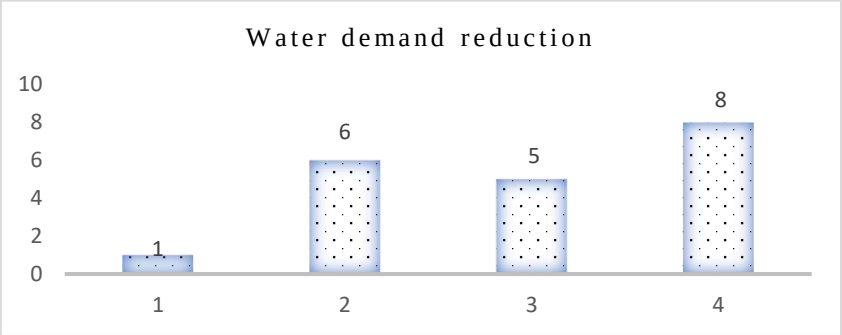
Outdoor & indoor water use reduction



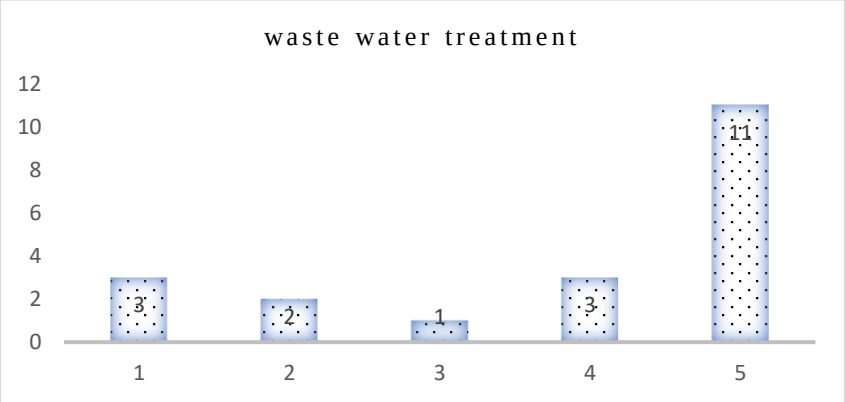
Water metering



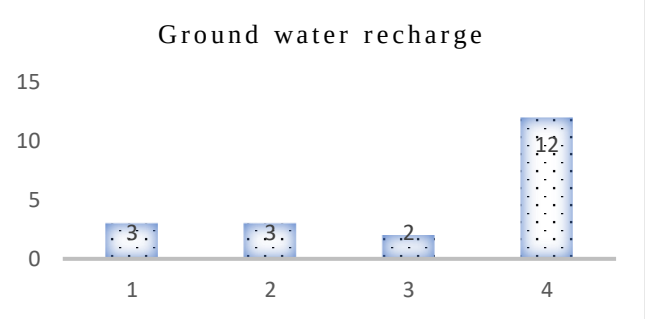
Water demand reduction



Wastewater Treatment



Ground water recharge

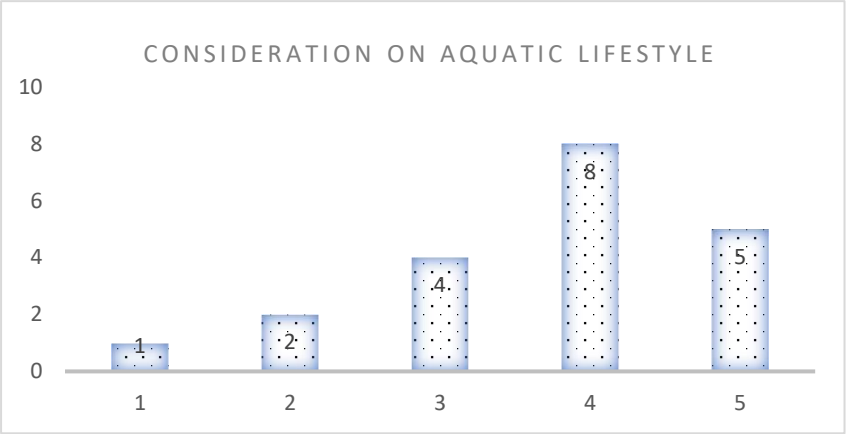


Environmental Efficiency based on water, rate out of 1-5

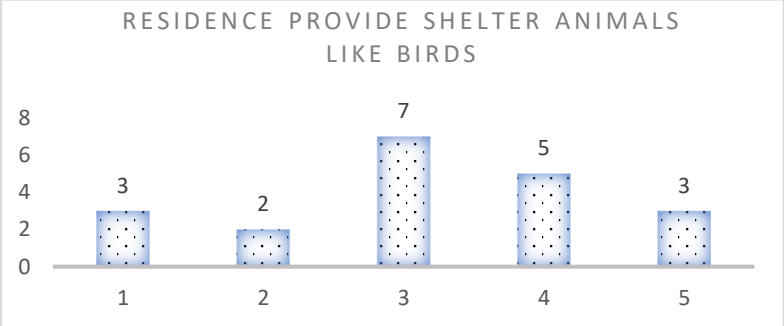
(Least=1, Highest=5)

