INTEGRATION OF RENEWABLE ENERGY IN FUTURE URBAN PLANNING:
USE OF SOLAR ENERGY

Thesis submitted in Partial Fulfillment for
the Award of the Degree of

Master of Urban and Regional Planning

by

Vedant Tarunbhai Patel
Second Semester, MURP II – 2020-21

Primary Guide: Hiral Shah
Secondary Guide: Shreya Modi

सत्यं शिवं सुन्दरम्

Master of Urban and Regional Planning (MURP) Program
Department of Architecture
Faculty of Technology and Engineering
The Maharaja Sayajirao University of Baroda
D. N. Hall, Pratap Gunj, Vadodara, Gujarat, India

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CERTIFICATE

INTEGRATION OF RENEWABLE ENERGY IN FUTURE URBAN PLANNING:

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The contents presented in this Thesis represent my original work and it has not been submitted for the award of any other Degree or Diploma anywhere else.

Vedant Tarunbhai Patel

This Thesis is submitted in partial fulfillment of the requirements for the Degree of Master of Urban and Regional Planning
at the Department of Architecture Faculty of Technology and Engineering
The Maharaja Sayajirao University, Vadodara, Gujarat, India

The present work has been carried out under our supervision and guidance and it meets the standard for awarding the above stated degree.

Primary Guide:
Hiral Shah

Secondary Guide:
Shreya Modi

Head of the Department Dr. Bhawana Vasudeva
Department of Architecture

ABSTRACT

Key-Words: -

Solar energy-Photovoltaics-Urban Planning-Planning process

-Solar Landscapes-Urban Density-Solar Radiation-Urban morphology

The population of the world continues to grow, so does the average standard of living, increasing demand for food, water and energy and placing increasing pressure on the environment. The population of the world doubled from 3.2 billion in 1962 to 6.4 billion in 2005 and is forecasted to grow to 9.2 billion in 2050.Supplies of oil, gas, coal and uranium are forecast to peak as reserves are depleting. Simultaneously, dread of environmental change is squeezing the energy area to move away from carbon consuming to atomic, sunlight based and other harmless to the ecosystem choices. India is one of the quickest developing economies on the planet. With expanding monetary development there has been a un-priority upsurge in India's metropolitan area. Fast urbanization is laying tension on existing framework and normal assets. There is a nonstop expansion in the interest for energy in different areas supporting every one of the metropolitan focal points.

Metropolitan regions at present utilize 67% of world's energy and record for more than 71% of worldwide Green House gas (GHG) outflows which are required to ascend to 73 and 76 percent individually by 2030. With a particularly quick extension, there is a need to move in energy assets and to build up a system that will empower and help urban areas in surveying their current energy utilization status, setting clear targets and getting ready activity plans for creating energy through sustainable power sources and in preserving energy through energy proficiency gauges in conveying metropolitan services. The essential goal for sending environmentally

friendly power in India is to progress monetary turn of events, improve energy security, improve admittance to energy, and relieve environmental change. Economic advancement is conceivable by utilization of feasible energy and by guaranteeing admittance to reasonable, dependable, supportable, and present-day energy for residents. Solid government support and the undeniably fortunate financial circumstance have pushed India to be one of the top chiefs on the planet's most appealing sustainable power markets. The public authority has planned arrangements, programs, and a liberal climate to pull in unfamiliar ventures to increase the country in the environmentally friendly power market at a quick rate. It is expected that the environmentally friendly power area can make countless homegrown positions throughout the next years.

The objective of this research is to study the renewable energy policies of Gujrat government. The study is extended for knowing the present scenario of existing tp schemes and problems faced by solar panel implementation process in these areas. Also, to analyze and propose how tp schemes can be planned with priority to the orientation of its physical infrastructure such as roads, the residential and commercial plots will automatically align in accordance of maximum solar efficiency.

This thesis is dedicated to my father

Tarunbhai J Patel
for his constant support to my career
and to my mother
Pallavi T Patel
who always supports me in thick and thin

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1 CHAPTER

INTRODUCTION

1 INTRODUCTION

1.1 Abstract

The population of the world continues to grow, so does the average standard of living, increasing demand for food, water and energy and placing increasing pressure on the environment. The population of the world doubled from 3.2 billion in 1962 to 6.4 billion in 2005 and is forecasted to grow to 9.2 billion in 2050.Supplies of oil, gas, coal and uranium are forecast to peak as reserves are depleting. Simultaneously, dread of environmental change is squeezing the energy area to move away from carbon consuming to atomic, sunlight based and other harmless to the ecosystem choices. India is one of the quickest developing economies on the planet. With expanding monetary development there has been a un-priority upsurge in India's metropolitan area. Fast urbanization is laying tension on existing framework and normal assets. There is a nonstop expansion in the interest for energy in different areas supporting every one of the metropolitan focal points. Metropolitan regions at present utilize 67% of world's energy and record for more than 71% of worldwide Green House gas (GHG) outflows which are required to ascend to 73 and 76 percent individually by 2030. With a particularly quick extension, there is a need to move in energy assets and to build up a system that will empower and help urban areas in surveying their current energy utilization status, setting clear targets and getting ready activity plans for creating energy through sustainable power sources and in preserving energy through energy proficiency gauges in conveying

metropolitan services. The essential goal for sending environmentally friendly power in India is to progress monetary turn of events, improve energy security, improve admittance to energy, and relieve environmental change. Economic advancement is conceivable by utilization of feasible energy and by guaranteeing admittance to reasonable, dependable, supportable, and present day energy for residents. Solid government support and the undeniably fortunate financial circumstance have pushed India to be one of the top chiefs on the planet's most appealing sustainable power markets. The public authority has planned arrangements, programs, and a liberal climate to pull in unfamiliar ventures to increase the country in the environmentally friendly power market at a quick rate. It is expected that the environmentally friendly power area can make countless homegrown positions throughout the next years. The objective of this research is to study the renewable energy policies of Gujrat government. The study is extended for knowing the present scenario of existing tp schemes and problems faced by solar panel implementation process in these areas. Also to analyze and propose how tp schemes can be planned with priority to the orientation of its physical infrastructure such as roads, the residential and commercial plots will automatically align in accordance of maximum solar efficiency.

1.2 Need of the Project

- This will lead to financial saving in terms of bills and reduction in greenhouse gas emissions and reduce the increasing energy demand; and dependence on fossil fuels to meet this demand across the city.
- The government has implemented Surya Gujarat roof top policy in 2018-19, 2019-20 where 600 MW subsidy was released while only 493MW in 18-19 and 456 MW in 19-20 subsidy was tapped by the end consumer.

- To explore geometric forms of urban blocks and the potential of solar energy to the local production of energy.
- Since the government is promoting e- transportation, requirement of clean energy would increase in metropolitan cities.

1.3 Aim

To evaluate the potential of solar energy as a primary source of power in urban areas.

1.4 Objectives

- To study the current energy situation in different sectors – Housing/ Industrial Sector.
- To analyses the renewable energy usage in the Vadodara city.
- To identify the future energy demand and requirement of the renewable energy in different sectors - Housing/ Industrial Sector.
- To provide the active and passive solar planning strategies and recommendations based on it.
- To study the current government policies and schemes related to solar energy.
- To identify the gap in implementation and efficiency of government scheme.
- Substituting the energy demand on a demonstrated area within Vadodara city which can be applied to larger context.

1.5 Scope of Work

- Analyze the source of energy and consumption for a city.
- Analysis for Integration of solar energy at micro level along with affordability index taken into consideration.
- Proposed model can be used as a base for new TP scheme designs.

1.6 Limitation

- Energy consumption data will not be considered in the hypothesis.
- The study area has been restricted to east zone of vadodara city.
- Tp scheme has been studied only for model purpose and not any data assumptions.
- Tp scheme land use will remain unaffected, only planning orientation will be analysed.

1.7 Methodology

I. Defining aim, objectives and scope of the study.

II. Defining and understanding solar energy, energy generation and values of active and passive solar energy in urban planning through extensive literature review and research papers, journal articles, and Case studies.

III. Gathering relevant information on the focused study area.

IV. Studying policy and guidelines related to Solar photovoltaic.

V. The study area profile is selected on definitive parameters.

VI. Categorization of study area after delineation followed by collecting and collating the secondary data pertaining to the study area, obtained from Vadodara Municipal Corporation, ministry of urban affairs, and other relevant authorities.

VII. Through Geographical Information System (GIS), sketch up with shadow tool, Solaris for generation capacity and solar dynamic analysis of current proposal will be analysed.

