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ANALYTICAL EXAMINATION OF SUSTAINABLE DEVELOPMENT GOALS: DEFINING A BETTER LIVING ENVIRONMENT WITH SPECIAL REFERENCE TO SOLAR ENERGY

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ABSTRACT

This research critically analyzes the Sustainable Development Goals (SDGs) with a particular emphasis on their role in defining and promoting a better living environment. Focusing on the integration of solar energy technologies within the framework of sustainable development, the study explores how advancements in solar energy can contribute to achieving key SDG targets related to clean energy, climate action, and sustainable cities and communities. Through a comprehensive analysis of relevant literature, policy documents, and case studies, the research evaluates the potential benefits, challenges, and policy implications of harnessing solar energy to enhance living environments in urban context. By examining the interplay between solar energy adoption, developments, and environmental sustainability, the study aims to provide valuable insights for policymakers, architects, and energy practitioners seeking to advance sustainable development agendas.

Keywords: Sustainable Development Goals, Renewable Solar Energy, Climate Crisis, Climate Action

OBJECTIVES

1. To critically analyze the relevant Sustainable Development Goals (SDGs), particularly those related to clean, renewable energy and climate action helping to make sustainable cities and communities.
2. To examine case studies and best practices from different regions to illustrate successful initiatives and innovative approaches for leveraging solar energy to improve living standards and promote sustainable development.
3. To provide recommendations for policymakers, architects, and energy practitioners on strategies for effectively integrating solar energy into sustainable development agendas, with a focus on enhancing living environments and ensuring equitable access to clean energy resources.

1. INTRODUCTION

The Sustainable Development Goals were derived at the United Nations Conference on Sustainable Development held in Rio de Janeiro in 2012. The objective was to effectively tackle the challenges of the contemporary global landscape and prepare for forthcoming circumstances through a comprehensive comprehension of the prevailing political, economic,

and environmental concerns. SDGs, consisting of 17 SDGs and associated 169 goals, were adopted in 2015 after a thorough implementation process. SDGs have a specific emphasis on the year 2030. These goals seek to eliminate poverty, guarantee food security, enhance health and education, promote gender equality, ensure access to clean water and energy, establish sanitation systems, create employment opportunities, develop infrastructure, diminish inequality, foster sustainable urbanization, encourage responsible production and consumption practices, address climate change, and preserve ecological systems. These goals must be implemented by all member nations of the United Nations. The study titled "Sustainable Development" by the U.N. Department of Economic and Social Affairs in 2023.

For a long period, human activities are the main core contributor of climate change, and primarily huge amounts of burning of natural resources like burning of fossil fuels like coal, oil and gas. Greenhouse gasses are generated from the sectors such as Energy, industry, transport, buildings, agriculture and land use. Addressing the major issue of climate change, the Paris Agreement came into existence to get actions on cutting emissions, adapting climate impact along with financial adjustments.

UN Climate Change Conference (COP21) in Paris, adopted a legally binding international treaty on climate change as The Paris Agreement on 12Dec2015, France. The Goal is to limit global warming to 1.5C, emissions of greenhouse gas should be least and decline by 2030. The need of defining 1.5C as a threshold temperature is needed to combat severe climate change impact, which includes more frequent and severe droughts, heatwaves and rainfall. (United Nations, Climate Change, The Paris Agreement COP21, 2016)

UN Climate Change Conference (COP 28) in Dubai, 2023 was the first global event to conduct the stock of addressing the climate change action under Paris Agreement. It showed the slow progress across the areas of climate action ranging from reducing greenhouse gas emissions, strengthening resilience to changing climate, getting financial and technological support to vulnerable nations and taking a decision for increasing climate action by 2030. (United Nations, Climate Change, The Paris Agreement COP28, 2023)

This conference led to push and take up the required decisions as a transition from fossil fuel era to renewables such as solar and wind power for climate commitments. Growing countries are also committed to reaching net zero emissions by 2050, and emissions should be cut to half by 2030 to keep the global warming temperature to 1.5C. (United Nations, Climate Change, Science)

Sustainable Development Goal no.7 ensures Access to modern, cheap, sustainable and dependable energy to every man. It works upon Access to Electricity, Use of fossil fuel to basic needs of cooking, and Access to modern renewable resources. With the pace of time, the above mentioned areas have achieved good growth targets.