Water makes green consideration in trees

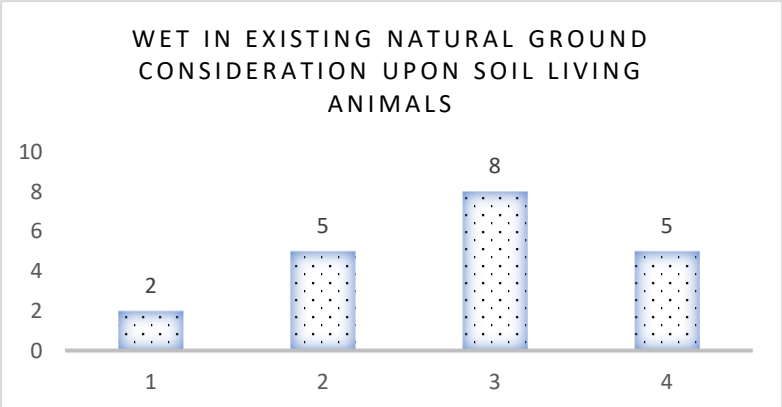
Consideration on aquatic lifestyle



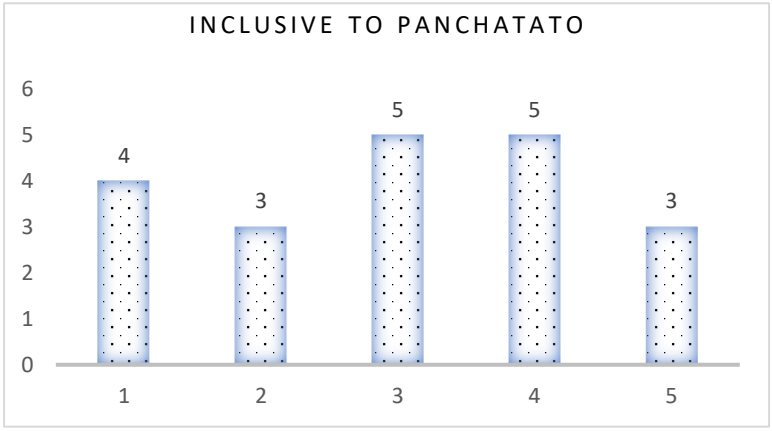
Residence provides shelter to other species like birds



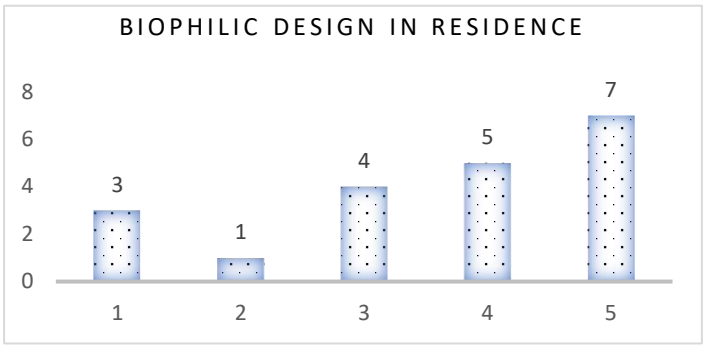
Wet in existing natural ground consideration upon soil living animals



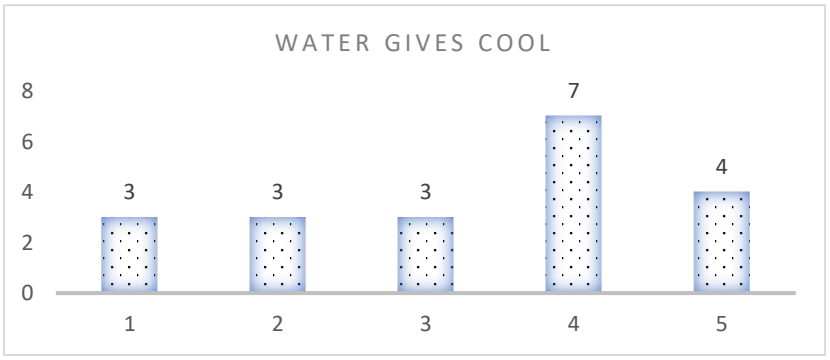
Inclusive to Panchatato



Biophilic design in residence



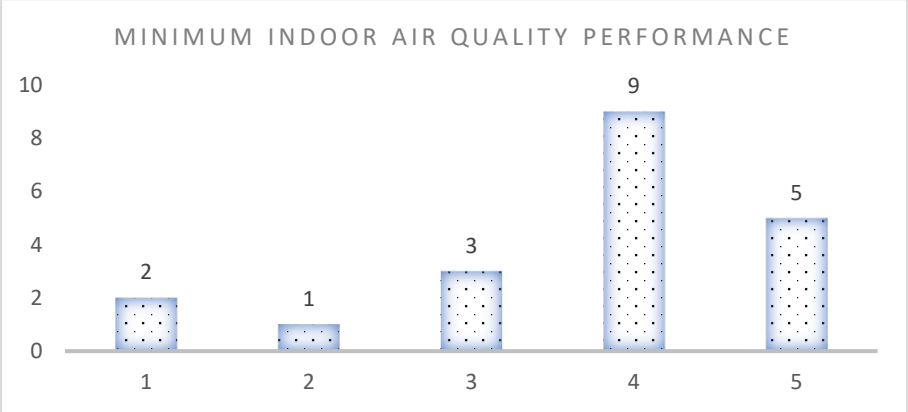
Water gives cool



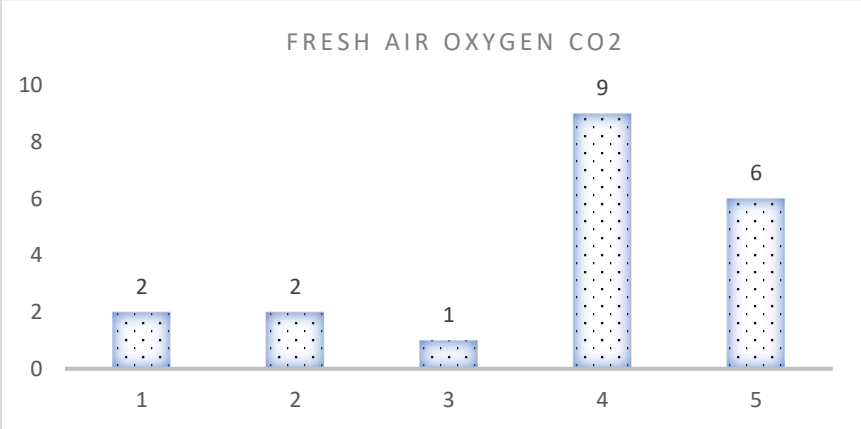
Energy Efficiency based on air, rate out of 1-5

(Least=1, Highest=5)