VIII. Urban plan conception, solar simulation, urban plan proposal and solar energy production calculation model for study area profile.

IX. Findings, inferences with guidelines, conclusions will be drawn.

1.8 Data source identification

- Data will be collected in two phases; primary data and Secondary Data.
- Primary data is regarding city profile and their perception.

- Secondary data will include study of demography, land use of city.

1.9 Expected out comes

Based on the data analysis various issues and gaps can be identified and recommendations and improvement strategies and policies can be identified and bringing solar Energy and Energy Efficiency interventions in different sectors can be formulated. Propose model of passive solar techniques based on data analysis.

1.10 Scope of further extension

The study could be expanded into other areas of city (other TP Scheme.

1.CHAPTER

LITERATURE REVIEW

2 LITERATURE REVIEW

2.1 Introduction

Literature survey is essential to identify the distinctive contribution one's research will make and to produce a rationale and justification for the study and also to learn how to present and discuss the research findings. An extensive review of literature was carried out to understand the necessity of using solar energy in urban scale and methods of using solar energy in cities.

2.2 General

More and more people are living in cities and this development seems to continue in the future. In Europe, cities are home to nearly 80% of the population, resulting in the production of 75% of all CO2 emissions. The metropolitan scale has regularly been disregarded in the discussion of energy utilization and environmental change, despite the fact that information showed that investment funds in energy cost of 20-half are conceivable through coordinated arranging via cautiously considering site direction and aloof systems. A broad usage of sun powered radiation in metropolitan territories seems, by all accounts, to be fundamental and a practicable technique however hugely affects the arrangement of urban communities to be completely successful. Another test is that, in Europe before the finish of 2020, all recently developed structures need to devour 'almost zero energy' and that their required energy should be created locally however much as could reasonably be expected and with sustainable sources. This prerequisite migh be difficult to meet in thick urban areas, where admittance to nearby sustainable power sources is restricted. Likewise, frequently metropolitan organizers don't have the specialized information to evaluate the capability of sun oriented energy the plan cycle.

Having the option to comprehend the sun based potential is likewise significant for planners when planning structures in metropolitan conditions. Incorporating sun oriented energy on the structure level, with rooftops and exteriors as the most sensible spots to reap sunlight based energy, should be painstakingly considered as it essentially influences the design. At the point when the reconciliation of dynamic sun based innovations is considered right off the bat in the plan interaction, it is bound to prompt more appealing arrangements. The early combination may be made simpler when planners know about areas where most energy can be created.

2.2.1 The increase of attention to solar energy

The increase of urban population, activities and technologies using fossil fuels, energy price, energy consumption and the increase of public concerns about environmental pollution and the destroy of non-renewable energy resources, are causing different experts including specialists related to building and construction to look for alternative ways of energy provision.

Building professionals have not considered the aim of good design aesthetically more and try to design the building's characteristics and requirements in depend on the decrease of using fossil fuels and avoidance of wasting energy.

Hagman (2005) says that great improvements in energy efficiency of buildings or the utilization of solar technologies on buildings have been made since 20 years ago. He says that visionary clients as well as a small but very active and innovative community of architects, designers and engineers took the risk to use and to develop further solar technologies and strategies for urban plans and buildings (Hagman, 2005). He also addresses to the cultural movement of Bernhard Rudofsky in the middle of 1960's in holding an exhibition "Architecture without Architects" in the Museum of Modern Art, New York. Building examples presented in the exhibition are effective in the attraction of architect's attention to the variety of design and structural solutions, Integration in the local landscape, exclusive use of locally available, natural construction materials, uniformity of the construction structures, application of traditional and time-tested construction techniques. In Germany, at the end of the 1960's a group of architects, designers, engineers and sociologist, called LOG ID, were aiming at a life within a green environment. The life and work in a greenhouse got tested and promoted. Home designs, similar energy gaining and a heatstorage. The idealistic goal was the dream of the self-supply (Hagemann, 2005). Then, straggle efforts have been done and various concepts such as " Biological design", "Natural Design", "Alternate Building Design", "Sustainable Architecture", "Ecological Architecture", "Solar Architecture", "Organic Architecture", "Vernacular Architecture", "Climate Architecture", "Green Architecture" and "Natural Architecture" have been created in order to create a healthy and environmentally friendly environment. Today these single approaches of the various directions are adopted under the umbrella of an "ecological and solar building design" which aims at a holistic design approach (Hagemann, 2005). "Ecological and Solar Building Design" can be described as any form of design that minimizes environmentally destructive impacts by integrating itself with the living processes (Hagemann, 2005). Some of the targets Hagman (2005) presented as the targets of ecological and solar design in its paper are lowest possible pollutant delivery at the environment, lowest possible power consumption from fossil energy resources, maximum use of renewable energy sources including the use of active and passive solar systems, exclusive use of renewable, recyclable and environmentally harmless construction materials, exclusion of all building materials with unhealthy out gassing, in particular if they are used inside the building, lowest possible interference of the environment including the use of land, improvement of the natural conditions for a diverse local-oriented animal and plant world, lowest possible consumption of drinking water, reduction and avoidance of the settlement waste to be deposited, optimal life-hygienic conditions and socially beneficial living conditions, cost effective building construction, creation of a long-term use-value, i.e. the building must be easily adjustable, alterable and repairable.

Albeit the exertion, the restricted data and information on modellers about new advancements and different plans of sunlight based innovations and its systems, the scant of constraints of structural arrangement, low information on metropolitan organizers on thought of requirements of building improvement and metropolitan specialists' deficient consideration in monetary and instructive projects to test projects, deny the immense advancement of utilizing the energy and related methodologies in urban areas. In this manner, the incessant utilization of sun powered innovations are restricted to single structures having no admittance to other fuelsources or fuel move to their situation isn't affordable.

2.2.2 The necessity of using solar energy in urban scale

There are three major reasons that interpret the necessity of using solar energy in urban scale and the consideration of its prerequisites in urban planning and urban design scales. The first is the acceleration of urban population growth around the world and the global prediction results showing the exhausting of none-renewable energy resources. In depend on the estimations done in Berlin, urban buildings consume 40% of urban energy mostly achieved by fossil fuel, while each building can provide its necessary energy from cheap, sustainable, clean and healthy solar energy by different methods of using solar energy especially through photovoltaic systems. The third reason is the long life of urban structures in comparison with urban planning

life and infrastructures' life. The difference and the possibility of changing urban infrastructure in order to use the maximum possible solar energy and the easy installation and change of photovoltaic equipment's on the buildings and even building reconstruction in this regard, are valuable and urgent because each action in urban buildings and infrastructures which are done today have the long result on the total urban structure.

Using the approach, some of the cities such as Berlin and New York have started some changes and reparations of the construction of residential buildings. And also through the application of some bylaws and codes, they appreciate or obeyed occupants to alternate unsustainable energy resources in their houses with solar technologies.

In addition, without any doubt, urban authorities and local management have a key role on empowerment and persuasion of using solar energy among individual parts and different groups of the society by introducing some local policies and an appropriate legal framework. As a result, the development and expansion of solar technologies in urban buildings could not be easily occurred without the consideration of necessary measures in urban scale.

Berlin could be mentioned as a successful city in the application of solar technologies. In the city, in 1996, European Charter for Solar Energy in Architecture and Urban Planning" was set. The charter mentioned some instructions, standards, statutory regulations and laws to guide the design of building and urban spaces in such a way that natural resources will be conserved and renewable forms of energy-especially solar energy-will be used as extensively as possible. Hagemann (2005) says that today, in some countries, such as Switzerland and Germany, approaches that were seen as "ecological" or "solar" in the past, are considered as a "state of the technology" and are applied for predominantly economic and technical reason.

In this respect, some standards are set for the serious application of solar technologies in Germany. Also, as Guedi et al (2006) say many cities like New York, San Francisco, Tel Aviv and Toronto have defined regulations to keep solar rights from a public point of view or to ensure the full use of private properties. In some countries such as Israel, although there are no general regulations to ensure solar rights for either public or private properties, although environment assessment is required when tall buildings are designed (Capeluto & etc., 2006). Moreover, PV City Guide makes indications and recommendations how strategic urban policies can be developed in order to increase the use of photovoltaic (Nowak & Gutschner, 2001). In addition, a solar urban master plan for Berlin was created by Ecofys in 2004 at the request of the City Council in order to determine the solar potentials of the different city quarters (Lindner, 2007).