Table 1

Sustainable development goal Report from 2016 - 2023, reflecting under Access to Electricity, Access to Healthy technologies and Access to Renewable Energy to the world

SDG Reports (2016-2023)	Access to Electricity	Use of unhealthyFossil Fuel of cooking	Access to modern Renewable resources
SDG Report 2016	85% have an access, still 1.1 Billion people (under-developing countries)are left	Use of clean gas reached 58%. But 3 billion people still depend on unhealthy technologies	World Energy consumption increased to 18.1%. Eastern Asia raised to72%
SDG Report 2017	96% access to urbanareas, while 73% access to rural areas	Fuel access of 78% tourban areas while 22% to rural areas.	Wind and solar sectorfor generating electricity reached to 22.3%, while for heat& transport is very low
SDG Report 2018	97% access to urbanareas, while 76% access to rural areas	41% still lack accessto healthy technologies	Close to same percentas last year which is 23%
SDG Report 2019	9 out of 10 have an access in urban areas but 87% still for ruralareas	61% of the global population have an access, but needs tobe tackled by policymakers	Good policy support and cost reduction allowed expansion ofwind and solar generated electricity
SDG Report 2020	90% have an access to electricity, still 620million people lack ofit	63% of global population have an access, while 2.3 billion people lack thebasic need	Good policy support leading to good expansion, leading toprovision to LDC

SDG Report 2021	90% access to electricity, while 1.1 billion received electricity for the firsttime	66% have an access to neat, clean technologies, leaving 1/rd population without it	It exceeds 25%, alongwith small percentageof heat and transport sector

United nations, Department of Economic and Social Affairs, Statistical Division (Sustainable Development Goals, 2023)
Large organizations of the countries are formulating key policies and models to understand the core problems of the world. UN introduces the key Sustainable Development Goals, Paris Agreement looks into the deeper aspect of Climate Change and greenhouse gasses, and SDG Reports brings the statistical data with urban as well as rural scenarios diving deeper for an access to Energy to all. These large social organizations suggest the need for bridging the gap between the urban and rural access, implementation of policies and the challenges faced by them, with the focus on Climate Action through Renewable Energy resources.

1.1 SUSTAINABLE DEVELOPMENT GOALS - THE INDIA STORY

The main think tank of the Indian Government, Niti Aayog has been given the duty of organizing the SDG, mapping initiatives relevant to the SDG and their respective targets, designating lead and supporting ministries for each goal target.
Furthermore, the Ministry of Statistics and Programme Implementation (MoSPI) has been leading the negotiations for developing national indicators for the SDGs. State governments are crucial to India's development toward the SDGs because they are in the best position to "put people first" and ensure that "no one is left behind." (“Our Work on the Sustainable Development Goals in India”) To ensure that no one is left behind, and keeping people first, the UN Country team in India supports NITI Aayog, Union ministries and State governments to address the interconnectedness and inter-dependentness for achieving the SDGs.

MINISTRY OF NEW AND RENEWABLE ENERGY

The Ministry of New & Renewable Energy is the key ministry for the Government of India for any matters related to energy and specifically to renewable energy. It’s goal is to create and implement renewable energy sources for building the nations energy meet.
National Institute of Solar Energy is the autonomous institute under the Ministry of New and Renewable Energy, for research and development of solar capacity building, products and its applications. It has been established for the solar energy sector to bring in newer technologies, developing practices standard and cater to the changing needs of the industry. This institute estimates the country’s solar potential to be around 748GW assuming 3% of the waste land to be covered by solar panels. (Ministry of New and Renewable Energy, Solar Overview, March 2024). Every country wants to take up Solar as a nodal point for development. So, India‘s National Action Plan on Climate Change is to take Solar energy as the center for Sustainable Development through the National Solar Mission. This was launched on 11th Jan2010. This initiative at the National level connects all the states to participate and promote sustainable growth through India’s Energy challenges. It will allow ecological growth meeting the global contribution for climate action challenges. The Objective of it is to establish India as a global leader in solar energy by carving policies for solar technology penetrating into every corner of the country as soon as possible. Government initiatives like access of foreign direct investment, defining complete roles of stakeholders and consumers for Renewable energy, inter-state exchange of power units etc will definitely bring positive change to the country along with becoming one of the major renewable energy generators at global level.