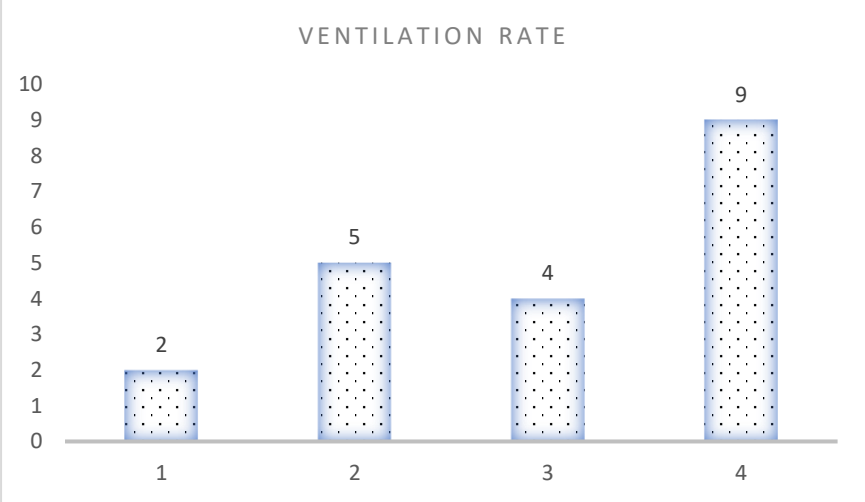
Minimum indoor air quality performance



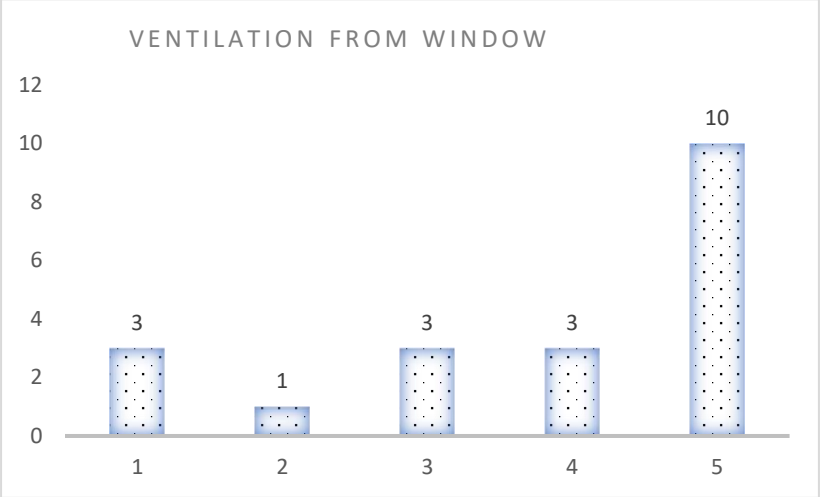
Fresh air Oxygen & CO2



Ventilation rate



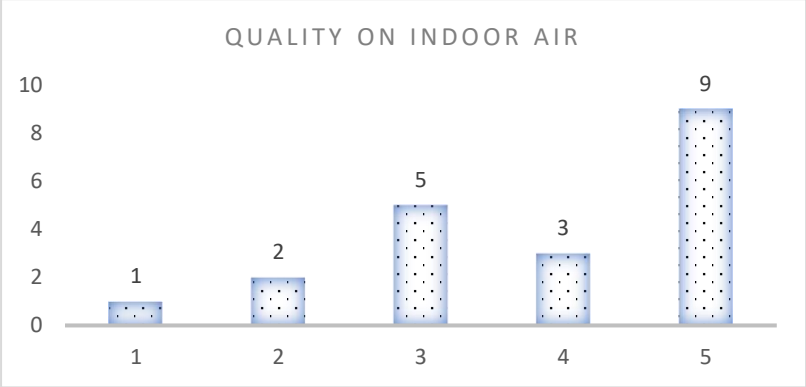
Ventilation from window



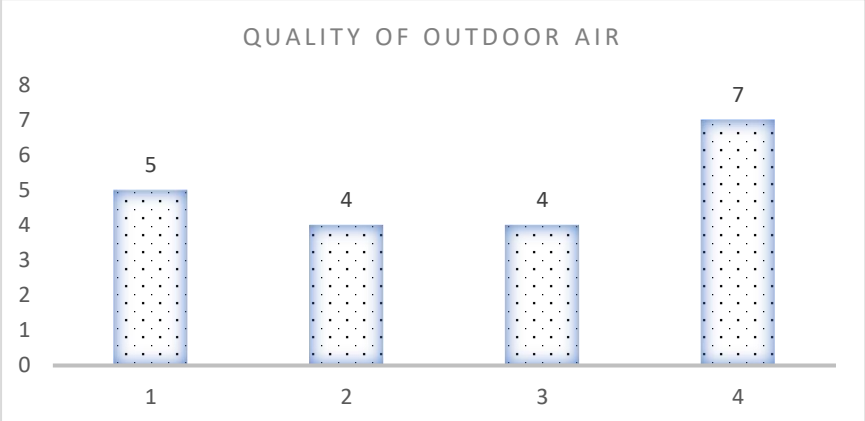
Environmental Efficiency based on air, rate out of 1-5

(Least=1, Highest=5)