2.2.3 Methods of using solar energy in cities

In recent years, solar energy is applied by different systems and for different aims. The first method is using solar thermal energy in two ways: in the first method, the energy is used in house equipment's and other daily necessity tools such as solar heating, ventilation and air-conditioning system and solar water disinfection system.

The second method of using solar energy is solar cells or a kind of installation named Photovoltaic (PV). Photovoltaic is perhaps the most promising active solar technology utilized on a building. Different from other solar technologies it has achieved a popularity and offers sophisticated design solutions for various applications on a building (Hagemann,2005). Photovoltaic offers unique opportunities to produce (solar) electricity in the urban environment. There is in fact hardly any other renewable energy technology with such a potential in the urban context. This can make photovoltaic increasingly interesting when considered in the local urban design as well as in the local energy portfolio (Nowak &Gutschner, 2001).

2.2.4 Solar Urban Planning

The aim of solar building, which is similar to solar building design and ecological design, is the reduction of using fossil fuel, efficient use of energy, providing environmentally friendly, healthy and economical style of life and use the solar energy actively and inactively through the complete and accurate understanding of ecological condition. Solar urban planning means integration of energy efficiency and solar energy in town planning via urban renewal, urban removal and new developments (Lindner, 2007). The choose of technical and planning measures that are useful in solar urban planning and solar building projects economically and technically depends on the specific characteristics of each project such as topography, climate, consumers' demands and the financial resources of the project.

In this regard, solar master plans can be mentioned. Solar master plan is a tool to distinguish the solar potential of each part of a city, the determination of regions with high priority, the definition of measures for the conversion of the potential to trial projects. The solar factor ranking in the plan is a tool in order to determine the solar potential of different regions in depend on the absolute area of developed lands of the regions and existed buildings. The main subjects outlined in the preparation of solar master plans and solar planning are the presentation and proposition of instructions to find the solar potentials of each part of cities, the study of orientation and the shading position (through simulation methods), the feasibility study technically and legally, the study of demand and consumption potentials of energy (thermal and power energy) and the identification of regions with high priorities.

Determining a correct vision and practical goals are important steps of solar planning like every planning programs. Considering the importance of using solar energy and determining appropriate goals in this direct are essential. For example, the visions of the strategic program of solar city Goteborg until 2050 are the development of sustainable energy systems for a sustainable community, smart and efficient use of energy, renewable energy supply, changing life-styles and shifts in values, energy efficient urban planning, and energy storage in a Hydrogen society.

Solar urban planning use three approaches concluding urban renovation, urban clearance and new developments for the expansion of solar technologies application. In addition to the idealist renovation plans like solar floating city in Monaco as a new solar city which provide their necessary energy from clean energies, there are multiplestudies done in existed urban textures or urban blocks which are destroying and renovating for the usage of solar technologies.

Without any doubt, in solar urban planning that consider the goal of sustainable city, three aspects of environment, economical benefit and society must be always considered. Therefore, urban planners should reflect the aspects in three important elements of cities include:

- Buildings and urban spaces
- Urban land uses
- Infrastructures (the provision and transformation grid of energy)

2.2.5 Globally scenario of solar energy

The world is experienci1ng increasing urban growth while at the same moment beginning to feel the increasing impact of rising temperatures as a result of climate change. One of the largest known contributors to the latter is the ferocious appetite that urban centres possess in both the developed and developing world in terms of energy demand. The impacts of urbanization, with significant influence from western ideology and dogmatic development frameworks of progress, rely largely on the reliability and availability of electricity and energy supply to fuel both industry and technology. Questions have been raised as to how urbanization strategies will be able to boldly address both the desire to produce massive volumes of energy while halting at minimum, if not reducing, carbon emissions produced by current energy production sources.

Power generation from solar PV is estimated to have increased by 22% in 2019, to 720 TWh. With this increase, the solar PV share in global electricity generation is now almost 3%. In 2019, PV generation overtook bioenergy and is now the third- largest renewable electricity technology after hydropower and onshore wind. Solar PV electricity generation increased by 131 TWh globally in 2019, second only to wind in absolute terms, to account for 2.7% of the electricity supply. This growth was significantly lower than in 2018, however, because global solar PV capacity additions stalled in 2018 and China's deployment further contracted in 2019. This was mainly as a result of a sudden change in China's solar PV incentives to curb costs and address grid integration challenges to achieve more sustainable PV expansion. The European Union, India and the United States contributed equally to the solar output increase.

Solar PV generation rose sharply in Southeast Asia, driven by a surge in new capacity in Viet Nam from 0.1 GW to 5.4 GW. Capacity additions increased in the United States, the European Union, Latin America, the Middle East and Africa, which together compensated for the slowdown in China, resulting in a record year for PV deployment – 109 GW were installed in 2019.

Solar PV is well on track to reach the Sustainable Development Scenario (SDS) level by 2030, which will require electricity generation from solar PV to increase 15% annually, from 720 TWh in 2019 to almost 3 300 TWh in 2030.

Stimulated by strong policy support concentrated mostly in Europe, the United States and Japan, deployment of distributed solar PV systems in homes, commercial buildings and industry has been growing exponentially over the last decade.

In most countries, commercial and residential systems already have electricity generation costs that are lower than the variable portion of retail electricity prices. The increasing economic attractiveness of distributed PV systems could therefore lead to a rapid expansion in the coming decades, attracting hundreds of millions of private investors.

In China, solar PV capacity additions slowed for the second year in row to 30.1 GW in 2019. This expansion is significantly lower than the 53.1 GW in 2017, when the

government phased out feed-in tariffs and introduced deployment quotas (in June 2018) to control costs and tackle grid integration challenges. Overall, this policy shift is expected to make solar PV technology more cost-competitive within and outside China, leading to more sustainable development over the longer term. A large number of subsidy-free projects were already in development in multiple provinces in 2019.

Distributed solar PV capacity is expected to increase rapidly in China, driven by new auctions for commercial and industrial applications and subsidies for residential systems.

2.3 Renewable energy scenario in India

2.3.1 Overview of solar energy in India

India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar photovoltaic power can effectively be harnessed providing huge scalability in India. Solar also provides the ability to generate power on a distributed basis and enables rapid capacity addition with short lead times. Off-grid decentralized and low-temperature applications will be advantageous from a rural electrification perspective and meeting other energy needs for power and heating and cooling in both rural and urban areas. From an energy security perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar energy (if captured effectively) can meet the entire country's power requirements.

There has been a visible impact of solar energy in the Indian energy scenario during the last few years. Solar energy based decentralized and distributed applications have benefited millions of people in Indian villages by meeting their cooking, lighting and other energy needs in an environment friendly manner. The social and economic benefits include reduction in drudgery among rural women and girls engaged in the collection of fuel wood from long distances and cooking in smoky kitchens, minimization of the risks of contracting lung and eye ailments, employment generation at village level, and ultimately, the improvement in the standard of living and creation of opportunity for economic activities at village level. Further, solar energy sector in India has emerged as a significant player in the grid connected power generation capacity over the years. It supports the government agenda of sustainable

growth, while, emerging as an integral part of the solution to meet the nation’s energy needs and an essential player for energy security.

There are 280 clear sunny days in most parts of the country. Most parts of the country receive solar radiation sufficient enough to effectively utilize solar energy systems.

The Government of India (GoI) has set ambitious renewable electricity targets for the short to medium term. By 2022 the country aims to have 175 GW of installed renewable electricity capacity. In 2018 the GoI announced an increased ambition of 227 GW renewable capacity by 2022 and 275 GW by 2027. At the United Nations' Climate Summit in New York on 23 September 2019, the Prime Minister of India announced a new target of 450 GW of renewable electricity capacity, without specifying a date.