2. NATIONAL SOLAR MISSION

National Solar Mission, is one of the eight core missions that defines the National Action Plan on Climate Change. It was set up on 30th June, 2008 to identify solar energy technology in the nation. The government sanctioned the mission on 11th Jan, 2010 with the goal of installing 1,00,000MW of grid connected solar power by 2022. This establishes that the National Solar Mission will position India as a global leader in solar energy by establishing the legislative framework for its rapid acceptance and execution throughout the nation.

The Mission will adopt a 3 - phase approach, Phase 1 (up to 2012 - 13), Phase 2 (2013 - 17) and Phase 3 (2017 - 22). The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level.

Phase 1 (2010-13)

Establishing 1,000 MW grid-connected solar plants (33 KV and above), 100 MW of rooftop and small solar plants connected to the LT/11 KV grid, and 200 MW capacity equivalent off-grid solar applications are the goals of the Jawaharlal Nehru National Solar Mission.

Phase 2 (2013-17)

In addition to the current goal of 60 cities, the National Solar Mission envisions the installation of approximately 10 GW of utility-scale solar power projects, 1000 MW of rooftop PV projects (both grid-connected and off-grid), 15 Solar Cities, 4 GW of which would be developed under the central scheme, and 6 GW under various State-specific schemes.

Phase 3 (2017-22)

The goal for phase three was to install 20 million square meters of solar thermal collectors, 2000 megawatts of solar electricity for off-grid uses, and 20,000 megawatts of grid power, including small and rooftop plants. (Jawaharlal Nehru National Solar Mission Towards Building SOLAR INDIA, Mar 2024)

2.1 OFF GRID SOLAR

It is one of the earliest initiatives of the ministry, off-Grid Solar PV Applications program which aims to provide Solar PV based applications in areas where grid power is either

unavailable. Generally Rural areas of the country or Low Developing countries still lack access to electricity. The above statement can also be referred from SDG Report 2016. Common service elements like Solar lanterns, Solar street lighting systems, solar study lamps, solar power plants and solar pumps will be covered under this initiative.

Table 2

Phase wise - Generated Solar values for off grid generation

PHASE	SANCTIONED	INSTALLED
Phase I	252.5 MW	117 MW
Phase II	713 MW	345.5 MW
Phase III	20.09 MW	15.67 MW

2.2 ON-GRID SOLAR

As climate change needs to be addressed with better policies for use of renewable solar energy, the government addresses the country's energy needs through the growth of the solar power industry. The government of India has launched various schemes to promote solar power generation in the country to achieve the global target. Schemes like Solar park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal Top Scheme, Grid Connected Solar Rooftop Scheme, etc provide assurance from Government for promotion of grid connected solar power and fulfilling individual as well as community needs.

3. CURRENT SCENARIO: POLICY IMPLEMENTATION AND ACHIEVEMENTS

Sustainable Development has gone through a long journey with commitments from government officials, policy makers, and executors of the same. COP26 Summit, 2021 is UN Climate Change conference, where all the world leaders, delegates, participants, media representatives and many more came together to tie the facets of climate change through science, solutions, political and action plans.

During this conference, Prime Minister Narendra Modi in his address, said that India would achieve net zero emissions by 2070. ("National Statement by Prime Minister Shri Narendra Modi at COP26 Summit in Glasgow")

He presented core 5 key aspects for India as below:

- Firstly, India will increase its non-fossil energy capacity to 500 GW by 2030
- Secondly, India will fulfill 50% of its energy requirement through source of renewable energy
- Thirdly, India will cut down its carbon emission by 1 billion tonne till 2030
- Fourthly, India will bring carbon intensity down by more than 45% till 2030
- Fifthly, India will achieve the target of Net Zero.