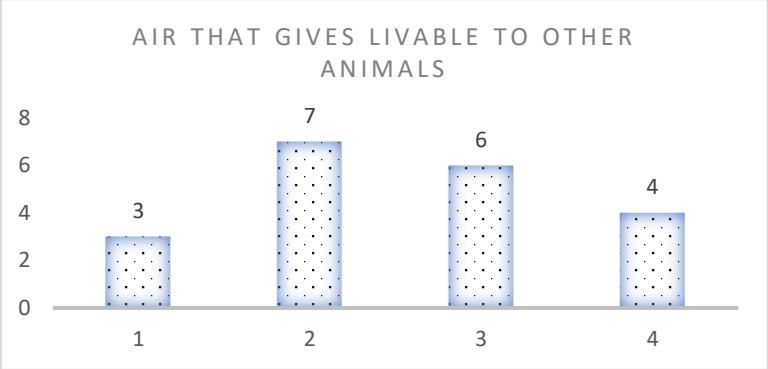
Quality on indoor air



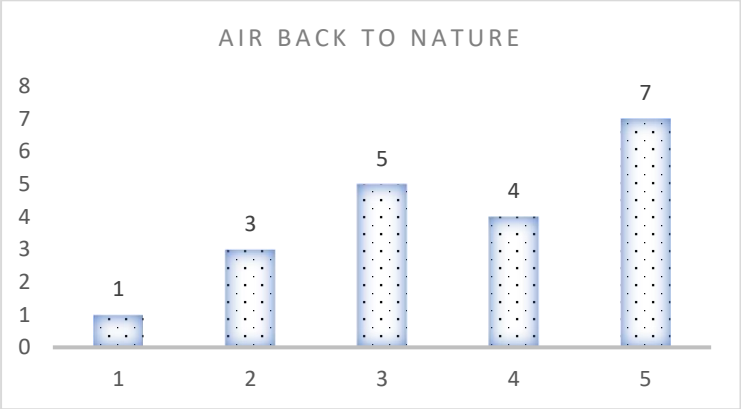
Quality of outdoor air



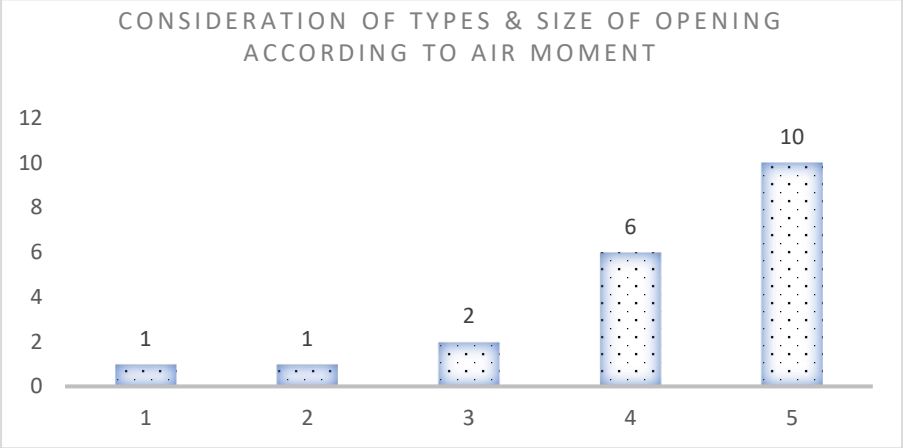
Air that gives livable to other animals



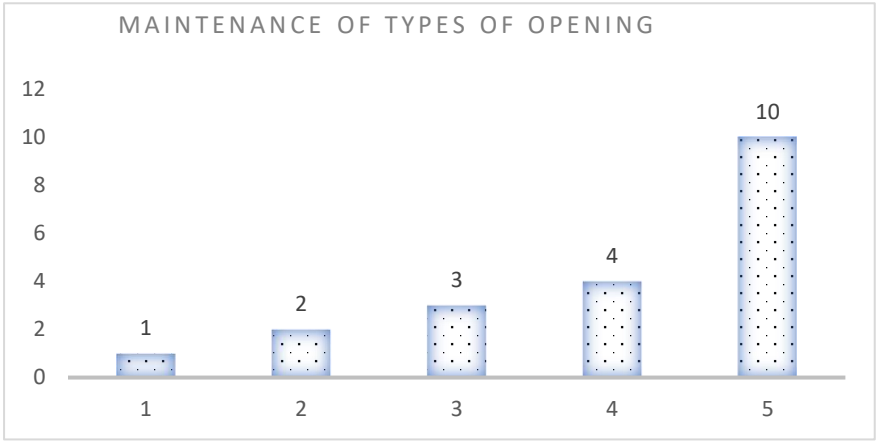
Air back to nature



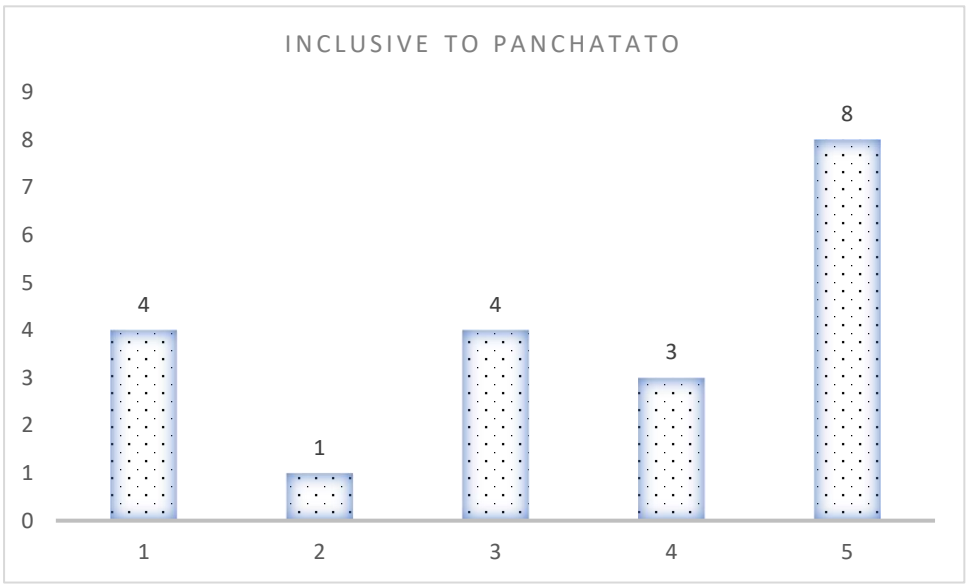
Consideration of types & size of opening according to air moment