At the end of November 2019 grid-connected renewable electricity capacity reached 84 GW, with 32 GW coming from solar photovoltaic (PV), around 37 GW from onshore wind and the remainder from small hydro. Solar PV has been on a rapid rise in recent years. To increase investment in renewable electricity in a cost-effective way, India has introduced national competitive auctions for wind and solar PV. Lessons have been learned following the abrupt change in the renewables support scheme from feed-in-tariffs to centrally run reverse auctions. Current auction volumesshow that wind power has developed at a much slower pace than solar PV. The auctions complement other policy measures at state level, such as Renewable Purchase Obligations, and at a local level, such as further support for rooftop PV installations. To ensure continuous progress in the growth of renewables, auction

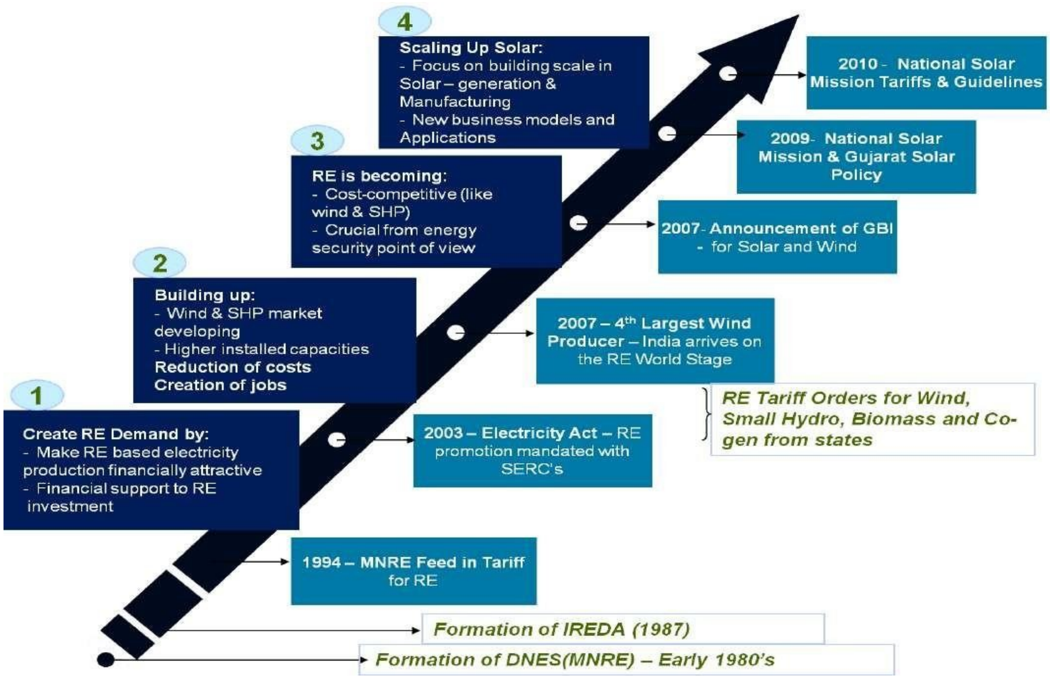


Figure 2.1 key development for renewable energy

Source: IEA World Energy Balances 2019

design, grid connections and the financial health of the power distribution companies (DISCOMs) are critical elements for reform.

Modern renewable energy is not only used in electricity generation – the potential is also great for heating, cooling and transport. India needs a holistic strategy for renewable energy to tap into this potential and to make sure that market development can be beneficial for sustainable development more generally, including local air and water quality. Potential also exists to scale up the use of bioenergy, including energy- from-waste (EfW), which requires robust sustainability governance.

Recently, India achieved 5th global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March, 2014 to 30 GW in July, 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.

2.3.2 Energy consumption in India

India's TFC increased by 50% in the decade from 2007 to 2017, with

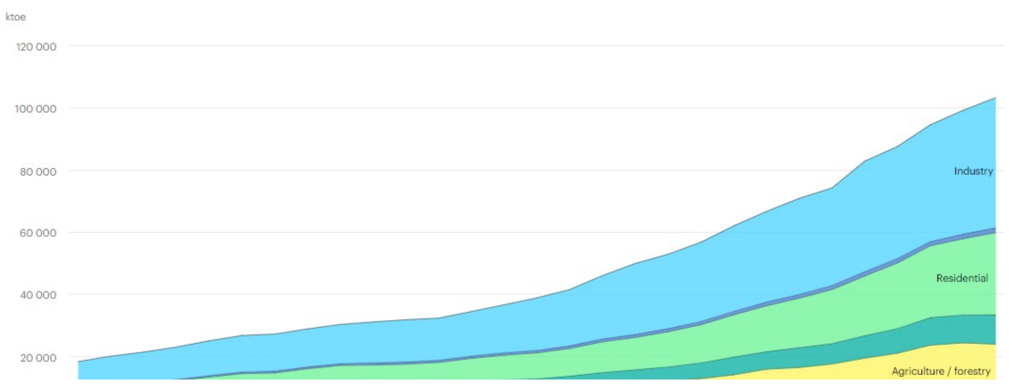


Figure 2.2 TFC by sector, 1973-2017

significant growth across all sectors. Half of the growth came from the industrial sector, which accounted for 42% of TFC in 2017, including non-energy consumption.

Source: IEA World Energy Balances 2019

Industry consumes a mix of coal, oil, natural gas, electricity and biofuels, with fossil fuels together representing 56% of total consumption (not counting electricity production).The residential sector is the second biggest energy consumer at 29% of TFC in 2017.Traditional use of biomass for heating and cooking accounts for the largest share of residential energy consumption, although the lack of sufficient data collection makes the numbers uncertain. The transport sector is the third-largest energy consumer at 17% of TFC in 2017, dominated by oil fuels. Transport energy demand has more than doubled in a decade, accounting for one-quarter of TFC growth. Finally, the service sector including agriculture consumed 12% of TFC in 2017, with electricity accounting for more than half.

2.3.3 Proportion of population with access to electricity, 2000-30:

Universal household and village electricity access 1 has been a key priority for the Government of India (GoI) for the past 15 years (with particular focus on rural areas). In April 2018 the GoI announced that India had achieved its goal of providing electricity to every village in India (600 000 villages). A year later, in April 2019, the GoI announced that it had effectively connected all the households that were willing to do so (26 million), according to the latest government data.

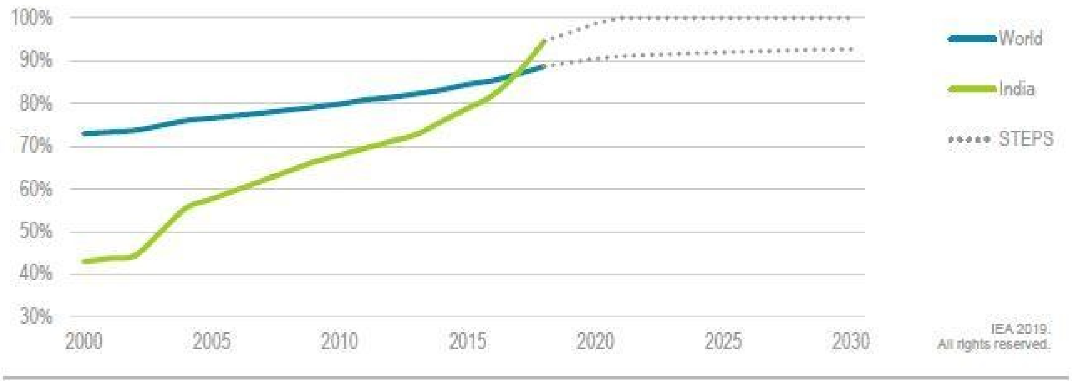


Figure 2.3 Proportion of population with access to electricity, 2000-30:

Source: IEA World Energy Balances 2019

2.3.4 The outlook for air quality

India is expected to become the most populous country in the world by the mid-2020s, according to the United Nations, with an additional 315 million people expected to join th urban population by 2040 (and population density increasing to an average of 540 inhabitants per square kilometre [km2]), with a corresponding increasein demand for additional housing, transport infrastructure and electricity, all of which drive air pollution. Policy action to curb the growth of air pollutant emissions is therefore essential. Successful implementation of the impressive policies already stated by the GoI will, according to IEA estimates, help to keep the growth in check (Figure 3.7). Without these policy measures, SO2 and PM 2.5 emissions wouldroughly double by 2040 and NOX emissions would grow almost 2.5 times. However, the decrease in pollution from sources covered by regulation (power and transport sectors) will be outstripped by the growth of pollution from industria expansion,notably for PM 2.5.