("National Statement by Prime Minister Shri Narendra Modi at COP26 Summit in Glasgow")

India now ranks fifth in the world for the use of solar electricity. (IRENA's Renewable Capacity Statistics 2023) [12] As of June 30, 2023, 70.10 GW of solar power had been put into service nationwide. A total of 10.37 GW from rooftop solar projects, 2.51 GW from off-grid solar projects, and 57.22 GW from ground-mounted solar projects make up the 70.10 GW capacity. ("Renewable Energy Capacity Statistics 2023")

Table 3

Capacity of Renewable Energy/Solar Energy/Solar PhotoVoltaic from 2013-2022, India. The first three columns are On-Grid Capacity while last three columns are of Off-Grid Capacity

YEAR	Total Renewable Energy MW	Solar Energy	Solar Photovoltaic	Total renewable energy	Solar Photovoltaic	Renewable share capacity of electricity
2013	63589	1599	1446	9357741	269577	22.5
2014	71889	3773	3444	2010101	381328	22.9
2015	78579	5693	5365	3555641	486114	22.7
2016	90411	9979	9651	5661521	637861	24.8
2017	105253	18252	17923	805507	870886	27.1
2018	118195	27453	27125	2079650	1098628	28.1
2019	128428	35203	34861	2081682	1130378	29
2020	134455	39385	39043	2238922	1190378	29.9
2021	147122	49684	49342	2081682	1367173	31.5
2022	162963	63146	62804	2774857	1722113	33.7

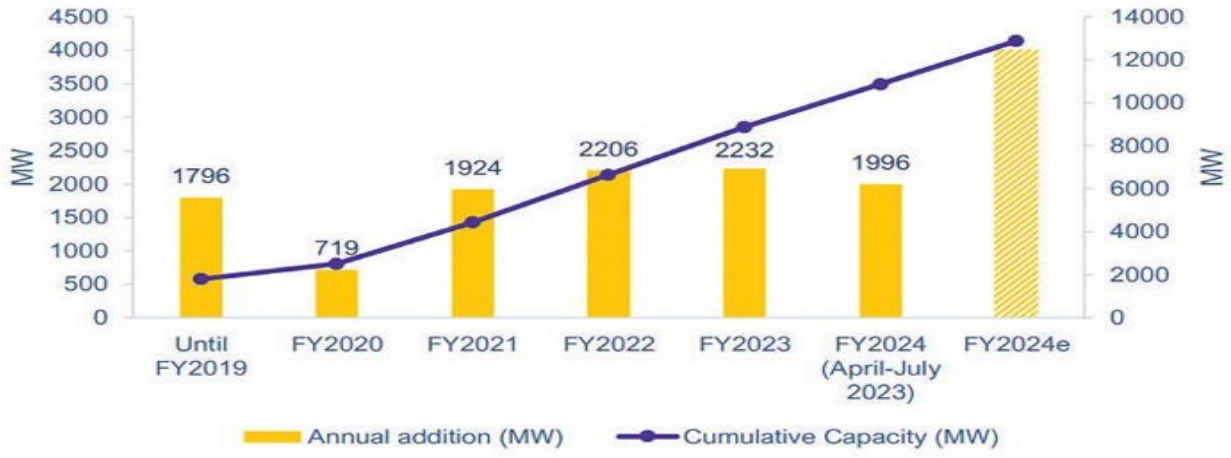
("Renewable Energy Capacity Statistics 2023")

The above Table clearly communicates that overall the generation of Renewable Energy has increased over the years. It could be part of On-Grid or Off Grid capacity. The intent of forming SDG globally by UN, 2012 and transforming Developing countries is reflected through the above shared numbers. India is making efforts through the support of government officials, policy makers as well as ground officials.

The introduction of the Pradhanmantri Suryodaya Yojana in the interim Union Budget 2024–2025 signals a major advancement for the rooftop solar industry in India. This program, which is envisioned by Finance Minister Nirmala Sitharaman, will provide up to 300 units of free electricity each month to beneficiaries, therefore electrifying the country's renewable energy landscape. With the help of this massive project, which aims to benefit 10 million people, extra solar energy will be able to be sold, promoting an ecosystem that produces its own energy.