Maintenance of types of opening

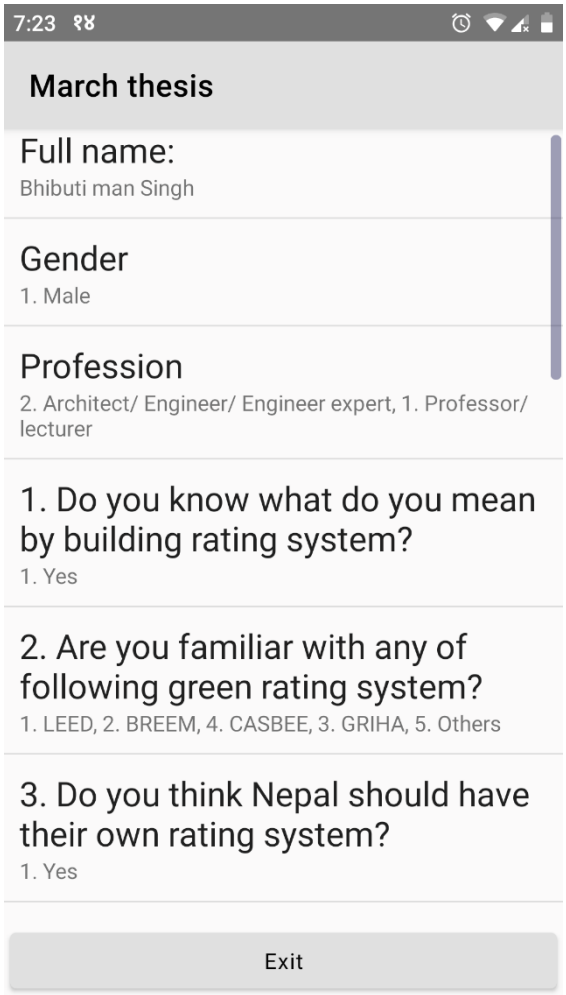


Inclusive to Panchatato



Annex C: KOBO Data collection

Annex C: KOBO Data collection



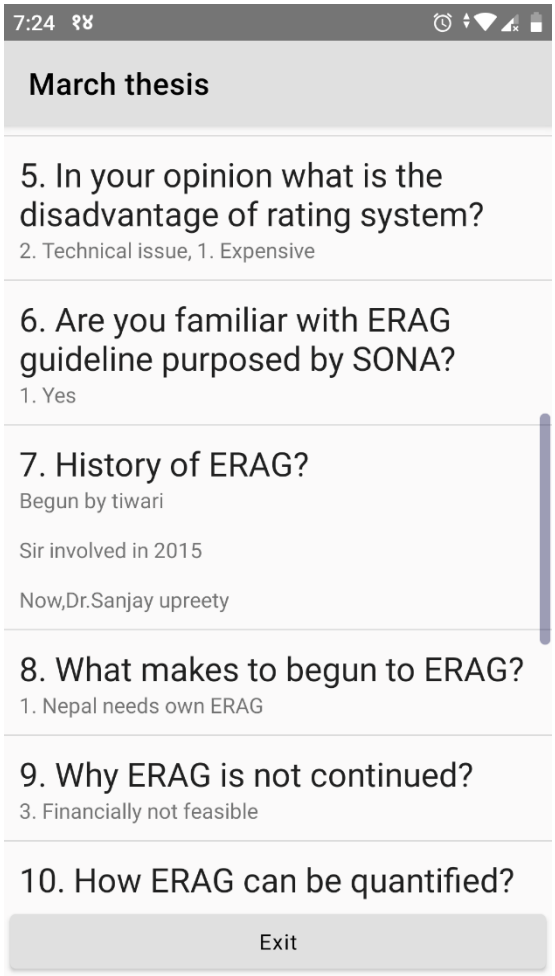


Figure 123: KOBO Data collection

Annex D: Article

Full_name	Gender	Profession	Profession/1	Profession/2	Profession/3	Profession/4	1 Do you know what ilding rating system?	_2_Are_you_familiar_green_rating_system	_2_Are_you_familiar_green_rating_system/1	_2_Are_you_familiar_green_rating_system/2	_2_Are_you_familiar_green_rating_system/3	_2_Are_you_familiar_green_rating_system/4	_2_Are_you_familiar_green_rating_system/5	_2_Are_you_familiar_green_rating_system/6	_3_Do_you_think_NEpa_ir_own_rating_system	_4_In_your_opinion_w_age_of_rating_system	_4_In_your_opinion_w_age_of_rating_system/1	_4_In_your_opinion_w_age_of_rating_system/2	_4_In_your_opinion_w_age_of_rating_system/3	_4_In_your_opinion_w_age_of_rating_system/4	_5_In_your_opinion_w_age_of_rating_system	_5_In_your_opinion_w_age_of_rating_system/1	_5_In_your_opinion_w_age_of_rating_system/2	_5_In_your_opinion_w_age_of_rating_system/3	_5_In_your_opinion_w_age_of_rating_system/4	_6_Are_you_familiar_ine_purposed_by_SONA	_7_History_of_ERAG	_8_What_makes_to_begun_to_ERAG	_8_What_makes_to_begun_to_ERAG/1	_8_What_makes_to_begun_to_ERAG/2	_8_What_makes_to_begun_to_ERAG/3	_8_What_makes_to_begun_to_ERAG/4	_9_Why_ERAG_is_not_continued	_9_Why_ERAG_is_not_continued/1	_9_Why_ERAG_is_not_continued/2	_9_Why_ERAG_is_not_continued/3	_9_Why_ERAG_is_not_continued/4
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_9_Why_ERAG_is_not_continued/5	_10_How_ERAG_can_be_quantified	_10_How_ERAG_can_be_quantified/1	_10_How_ERAG_can_be_quantified/2	_10_How_ERAG_can_be_quantified/3	_11_What_is_the_best_way_to_continue_ERAG	_11_What_is_the_best_way_to_continue_ERAG/1	_11_What_is_the_best_way_to_continue_ERAG/2	_11_What_is_the_best_way_to_continue_ERAG/3	_12_According_to_you_water_rate_for_1_5	a_Outdoor_indoor_water_use_reduction	b_Water_metering	c_Water_demand_reduction	d_Wastewater_treatment	e_Ground_water_recharge	_13_According_to_you_water_rate_for_1_5	a_Water_makes_gre e_nsideration_on_in_trees	b_Consideration_on_aquatic_lifestyle	c_Residence_provide_r_animals_like_birds	d_Wet_in_existing_soil_living_animals	e_Inclusive_to_panchatato	f_Biophilic_design_in_residence	g_Water_gives_cool	_14_According_to_you_on_air_rate_for_1_5	a_Minimum_indoor_ai_quality_performance	b_Fresh_air_Oxygen_CO2	c_Ventilation_rate	d_Ventilation_from_window	_15_According_to_you_on_air_rate_for_1_5	a_Quality_on_indoor_air	b_Quality_of_outdoor_air	c_Air_that_gives_li_ble_to_other_animals	d_Air_back_to_nature	e_Consideration_of_ording_to_air_moment	f_Maintenance_of_types_of_opening	g_Inclusive_to_panchatato		IIn_this_project_I_ironmental_parameter	_status	_submitted_by
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Quantitative Exploration on Ecologically Responsive Architecture Guideline(ERAG)of SONA

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Abstract
Modernization and expansion of many countries have been expedited by the industrial revolution in the developed world and developing world. Humans now require housing in order to survive, and they also want to increase their level of comfort. With the increase in economic development and economic status of people in developing countries, demands for architectural resources like land, buildings or building products, energy and other resources augments too. Also in case of Nepal there is less or no planning in case of green & sustainable. There is no proper system to check sustainable parameters in Nepal. However, some guidelines are considered for architectural development which is purposed by society of Nepalese architects. This paper seeks to explore on Ecologically Responsive Architecture Guideline (ERAG)- purposed by SONA, done by closed ended questionnaire survey. To explore upon ERAG, 20 numbers of questionnaire survey were done with sustainable practicing architects & with senor architects involved in ERAG. Initially found out the reason on not continued of ERAG, maximum architects agree upon quantifying sub points is better options to continue ERAG. This paper explains about sub points to quantify ERAG based on 2 elements of Panchatatoo air & water, which I am looking upon environmental & economical perspectives. This research may be useful to SONA and sustainable practicing architect.