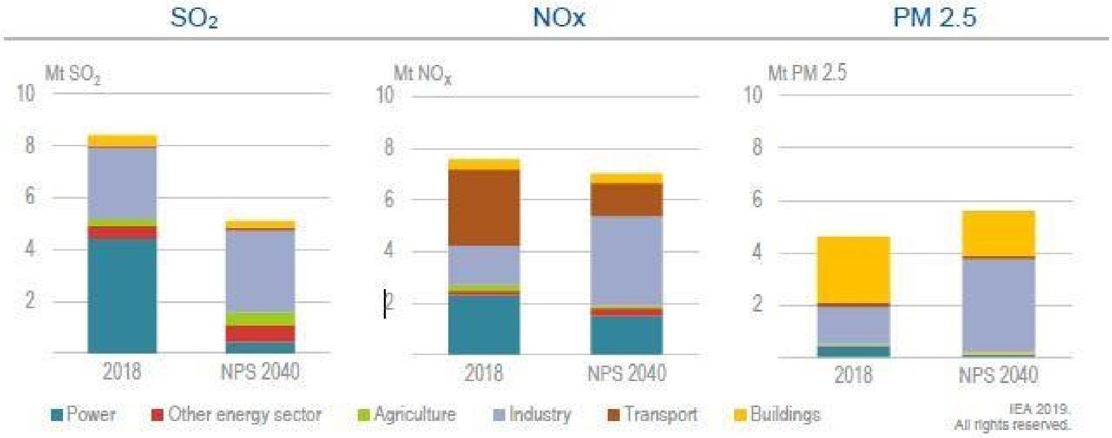


Figure 2.4 Emissions of major air pollutants, 2018 and 2040 (NPS)

Source: IEA World Energy Balances 2019

In the power sector, the successful implementation of the EPAR regulations and diversification of the power mix is expected to lead to a reduction in total SO2 emissions by 2040 relative to today, with the bulk of remaining SO2 emissions shifting to industry. NOX emissions drop slightly by 2040, as a strong decrease in emissions from coal plants is partially offset by increases from gas-fired plants and biomass combustion.

Nevertheless, power generation in India more than triples over this period, with coal showing stronger absolute growth than any other source of power generation in India. As power plants are often located near cities, towns and villages, the potential impact on health of regulatory implementation is significant. Therefore, resolving the issues related to delay in and non-compliance with EPAR application offers considerable potential benefits.

Implementation of EPAR requires the majority of the currently installed coal-fired capacity to be retrofitted with modern control technology and new-build plants to be equipped with advanced technologies for NOX, SO2 and PM control. Rapid expansion of modern renewables, including solar PV and wind power (underpinned by ambitious policy support), in industry, the implementation of tighter emissions standards is expected to improve the emissions intensity of key industrial sectors. Yet, air pollutant emissions from industry are expected to grow substantially over the coming decades to around two and a half times higher in 2040 than today. The growth in industrial output results in almost fourfold growth in coal consumption, with a large absolute increase in pollutant emissions. Despite policy efforts to improve emission intensities, regulation remains weak by international comparison and less stringent than in other sectors (for instance in transport). Three energy-intensive subsectors (steel, cement, chemicals and petrochemicals) give rise to the vast majority of emissions for each pollutant. The steel subsector alone gives rise to almost 50% of total PM 2.5 emissions from the industrial and transformation sector today.

This share increases to almost 70% by 2040 as crude steel production increases by a factor of 4.5, compared with 2015 levels based on current and announced policies (Figure 3.8). Despite the low sulphur content of Indian coal, SO_2 emissions also increase dramatically, especially from the iron and steel subsector.

2.3.5 Sectoral GHG status and stated policy outlook

Coal and oil dominate energy-related CO_2 emissions. Coal is the largest energy source in both power generation and industry, and its use accounted for 70% of total energy-related CO_2 emissions in 2017 (Figure 3.12). While coal-related emissions stabilized during 2014-16, their growth has resumed over the last two years, driven mainly by the power sector. Oil accounted for 27% of emissions in 2017, and the share is growing as oil consumption increases in both transport and industry.

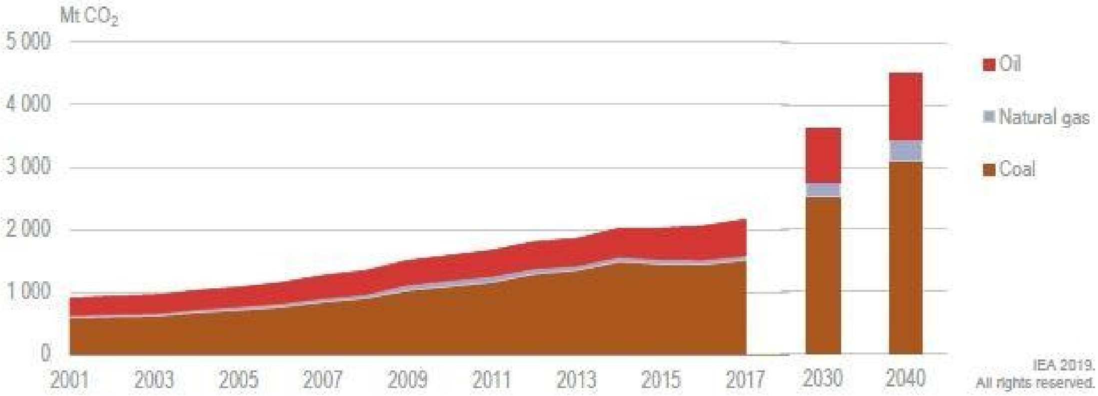


Figure 2.5 Energy-related CO_2 emissions by source, historical and NPS projections for 2030 and 2040

Source: IEA World Energy Balances 2019

2.3.6 Political system and energy sector governance

Prime Minister Modi presides over the large energy portfolio, which is spread across central (federal) and state governments, with the states having some autonomy over energy policy. At federal level, India does not have one single ministry in charge of energy policy. The Government of India (GoI) has at least five ministries with responsibilities for energy: the Ministry of Power (MoP), the Ministry of Petroleum and Natural Gas (MoPNG), the Ministry of New and Renewable Energy (MNRE), the Ministry of Coal (MoC) and the Department of Atomic Energy (DAE).

The MoP governs the electricity sector in India and also hosts the Bureau of Energy Efficiency (BEE). The Central Electricity Authority (CEA) is the main advisor to the MoP and is responsible for the technical co-ordination and supervision of programmers and data collection and dissemination, notably through the five-year National Electricity Plan. Under the Electricity Act 2003 the Central Energy Regulatory Commission (CERC) is responsible for: fixing tariffs (regulated tariff and the tariff discovered through competitive bidding); licensing of transmission and trading; market development (facilitating open access, licensed traders, power exchanges); grid security (grid code, deviation settlement mechanism, ancillary services); regulating the interstate transmission system; adjudication of disputes; promotion of renewable energy sources; consumer protection; among other matters. The State Electricity Regulatory Commissions (SERCs) collaborate through the Forum of Regulators (FoR).

Public-sector undertakings (PSUs) under the MoP include the Power Finance Corporation (PFC) and Rural Electrification Corporation, which function as non-banking financial institutions and provide loans for power sector development. National Thermal Power Corporation (NTPC) is India's largest integrated thermal power company and the National Hydroelectric Power Corporation (NHPC) the largest hydropower producer. In addition, the MoP oversees the functioning of the North Eastern Electric Power Corporation (NEEPCO), the system operator Power System Operation Corporation (POSOCO) and the central transmission utility Power Grid Corporation of India Limited (Powergrid). India has several electricity transmission operators in the country. Powergrid owns and operates the majority of the interstate transmission lines, while intrastate lines are owned by the state transmission utilities. As recent reforms opened the sector to private or merchant investment, private-sector entities also build, own and operate interstate transmission lines.

Some energy-related departments are run directly under the Prime Minister's Office. These include the DAE, which works on the development of nuclear power technology and the application of other radiation technologies, and NITI Aayog, which is an official think tank and policy advisory body of the GoI, coordinating activities that are inter-ministerial in nature, such as India's electric vehicle (EV) programme and reform of energy data. The DAE has a mission to enhance the share of nuclear power in the power sector by deployment of indigenous and other proven technologies, as well as thorium-based reactors with associated fuel cycle facilities. A central-government-owned corporation administered by the DAE, the Nuclear Power Corporation of India Limited (NPCIL) is responsible for the generation of nuclear power, operating India's 21 nuclear reactors. The MNRE is in charge of the development of solar, wind and other renewables in India.