The launch of the programme coincides with India's efforts to increase the country's rooftop solar installations, which is a crucial moment. Less than 15% of the objective was reached by mid-2021, indicating that progress has been slow even though the ambitious aim of 40 GW by the end of 2022 was set. To close the gap and help India realize its goals for renewable energy, the Pradhanmantri Suryodaya Yojana promises to provide this industry with fresh impetus. (verma)

Table 4
On-Grid Connected Rooftop Solar Installation in India



(MNRE/IEEFA Report, Saur Energy International) [14]

4. CASE STUDY

India is expanding and exponentially growing in the area of the construction industry. Most of the buildings and structures in various typologies have installed rooftop solar panels to meet their electricity needs. Every region has different climatic conditions which leads to planning the needs of it uniquely. So, let's understand through various case studies of residential typology to overview the design of rooftop solar panels.

CASE 1: AVADH HELICONIA GREENS, VAPI, 2018

The project is a premium housing project located at Vapi. It hosts amenities like Indoor games, Lavish Guest Rooms, Wellness Center, Spa, Fine Dine restaurant, Conference Room, Event Lawn, Banquet Hall and many more.

It is defined as a duo of luxury and nature, with every element developed under a green canopy which brings sophistication and serenity.

Image1: It depicts the huge spread of the project with green spaces and land around it

Source: Avadhprojects.com

The project has various categories of Individual Unit. These units vary from 3BHK to 5BHK. Every unit has its own boundary to express its own individuality along with the common cluster formation with larger communities. All the amenities are inclusive in the township ranging from small shop to restaurant. Coming to the architecture of it, the typologies are of either G+2 or G+3. All the sides of the unit are open along with the roof space. Connecting roads are wide enough for maneuvering a 4 wheeler. Common spaces are green in nature. One will find planned landscape, green outdoor spaces and well lit public areas. Individual Units are very well planned along with visual access and treat to nature. They are spreaded on the huge acre piece of land which has a seamless sense of expansion around the project.

Image 2: Scale and spread of the project with seamless and expansion of nature around it

Source: Avadhprojects.com

Construction group has provided good structure, Good architectural language, sophisticated and luxurious amenities with plenty of soft and hard landscape natural elements. Moving ahead, the trigger is can we say the above luxurious township as a sustainable housing scheme. As the Use of Resources will define its acceptance of functionality for running and maintaining the township. One of the owners (Mr. A M Balaji) of Individual Unit, opted for RoofTop Solar Panels 8.5KW for his house. He opted for renewable energy to run his house completely making it green along with the provided natural environment. He used the Service of Solar techno (Indian Company) and SD G2 Series Inverters of GoodWe International company, It generated 40W of electricity which makes his Net Zero Building.

Image 3: Application of Rooftop Solar panels by the Individual House owner without hampering the aesthetics of the structure

Source: Saur Energy International

The combination of planned structure and culminating the solar panels along with the architectural language of building makes a good blend of aesthetics and functionality. This expression of the user states that there is a definite need to incorporate Inclusion of a rooftop solar system for decreasing the carbon footprint of the building.

4.1.1 CASE STUDY ANALYSIS

Architectural Typology: Individual units have the luxury of land spread. It uses the horizontal span of land to fulfill the needs of the user. It's a G+1 and G+2 typology of structure. In this case, individual owners of the house have included rooftop photovoltaic panels to cater their needs. Spread and provision of huge Common amenities demand more consumption of natural resources. There is a good scope of using elements like solar lights, using the roof area for amenities building and many more.

Net Zero target: As the individual owner is the decision maker for consuming and generating renewable energy, he fulfills the unit demand making it unit close to net zero. But the whole project consumes all the natural resources without giving back to it, which is not a sustainable development Policy Suggestion: As the township is a luxurious category of project, the builder should be a core stakeholder for providing the sustainable technology to the scheme. For common amenities, it should be mandatory to use renewable energy as there is a huge area to be incorporated. Along with it, the designed units should be provided with the framework so that they can also contribute for the renewable energy generation.