Keywords
Air, water, environmental, economical, quantify

1. Introduction

According to Oxford dictionary sustainable means able to be maintained at a certain rate or level. A sustainable building or green building is an outcome of a design philosophy which focuses on increasing the efficiency of resource use in energy, water and materials while reducing building impacts on human health and the environment during the building's life cycle, through better siting, design, construction, operation, maintenance and removal [1]. Nepal is one of developing country in world, there is least consideration upon sustainability. Also according to [2], Nepal government is short-term firefighting solutions rather than to focus on long-term sustainable plans and policy like lack of the goverment's policy and interest in the sustainable development in country context.

Energy rating Mandatory in their country like LEED, GRIHA, BREAM, etc.[3]. For each & every design there is requirement of rating system. GRIHA is Green Rating for Integrated Habitat Assessment that addresses various concerns of green buildings through the design, construction and operations phase of any building in order to ensure minimal negative impact on the environment by using philosophy of five 'R's i.e. recycle, reuse, reduce, refuse and reinvent [4]. GRIHA is used in India for rating.

Nepal doesn't have such mandatory but have many professional that can make an efficient "green building team[5]. Although, there are some initiatives are been carried out by SONA; had purposed Ecologically Responsive Architecture Guideline (ERAG). ERAG is ecologically responsive architecture guide for Nepali context, which is initiated by Society of Nepalese Architects (SONA) by Past President Ar. Bibhuti Man Singh to provide own building guideline for Nepal. ERAG's was begun "For contextual sustainable building design in all the geographical regions within Nepal"[6]. ERAG was begun in 2012 A.D. however ERAG is not been continued till now. This research is aimed to analyze

upon ERAG purposed by SONA & draw some parameters for quantitative analysis on residential building of Nepal.

1.1 Problem statement

Nepal has Building code just in reference to safety measures but doesn't have any Residential Sustainable Building Rating System and it is likely to have the largest environmental impact and the largest benefit from sustainable design[5]. Although there is high energy demand with haphazard development, here no such initiation upon sustainable guideline for building design in case of Nepal. There is begun some building code and guideline by municipalities. Ecologically responsive architectural guideline (ERAG) is the guideline which is debuted by SONA. Term of ERAG was proposed by Prof. Dr Sudarshan Raj Tiwari during the 2nd SONA Committee on Green & Sustainable Architecture (SCGSA) led by Ar Bibhuti Man Singh in 2012A.D. ERAG was begun because international rating system has lengthy process, costly, intense documentation required. SONA came up with matrix of topics that comes under it which can be used as guideline for building design. According to survey, most of architect aspects that ERAG is not continued because ERAG cannot be used as quantifying tools for buildings. Also, most of aspects comes under philosophical approaches rather than implementation for building design.

1.2 Objective

Ecologically responsive architecture, is an approach to building that minimizes harmful effects on human health and the environment [5]. ERAG is ecologically responsive guideline proposed by SONA. At first the aim was to establish Nepal's own GSA rating system during the 1st SCGSA duration and various meetings into the subject was held among the experts, stake holders and architecture fraternity and also UN Habitat where other Government/Non-government Organizations were also involved. ERAG was begun in past year but which was not continue till now. So, this research is based continue on ERAG & explore more on ERAG.

1.Quantitative explore upon Ecologically Responsive Architecture Guideline (ERAG).

1.3 Relevance and Importance of Study

In Nepal, design and construction of green buildings are still considered to be not so common and most of the customers/builders are not aware about the effectiveness and performance of those kind of buildings[7]. Also, there is no such strike building rules and regulations in our country context. So, might be that is a reasons why users of residence are less focused in sustainable parameters for building construction. By continuing upon Ecologically Responsive Architecture Guideline (ERAG) we can target upon making building towards sustainable. By continuing upon ERAG Nepal would have its own guidelines for building design that provides green buildings for society & would support national energy crisis.

2. Literature review

On literature review study of sustainable architecture, LEED, GRIHA, SDGs'. In case of architecture, sustainability concept reflects Green architecture, development of architecture according to naturally suitable, living favorable conditions and that condition which affects least impact toward living animals, plants and other environmental factors[1]. Building ought to be sustainable from plan, develop, construction in field to operation and upkeep stage. Use of proper planning in design, site wise suitable planning & design and easy on phase of operation and maintenance. Consideration of nature & natural parameters provides green features for living parameters. Financial, natural, cultural and social sustainability are like column for all sustainability concept; combination of these measures in appropriate way gives way better sustainable society. Sustainable architecture is designed to decrease the by and large effect of the built environment on human wellbeing and the natural environment by efficiently using energy, water, and other resources, securing inhabitant wellbeing and progressing worker efficiency and Decreasing squander, contamination and natural degradation[8]. LEED & GRIHA are rating system, used in sustainable building. LEED is Leadership in Energy and Environmental Design which consists of a set of performance standards used in the certification of commercial, institutional and other building types in both the public and private sectors with the intention of promoting healthy, durable, and environmentally sound practices. Green Rating for Integrated Habitat Assessment that

addresses various concerns of green buildings through the design, construction and operations phase of any building in order to ensure minimal negative impact on the environment by using philosophy of five 'R's i.e. recycle, reuse, reduce, refuse and reinvent[4]. SDG 11 is a dedicated goal that focuses on cities and human settlements and is built around urban sustainability. ERAG is ecologically responsive architecture guide for Nepali context, which is initiated by Society of Nepalese Architects (SONA) by Past President Ar. Bibhuti Man Singh. ERAG's major objective is rating guideline for "For contextual sustainable building design in all the geographical regions within Nepal". ERAG is started because international rating system has lengthy process, costly, intense documentation required. SONA came up with matrix of topics that comes under ERAG. It consist of three sections: the middle section or core, basic constituent of the universe were placed i.e. Jal, Vayu, Agni, Prithvi and Aakash. According to society of Nepalese Architects each of these elements were to be used as the medium through which to view each of the 'aspects' ranged on each side.