Under the MNRE are the National Institute of Solar Energy, the National Institute of Wind Energy and the Indian Renewable Energy Development Agency (IREDA), which functions as a non-banking financial institution providing loans for renewable energy and energy efficiency projects. Solar Energy Corporation of India (SECI) is responsible for the implementation of various MNRE subsidy schemes, such as the solar park scheme and the grid-connected solar rooftop scheme. Biofuels are managed by the

Source: IEA World Energy Balances 2019

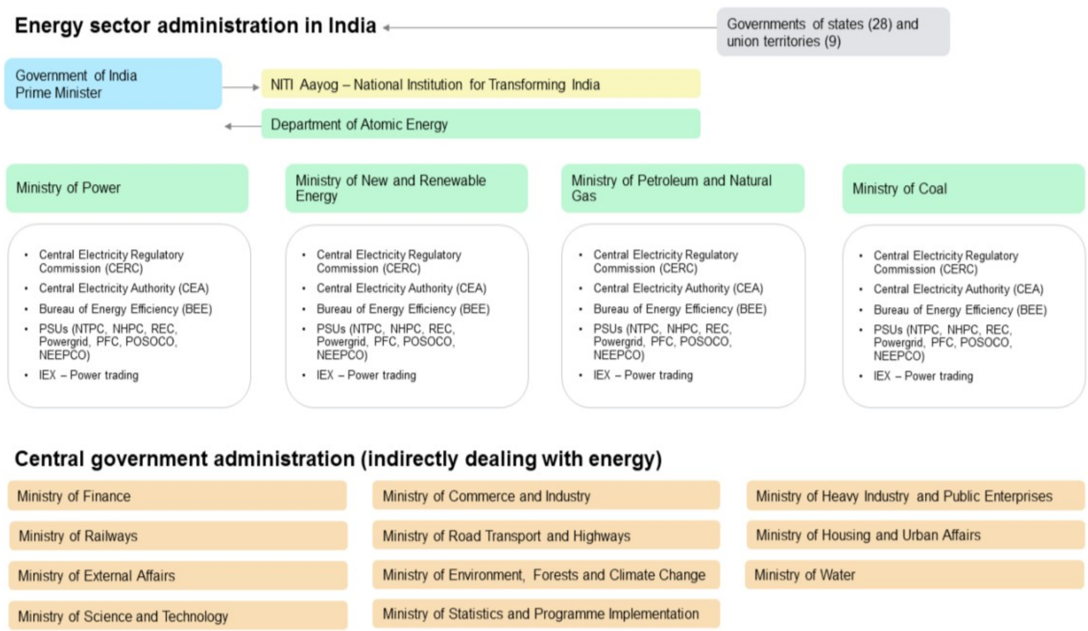


Figure 2.6 Main institutions involved in energy policy making in India

2.3.7 Energy sector role in GHG mitigation policy

A National Action Plan on Climate Change (NAPCC) was adopted in

2008 with the aim of driving measures that promote India's developmental objectives while addressing climate change as a co-benefit. This objective was to be implemented through eight national missions covering both mitigation as well as adaptation efforts, with the energy sector being instrumental in delivering upon their objectives. The eight missions are:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change.

Missions that directly relate to the energy sector include: solar; enhanced energy efficiency; and sustainable habitat, which includes a sub-focus on buildings codes and energy conservation, urban transport planning, and waste management. However, the energy sector also has potential impacts on some of the less directly related missions, such as water. In 2015 four more missions were added, including for wind and waste- to energy. States were instructed to elaborate their own Climate Change Plans, most of which have been completed.

India is the third-largest national emitter of GHGs (after China and the United States), and with rapidly rising emissions, India also plays a key role in the international dialogue on climate change as a major developing country. In 2009 at the Conference of the Parties (COP) 15 in Copenhagen, India announced voluntary targets to reduce the emissions intensity of its GDP by 20-25% against 2005 levels by 2020. Then, in 2015 the Go built on this target in its submitted Intended Nationally Determined Contribution (INDC), which became India's first NDC after the GoI ratified the Paris

Agreement in 2016. India's NDC includes the following new energy sector-related targets:

- To reduce the emissions intensity of its GDP by 33-35% from 2005 levels by 2030.
- To increase the share of non-fossil fuel-based energy resources to 40% of installed electric
- Power capacity by 2030, 12 conditional on technology transfer and international climate finance support, such as the Green Climate Fund (GCF).
- To create an additional (cumulative) carbon sink of 2.5-3 GtCO2-eq through additional afforestation by 2030.

2.3.8 Energy sector climate change adaption and resilience

India is a country particularly vulnerable to climate change. Energy should play an important role in addressing climate change adaptation challenges. The sector will need to become more resilient to ensure security of supply during extreme climatic impacts such as heat waves, floods, droughts and a rise in overall temperatures. The sector can also contribute to mitigating the impact that climate change will have on the country.

According to the ND-GAIN (University of Notre Dame Global Adaptation Initiative) adaptation score, India is the 51st most vulnerable country and the 71st least ready to adapt. 17 The country has a great need for investment and innovation to improve its readiness to adapt to climate change, and a great urgency for action. The adverse impacts of climate change are amplified by the widespread poverty and the dependence of India's population on climate-sensitive sectors. Adaptation and resilience are key priorities for the

Go. India's NDC highlights current adaptation initiatives and the plans under development in each Indian state. Climate vulnerability varies significantly from state to state, depending on the topography, climatic conditions, ecosystems and diversity in social structures and economic conditions.

The issue of climate change vulnerability has been raised to the highest political attention with the establishment of the Prime Minister's Council on Climate Change (PMCCC) in 2008. PMCCC ensures a coordinated response to climate change issues, overseeing the formulation of action plans not only for mitigation, but also for adaptation and monitoring key policy decisions. Of the eight national missions in the NAPCC, five have a focus on adaptation. These are in key sectors, such as agriculture, water, Himalayan ecosystems, forestry, capacity building and knowledge management. The NAPCC is intended to be supplemented by sub-national actions at the state government level. Currently around 2.8% of India's GDP is dedicated to programmes with critical adaptation components.18 Enhanced investment in adaptation activities will require additional domestic and international financial support. In its NDC, India estimates that USD 206 billion will be needed to implement these adaptation measures over the period 2015-30. A National Adaptation Fund has been set up with an initial allocation of INR 3 500 million (around USD 50 million) to support the activities carried out by each state and ministry. The water- food-energy nexus is particularly relevant for the energy sector in India. Water is essential for energy production and constraints on water can challenge the reliability of existing operations as well as the physical, economic and environmental viability of future projects. India is already classified as "water stressed" and between 2013 and 2016, 14 of India's 20-largest thermal power stations were on occasion forced to shut down operations due to water shortages (Luo et al., 2018). As such it is particularly important to assess existing and potential future water needs when planning energy sector investment in order to avoid potential choke points and identify positive synergies. India's groundwater consumption in agriculture has increased strongly, as other sources of water are scarc and electricity for pumping is unmetered and highly subsidized. India extracts a quarter of the world's groundwater annually, more than China and the United States combined. Besides making available alternative water sources, electricity subsidy reform can help reduce groundwater use. In 2016 India's total energy-related water withdrawals 19 were around 35 billion cubic metres (bcm), while energy-related water consumption20 was roughly 5 bcm. The IEA World Energy Outlook projects India's total energy-related water withdrawals to almost double in the NPS by 2040, while energy-related water consumption increases almost fivefold. The increases reflect a growing role for nuclear as well as a continued, though diminished, reliance on coal-fired powerplants, many of which are located in areas of water stress. IEA analysis of water availability constraints for India's coal-fired power generation show that water stress could have an increasingly material impact on the and deployment of cooling technologies and the location of new coal-fired power plants.

By 2040 more coal-fired power plants are expected to utilise wet tower and dry cooling, with more plants built in close proximity to coal mines, which are predominately located in areas not expected to experience water stress. As a result, generation costs are projected to increase due to costs related to fuel transport, coolingsystems and network expansion (IEA, 2015).

While India has announced ambitious renewable energy targets, this IEA analysis stillprovides an illustrative message about the potential impact of water availability on energy choices in the future. Moreover, it is important to note that low-carbon technologies are not immune to potential disruption from water scarcity either. In fact, while a lower-carbon pathway offers significant environmental benefits, the suite of technologies and fuels used to achieve this pathway could, if not properly managed, exacerbate water stress or be limited by it.

Some technologies, such as wind and solar PV require very little water.

However, the more a decarbonisation pathway relies on biofuels production, the deployment of concentrating solar power, carbon capture or nuclear power, the more water it consumes, making it important to incorporate water into any energy policy decision.

2.3.9 Access to electricity

The power sector represents the largest emitting sector in India. The carbon intensity of India's power generation has declined by over 10% since 2010, thanks to more renewable energy sources and a step change in coal power efficiency (up 6% over the last five years) after a suite of new plants were installed. The dominance of coal power still gives India significantly higher carbon intensity than the more mixed power supplies of the People's Republic of China and the IEA average on electricity, following Figure, but India has witnessed a stronger downward trend recently.