CASE 2: SUVIDHA HOUSING SOCIETY, BANGALORE, 2017

It is a modern retirement housing scheme spread on the huge 30 acre of land, on the outskirts of bangalore, having 160 cottages along with 3 acres of water body. It is planned keeping the topography, user need, available natural resources, Age friendly design, and construction rules as it is on the edge of a National park. It has all the required amenities like Club House, Management Office, Gymnasium, Library, Gaming Areas, Badminton court, Snooker and Health Centre.

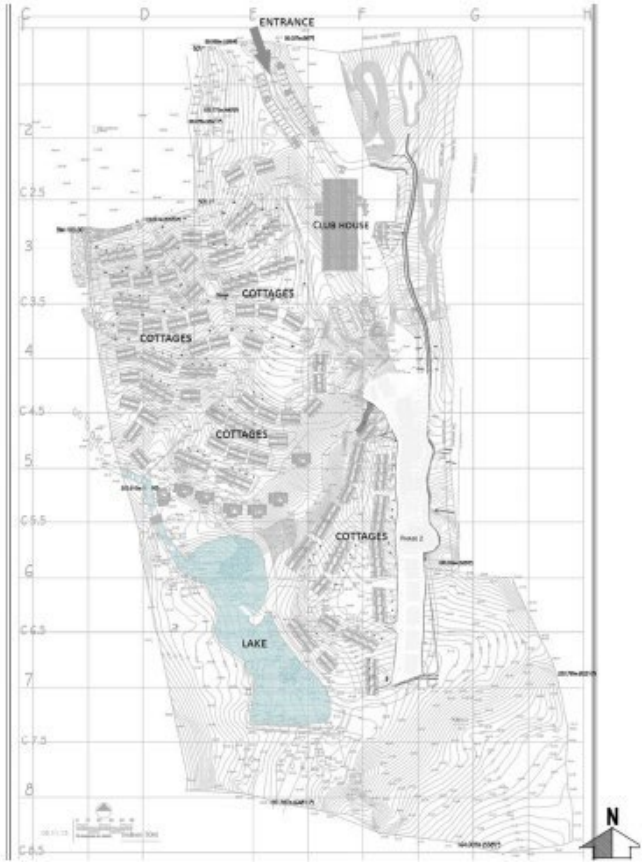


Image 4: Master Plan of Suvidha Housing (Image from Vishwanath & Associates)
Source: Retirement Community living in India: A case Study

It is a project which combines nature, social binding, with huge integration of nature.
Nature is a luxury which needs to be nurtured with conscious choice making of using renewable resources for a sustainable living environment. The project includes rain water harvesting as its planned keeping terrain condition which will make sure the surface water levels will be maintained. It also looks into biodegradable waste as a part of community living which allows to keep good soil condition. Every unit has a good exposure to natural elements from land to sun to green views and seamless vistas. But the use of Renewable energy has not been seen as an integral part of the project. On a few individual units, Solar photovoltaic panels are seen on Roof. They are located on one side of the unit depending on the unit location to the site. The pitch roof is seen differently than the photovoltaic panel leading to non-integration of architectural language of the Housing scheme.

Image 5: Solar photovoltaic panels on different row houses with varying orientation.

Source: Tata Power Solar

Image 6: Perception of Roof and rooftop photovoltaic panels at various levels

Source: YV Architects

In the project, TATA power has provided the service with 5.25 KW per unit and it is applied on 32 units. It creates 14,400 energy units annually, catering to their everyday needs. In Feb,2021 Suvidha finished 3 successful years of Solar generation. It was a joint venture between Suvidha company and shareholders. It has generated a return of 11% per annum to the Suvidha and shareholders. Well the original idea to use rooftops for solar power generation was shared by Prof. R Sankar and then it was formed with Tata Power Solar Limited in April 2016. The installation of 210 KW grid connected Net metering Solar system was chosen recently to suffice the electricity consumption for domestic, water pumping and street lighting along with the units needed. Thus, the solar energy generation creates savings on the BESCOM rate along with giving back to the grid for any excess power. The advantage of having solar power panels reduces the maintenance fee of the shareholder, along with provision of thermal insulation to the unit. It also saves on consumption of fossil fuels for generators which gives a pride for Green Cause. (Moogoor)("April-2021-Suvidha")