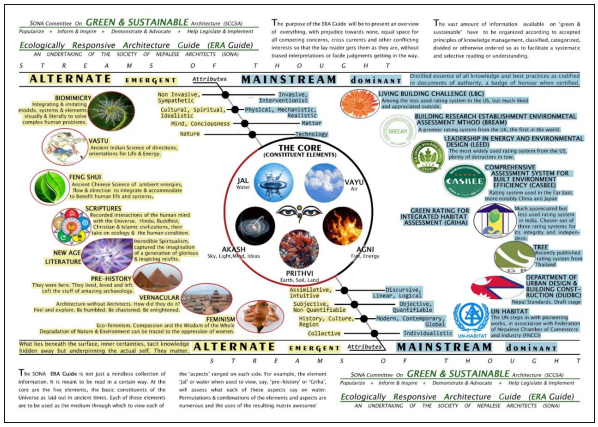

Figure 1: ERAG framework

3. Methodology

This research falls under post-positivist paradigms. According to the post-positivist paradigm believes that reality can be measured, which is believes as truth but not absolute. This research talks about evidences based facts on case study. According to ontological claim post-positivist paradigm talk about reality but only imperfectly and probabilistic, in this research by case study method facts will be identified by direct field observation. For epistemology, post-positivist paradigm talks about finding probable truth, facts of research where case study with analysis and observation will be done to meet research purpose. For objective to explore on ERAG, I will do 20 numbers of questionnaire survey, from architects practicing green. From this I will be familiar about architect perception upon national building design guideline.

Research methodology includes various sequential steps to find out result of given problem on a specific content. This research will be done through study of perceptions of architects and methodology will be:

To continue ERAG, I had done survey on why ERAG is not continue and what can we be done to continue ERAG. A quantitative questionnaire had been designed to obtain the answers to evaluate the perception of architects upon ERAG & know how we can make ERAG in quantifying way. The major focus will be to address the questions that can withdraw the desirable objectives on "To explore on ecologically responsive architecture guide (ERAG) system purposed by SONA." For this 20 numbers of Architect had been chosen for closed ended questionnaire survey. Numbers of architects had been decided by sample size calculation.

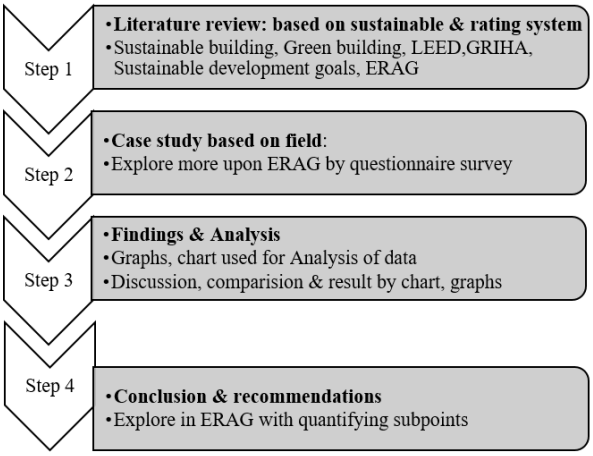

Figure 2: Methodology framework

4. Data Collection

Let's consider,

Sample size calculation

Maximum margin of error (€) = 5

Confidence level= 95

So, z= 1.960 The number of sustainable practicing architect are roughly 60 numbers.

So,

n=N * P(1-P)N/€(N-1)* €+Z * P(1-P)* Z

Therefore,

n= 20.28=20

Data had collected primarily from the questionnaire among the selected architect which is further processed to give suitable output.

5. Findings and Analysis

5.1 Reason to begin ERAG

Out of the 20 surveyed Architects, in reason to begin ERAG while proving multiple choice of selection 13 points comes under Nepal needs own ERAG, 5 points comes on other country context rating system does not match, 18 points comes on difficult to take grade of other rating system and 2 points shows agree to expensive in use option. As of international rating system their conditions are not easy to rate Nepali buildings.

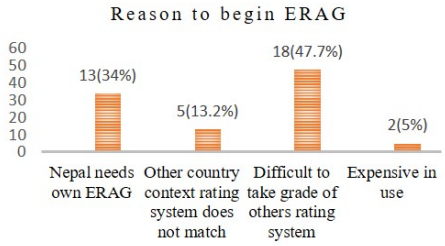

Figure 3: Reason to begin ERAG

5.2 Reason to ERAG not continued

ERAG while proving multiple choice of selection 13 points comes under Nepal needs From the survey of reason to ERAG not continue some respondent explain about not familiar and not required. Most of architect aspects about technically not feasible to further continue.

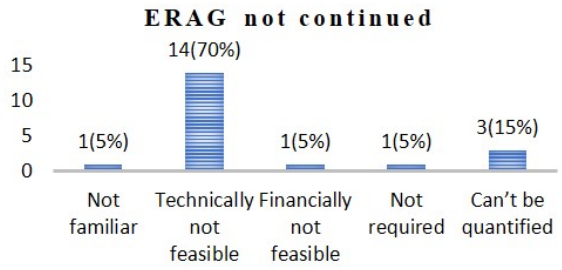

Figure 4: Reason to ERAG not continue

5.3 Better way to continue ERAG

From the survey of better way to continue ERAG, it was seen that 11 people aspects about giving knowledge on ERAG, 6 architect aspect upon providing appreciation to users and 3 aspects upon giving awards & credits. Most of architects aspects about making familiar on ERAG is by giving knowledge upon ERAG. After survey it was found that quantifying ERAG is the better point tp continue ERAG. To quantify ERAG elements of Pachatato air & water had been chosen based with energy efficiency & environmental aspects.