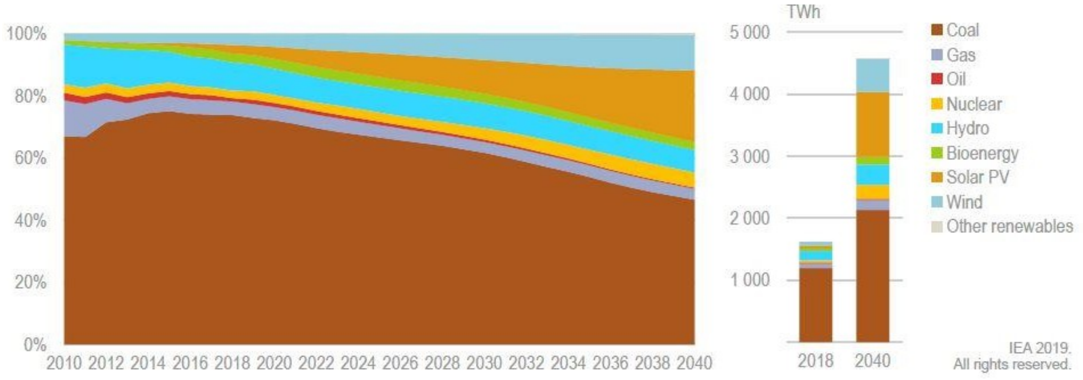


Figure 2.7 Electricity generation by source in India, historical and projected (STEPS)

Source: IEA World Energy Balances 2019

In the IEA projection based on current and announced policies, coal remains the primary source of electricity generation, but its share reduces from 74% today to 47% in 2030 and 48% in 2040 as renewables expand from the current 18% to 45% in 2040, resulting in 40% carbon-intensity reduction. Despite its falling share, the expansionary trend in coal power is the reason why power sector emissions increase by almost 80% by 2040 from 1.2 Gt CO_2 in 2017 to 2.1 Gt CO_2 in 2040.

While industrial CO_2 emissions contribute less than a quarter of the total, economic development in India, combined with several industrial initiatives, such as "Make in India", lead to industrial emissions more than tripling by 2040 from 0.5 Gt CO_2 in 2017 to 1.6 Gt CO_2 in 2040. Primary subsectors contributing to this growth are those considered as "hard to abate", with iron and steel continuing to account for around a third of emissions. Cement and chemicals, both accounting for about for around a tenth of emissions, are expected to grow significantly.

The transport sector represents a comparatively small part of GHG emissions in India, with its share expected to remain relatively stable. Nonetheless, overall it represents considerable growth from 0.3 Gt CO_2 in 2017 to over 0.7 Gt CO_2 in 2040. Road transport is almost solely responsible for growth in transport emissions, and this is expected to remain the case up to 2040.

2.3.10 Rooftop solar PV in India

The MNRE has adopted guidelines for the implementation of Phase II of its Grid-Connected Rooftop Solar Programme. The target is supported by RPOs, rooftop auctions and programmes that facilitate the Deployment of rooftop solar PV on government buildings across states. The MNRE has several policies to incentivise and facilitate rooftop installations: a) providing central financial assistance for residential, institutional, social and government buildings; b) advising states to implement net/gross metering regulations and tariff orders; c) providing a model memorandum of understanding, power purchase agreement (PPA) and CAPEX agreement for rooftop projects in the government sector; and d) appointing experts to support public-sector undertakings in the implementation of rooftop projects in ministries and departments. In February 2019 the Cabinet Committee on Economic Affairs (CCEA) approved financial support totalling USD 6.5 billion by 2022 to promote the use of solar among farmers. Solar deployment is picking up given India's high electricity retail prices with net metering programmes in 28 states with various tariff structures.

2.3.10.1 Off-grid solar PV

Various schemes are available at both national and state level to support the uptake of offgrid electrification, mainly through solar technologies. In 2015 the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) scheme was launched to support the adoption of decentralised distributed electricity in rural India via off-grid installations, mainly mini-grids. In 2017 the Off-Grid and Decentralised Solar PV Programme was put in place to facilitate uptake of various solar PV applications for lighting and water pumping in rural areas by providing financial means to the implementing agencies. The programme was extended until the end of the 2020 financial year In December 2018 the Atal Jyoti Yojana (AJAY) Phase II programme was initiated to finance the installation of over 3 million solar street lights in selected regions. Initiated by the GoI in February 2019 (and followed by guidelines in July 2019), the KUSUM scheme will support farmers to replace existing diesel pumps with solar PV pumps (with both on-grid and off-grid features). The scheme will allow farmers to become prosumers and sell power to the DISCOMs at a predetermined price. The scheme aims to add solar and other renewable capacity of 28 GW by 2022. It has three main components: a) financing of 10 GW of renewable energy plants, each up to 2 MW capacity; b) offering 1.75 million standalone solar agriculture pumps, central government to provide 30% subsidy and state government to provide 30% subsidy; and c) converting 1 million grid connected agriculture pumps to solar powered operation with central government and state government providing 30% subsidy each. India also supports off-grid EfW uptake by providing capital subsidies for the purchase and installation of biomass gasifiers in rural areas.

2.3.11 Barriers to investment in renewable energy projects

Besides permitting and network expansion delays, the key barriers to investment in renewable energy projects in India are the small transaction size for distributed energy projects, the credit rating of the off-taker, the absence of clear business models for rooftop solar and the disaggregated nature of the market.

India's DISCOMs are at the forefront of investing in solar PV. However, their financial viability as off-taker has come under pressure because of poor payment discipline, high commercial and technical electricity losses and consequent financial losses, cross subsidised electricity prices that do not cover costs, and a lack of metering and billing. Many states have also carried out competitive auctions, with some cancelling the PPAs due to a lack of financial viability of the sector, as PPAs offer fixed-price contracts.

In 2015 the GoI adopted the UDAY scheme, which seeks to alleviate high debt and interest cost burdens on DISCOMs, and has improved their financial health since its introduction. However, its impact varies considerably across states. As can be derived from following Figure, at least 40% of capacity additions needed to meet India's 2022 solar PV target are allocated to states with DISCOMS that have below-average to very low operational financial performance, according to government ratings (B-C grade).

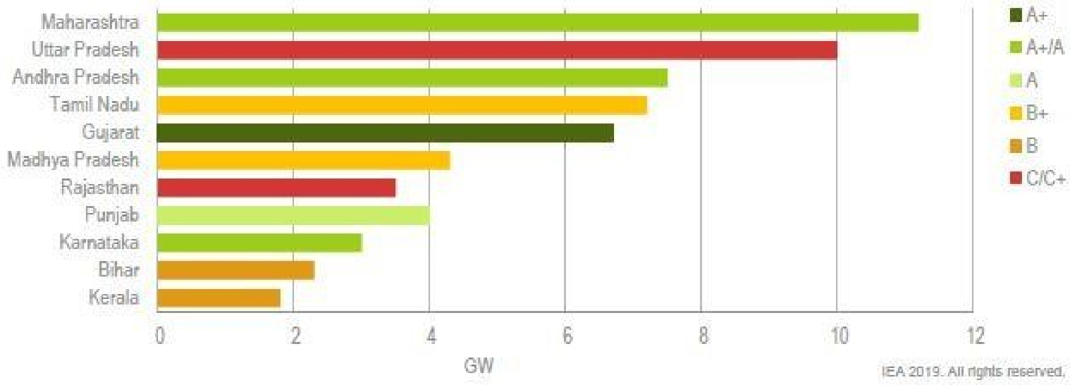


Figure 2.8 Solar PV capacity needed to reach 2022 targets and financial health of DISCOMs by state, July 2018

Source: IEA World Energy Balances 2019

Financing decentralized projects, such as solar irrigation pumps, rooftop solar and minigrids, is often more difficult than funding utility-scale projects despite the very large markets for these products. Local banks have limited capacity and tend to prefer the larger transaction sizes associated with utility-scale projects. Moreover, there is a lack of frameworks for evaluating the creditworthiness of smaller companies and consumers. Priority sector lending by the RBI and others now includes renewable energy projects and grid-connected solar rooftop systems (MNRE, 2018a). The Department of Financial Services advised all public-sector banks to provide loans for grid-connected rooftop solar systems as a home loan or a home improvement loan, and the Department of Expenditure reduced the guarantee fee from 1.2% to 0.5% for multilateral loans totaling USD 1.370 billion (these are: World Bank loan of USD 620 million through State Bank of India; Asian Development Bank loan of USD 500 million through Punjab National Bank; and New Development Bank loan of USD 250 million through Canada Bank).