Table 5
Comparison of Case 1 and Case 2 reflecting with shared parameters as below

PARAMETER	CASE 1- Avadh Heliconia, Vapi	CASE 2- Suvidha Housing, Bangalore
1. Typology	Row Housing,	Row Housing
2. Solar Panel	Rooftop at Various Level	Rooftop, single side
3. Efficiency	Planned for single unit need	Planned for single unit need
4. Scope of addition	Can be added more to roof andother areas	Can be added more to roof andother topographical areas
5. Integration with Building	Integrates well with roof, but notat amenities or community level	Integrates well with roof butnot with topography

4.2.1 CASE STUDY ANALYSIS

Architectural Typology: This luxurious housing project is planned on the needs of the community, on a huge piece of land around 32 acres with natural topographical condition. The individual units are typically G+1 structure with a combination of flat and sloped roof. It provides all the required amenities for the community. The project has included rain water harvesting while designing the topography and placing the units accordingly. Along with it organic waste management is also part of design, which takes complete care of planted trees and the manure for the soil.

Net Zero target: The implementation of Solar panels happened after a few years of the project. The decision for it was a duo of community and management team which was implemented by Tata Solar group. Well the need of the community along with the amenities is taken care of completely. The extra generated units are connected to On-Grid capacity which also gives them the leverage of getting return after 3 years of implementation of solar panels.

Policy Suggestion: It's a well architectural designed housing project where topography and the user needs are well planned and structured. Installation of generating solar energy through renewable energy was added later, which hampers the visual language of the project along with

the selection of community elements too. Here, policy by the government will play a major role where implementation of generating energy renewable sources should be incorporated at the initial stage of the project itself.

5. CONCLUSIONS

In today's context, where global warming is reaching out everywhere and one cannot negotiate with the overuse of current energy sources. Every part of the world is interdependent on each other's resources. The concept of sharing the same goal at various scales of intervention will bring us as one entity. Thus, the idea of Sustainable Development Goals are a key to our way of moving ahead. Table 1, reflects the growth of one of the Sustainable Development Goals, India defining the future of the country with the global and vice versa.

Harvesting of Renewable energy and integrating into the modes of energy needs is a one of the important demands for rapidly growing and developing cities. The energy demand in India will always increase due to growth in every sector along with the rise of population in cities.

Under SDG, renewable energy is a key focus throughout the world with active power systems. All the stakeholders, from the United Nations, Developing countries government, policy makers, scientists, civil members, and private sector along with various on-ground stakeholders are really pushing together for a better conscious future.

The Construction Industry is one of the major contributors to the consumption of energy. It provides the complete house with all the required amenities keeping nature in mind. The planning of the scheme does reflect structured architectural language with well designed landscape, serene views and expansive vistas. These needs are fulfilled by the construction industry. The question arises, what happens after the house becomes home. This is where the role of individuals to make sustainable choices are expressed through buying rooftop solar photovoltaic panels. This same gap is also seen in both the cases where the individual takes the call and along with the community as well. One sees the gap for defining the policy for the construction industry, so that certain common mandatory consumption are taken from renewable sources. During the conference COP26, Prime Minister Narendra Modi in his address, said that India would achieve net zero emissions by 2070. (United nations, Climate Action) [10]

Announcement about provision of free electricity upto 300 units, by Finance Minister Nirmala Sitharaman, during the interim Union Budget 2024-2025, reflects that government wants to generate electricity through renewable source and individuals will be the beneficiary. Such policy encourages an individual to be responsible for the nation. But this leads to distribution of power to random individuals showing random growth in the society. What if there is a structure of distribution of decision as a policy will offer planned capacity of generation.

Thus, looking at growth in the generation of renewable energy, the role of police maker is very crucial. The expert should have a vision for the country in terms of expansion of generation of electricity and penetrating to every corner of the country. Consumption of Construction Industry clearly states the needs of the buyer. If sustainable development as a choice is offered to the user, definitely the future will be achieved as per the defined goals.

CONFLICT OF INTERESTS

None

ACKNOWLEDGMENTS

None

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