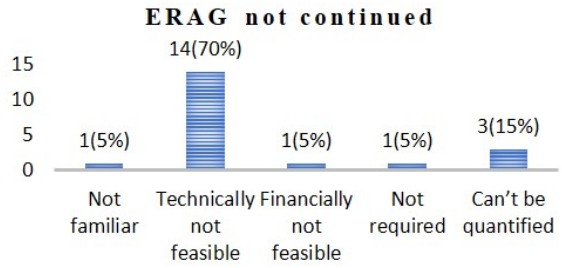

Figure 5: Better way to continue ERAG

5.4 ERAG can be quantify

From the survey of how ERAG can be quantified, it was seen that 1 respondents Aspect about providing rating system, 12 talk aspects about adding quantified sub points, 7 aspect about providing knowledge on ERAG. Most of people aspects about adding quantified sub points. That quantifying points gives to possible points for further continue of ERAG.

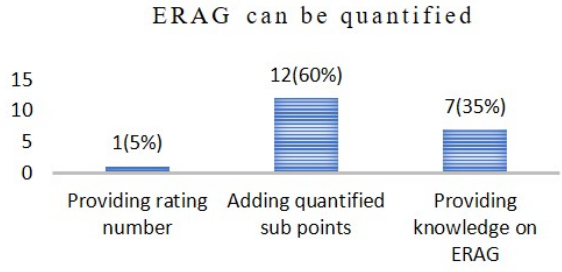

Figure 6: ERAG can be quantify

5.5 Energy Efficiency based on water, rate out of 1-5

While looking upon energy efficiency based on water, most of Architects gives water demand reduction, wastewater treatment, ground water recharge, these are most prioritize points.

S.No.	Indicators	Points
a.	Outdoor & indoor water use reduction	5
b.	Water metering	4
c.	Water demand Reduction	5
d.	Wastewater Treatment	5
e.	Ground water recharge	5

Figure 7: Energy efficiency based on water

5.6 Environmental Efficiency based on water, rate out of 1-5

According to survey, environmental efficiency based on environmental parameters had been prioritize upon biophilic design in residence design, that is natural things have to priories in have to considered highest point in ERAG guideline.

S.No.	Indicators	Points
a.	Water makes green consideration in trees	3
b.	Consideration on aquatic lifestyle	4
c.	Residence provides shelter to other species like birds	3
d.	Wet in existing natural ground consideration upon soil living animals	3
e.	Inclusive to Panchatato	4
f.	Biophilic design in residence	5
g.	Water gives cool	4

Figure 8: Environmental Efficiency based on water

5.7 Energy Efficiency based on air, rate out of 1-5

Ventilation rate & ventilation from window are highest scored indicators of energy efficiency based on year, there should be fulfill on minimum requirement upon sufficient ventilation.

S.No.	Indicators	Points
a.	Minimum indoor air quality performance	4
b.	Fresh air Oxygen & CO2	4
c.	Ventilation rate	5
d.	Ventilation from window	5

Figure 9: Energy efficiency based on air

5.8 Environmental Efficiency based on air, rate out of 1-5

According to survey, environmental efficiency based on environmental parameters had been prioritize upon quality on indoor air, used air should give back to nature, consideration of type & size of opening according to air moment, maintenance of types of opening & inclusive to Panchatato.

S.no.	Indicators	Points
a.	Quality on indoor air	5
b.	Quality of outdoor air	4
c.	Air that gives livable to other animals	2
d.	Air back to nature	5
e.	Consideration of types & size of opening according to air moment	5
f.	Maintenance of types of opening	5
g.	Inclusive to Panchatato	5

Figure 10: Environmental efficiency based on air

While looking on overall table, total sum of sub points based on air & water are as follows:-

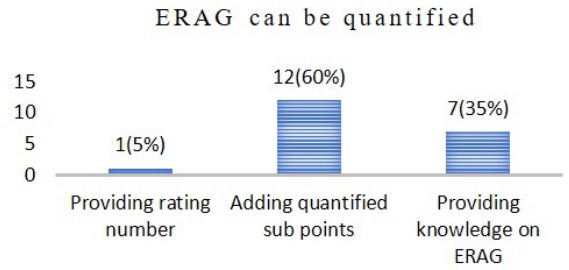

Figure 11: ERAG can be quantify

6. Conclusion and recommendations

6.1 Conclusion

The objective of study was to Quantitative explore upon Ecologically Responsive Architecture Guideline (ERAG). Quantitative analysis was done with 20 sustainable practicing architects to find out perspective of architect upon ERAG. While looking upon energy efficiency based on water, most of Architects gives water demand reduction, wastewater treatment, ground water recharge, these are most prioritize points. According to survey, environmental efficiency based on environmental parameters had

been prioritize upon biophilic design in residence design, that is natural things have to prioritized in have to considered highest point in ERAG guideline. Ventilation rate & ventilation from window are highest scored indicators of energy efficiency based on year, there should be fulfill on minimum requirement upon sufficient ventilation. According to survey, environmental efficiency based on environmental parameters had been prioritize upon quality on indoor air, used air should give back to nature, consideration of type and size of opening according to air moment, maintenance of types of opening & inclusive to Panchatato. From which it is found that, quantifying ERAG is best option to continue ERAG, from which water & air based parameters are being decided for; as shown in table four indicators has respective points for quantify; point giving aspect which can be used to quantify residence of Kathmandu.

6.2 Recommendations

Based on the findings of the research, following recommendations are suggested. As findings are obtained through case study method & quantitative analysis, questionnaire surveys done in with 20 sustainable practicing architect. The recommendation are drawn from views of the researcher.

1. There are five elements of Panchatato, for ERAG guideline where I had looked water & air; selection of other three elements could be better for ERAG rating analysis.

2. Continue of ERAG; SONA have to make some quantify points & have to strictly apply.

3. From my research it is found that, in Nepal there is required of quantifying tool to check sustainability in building for that either form SONA or from government of Nepal have to take initiated.

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Date: September 14, 2022

To Whom It May Concern

This is to confirm that the paper titled "*Quantitative Exploration on Ecologically Responsive Architecture Guideline(ERAG) of SONA*" submitted by **Samiksha Adhikari** with Conference ID **12031** has been accepted for presentation at the 12th IOE Graduate Conference being held in October 19 – 22, 2022 at Thapathali Campus, Kathmandu.

Khem Gyanwali, PhD
Convener,
12th IOE Graduate Conference

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