In July 2018 India's Ministry of Finance imposed a so-called safeguard import duty of 25% on solar imports from the People's Republic of China and Malaysia for two years, to protect domestic producers of solar panels for a period of two years (falling to 20% in 2019 and 15% thereafter). The duty is contested and legal proceedings are ongoing in the Supreme Court. This uncertainty is a risk for developers and has stalled some projects.

However, recent auction results, if commissioned, show a limited impact on projects due to recent cost reductions for Chinese imports. For tenders carried out by the central government, the payment security mechanism provided by the SECI was seen as supportive, but there are some concerns over its operation in practice. Moreover, the tripartite agreement between the RBI, central government and state governments may serve as the de facto guarantee mechanism for payment by DISCOMs. However, these frameworks for mitigating off-taker risk do not apply to PPAs struck directly with states. In 2019, the GoI requires DISCOMs to provide for a letter of credit before scheduling power supplies. The risks facing renewable investments generally fall into two categories: project development risks; and operational risks. These pose challenges to investments where they reduce the availability of financing, elevate the cost of capital or delay project development.

Similar to trends in other emerging economies, the average size of projects sanctioned under renewable tenders for utility-scale solar PV has grown over threefold since 2014 and almost fivefold for onshore wind, with a boost in 2017 from the introduction of wind auctions. However, persistent development risks remain, which delay project commissioning, centered on problems of land acquisition, rights of way, grid connection and availability of local infrastructure, including for evacuation of power. There is lack of clarity over land titles, with outdated records and fragmented landholdings, particularly in Jharkhand, Uttar Pradesh, Bihar and Odisha (IEA, 2018b). Wind power tenders have been designed to sell power through the interstate transmission system, rather through a specific state transmission utility. As a result, wind projects are generally being sited in relatively resource-rich states, such as Gujarat and Rajasthan.

The Green Energy Corridors project started in 2013 to establish dedicated grid infrastructure to connect resource-rich states and enable intra- and interstate transmission to load centers. A second project phase is now in preparation, with the integration of renewable energy management centers (see chapters on electricity and system integration). Continued investment in transmission networks remains crucial to enhance trade in electricity and balancing services across states. Transparent and timely communication to developers about the status of major transmission projects is important for managing integration risks, as is continued progress in transmission investment, such as through the Green Energy Corridors programme. The government's recent policy to facilitate solar–wind hybrid plants, which can include battery storage, may help to better optimize transmission infrastructure and balancing the needs of variable renewables.

Risk	Description	Potential managing mechanisms
Power prices	States expect low power prices from renewables, with some setting ceilings near INR 3/kWh, but developers face uncertainty over technology prices and duties.	Portfolio approach to project development supplemented by contracts with equipment suppliers.
Bankability of PPAs	Delays in the signing of PPAs or cancellations; higher-than-expected project costs relative to a fixed-price contract.	More rapid timelines and better standardisation for PPAs; project structuring to exploit economies of scale and factor in contingencies.
Contract renegotiation	States may seek to renegotiate power purchase contracts after seeing lower prices elsewhere.	Enforcement of sanctity of contracts by regulators.
Power purchase	Delays in the payment of power purchase and curtailment by off-takers.	Improving the financial viability of state DISCOMs and expanding options for third-party off-takers; project structuring with financial guarantees.
Transmission infrastructure	Insufficient exchange of electricity and system services across states, which can hamper balancing.	Communicating to developers the status of major transmission projects in a transparent and regular manner; hybridisation of wind and solar plants; continued progress in transmission investment, such as through the Green Energy Corridors programme.
Land acquisition	Lack of clarity over land titles, with outdated records and fragmented landholdings; rights-of-way concerns.	Solar parks.
Evacuation infrastructure	Availability of local grid connection and network is uncertain; no secondary market for connectivity rights.	Solar parks; timely planning for grid infrastructure; penalty mechanisms to protect generators in case of transmission non-availability.
Financing for small-scale projects	Lack of frameworks for evaluating creditworthiness of small companies; limited capacity of local banks, which prefer larger transactions.	Lines of credit from public financial institutions for on-lending; credit appraisal methods for small consumers and capacity building for local banks; state-supported aggregation mechanisms.
Transparency of asset-level risks	Lack of ongoing metrics for lenders to assess susceptibility of assets to become stressed.	Developing dynamic asset-level risk assessment for projects.

Figure 2.9 Risks and risk management for renewable investment in India

The waiver of interstate transmission charges for wind and solar energy projects that directly connect to these lines (adopted in 2016 and applicable to all projects commissioned before the renewables target deadline of 2022) further facilitates infrastructure access. Under its solar parks scheme, the central government provides financial support to the states to facilitate bringing parcels of land and supporting infrastructure together in a simplified process. Around half of utility-scale solar PV projects sanctioned in 2017 were designed to be developed in solar parks (Figure 5.6). Recognizing the risk management and efficiency benefits of solar parks, the central government approved in 2017 an upward revision to the targeted solar park capacity, from over 20 GW to 40 GW by 2020. While nearly 40 solar parks, covering potentially 22 GW of capacity, have already been sanctioned under the scheme, not all of these are operational yet.

Solar parks are playing a larger role in sanctioned utility-scale solar PV projects, but their potential is not fully exploited, in part due to their relatively high prices and government land acquisition challenges.

Figure 2.10 Role of solar parks in utility-scale solar PV project development

Source: IEA World Energy Balances 2019

2.4 Gujarat's Renewable Scenario-Current Status and Future Prospects Urbanization in India

Gujarat, a pioneer in energy, is surrounded by "Madhya Pradesh on the east, the Arabian Sea and the Pakistan province on the west, Rajasthan on the north and Maharashtra and the Union Territories of Diu, Daman, Dadra, and Nagar Haveli on the south". Even though

Gandhi Nagar is the capital of the state, Ahmedabad is well- thought-out as the financial city in Gujarat and is its largest city. Gujarat has been a pioneer of energy production, contributing 9% of India's energy demand. The generation from renewable energy resources has increased from 5.6% in fiscal year (FY) 2015–2016 to 9.2% during the year 2018–2019.

India has one of the most attractive renewable energy markets in the world. Gujarat contributed to 110,739 MW of renewable power generation during the year of 2017– 2018, which contributed 26% of total state generation; this is one of the highest valuesin comparison to the values of other states in India. In the case of solar generation capacity of states, Gujarat stands fifth after Tamil Nadu, with an installed capacity of about 1587 MW of solar projects. Gujarat Electricity Regulatory Commission (GERC) has enhanced the Renewable Purchase Obligation (RPO), with the minimum power to be purchased from green energy resources rising from the current 10% to 17% in the next five years. Renewable energy potential of various states in India is shown in following Figure.

The climatic characteristics of Gujarat play a significant part in deciding the most suitable renewable energy generation options, and thus knowing Gujarat's climate would be greatly beneficial. Gujarat experiences both tropical and subtropical steppe climates. The state also experiences occasional droughts and floods. Occasionally, cyclones occur along the coastline.

The state of Gujarat (the "State") intends to increase the share of renewable energy, particularly solar energy in its energy basket. It is with this intention that the State launched the Gujarat Solar Policy 2009, for which it received very enthusiastic response. The policy resulted in a cumulative solar capacity in excess of 1000 megawatts (MW) with investment of about INR 9,000 crores. This policy also witnessed setting up India's first and Asia's largest Solar Park at Charanka in Patan District, and the country's first MW scale canal-top

solar plant at
Chandrasan in Mehsana District of Gujarat.

The Government of Gujarat (the "State Government") has also acknowledged the fact that power from renewable sources is, at present, significantly more expensive than those generated from conventional sources like coal-based power plants. The increase of renewable energy in the total energy basket has to be done in a manner that does not add undue burden to the Consumers in the State. Therefore, this Solar Power Policy 2015 (this "Policy") is intended to facilitate and promote large scale addition ofsolar power generation capacities in Gujarat while taking into account the interest of all its stakeholders, such as the Investors, Developers, Technology Providers, Power Utilities, Grid Operators and the Consumers.

Gujarat gets 5.5 to 6.0 kWh/Sq.m/day which equates to 330 sunny days / year solar power can be used to meet energy requirements for centralized as well as decentralized.

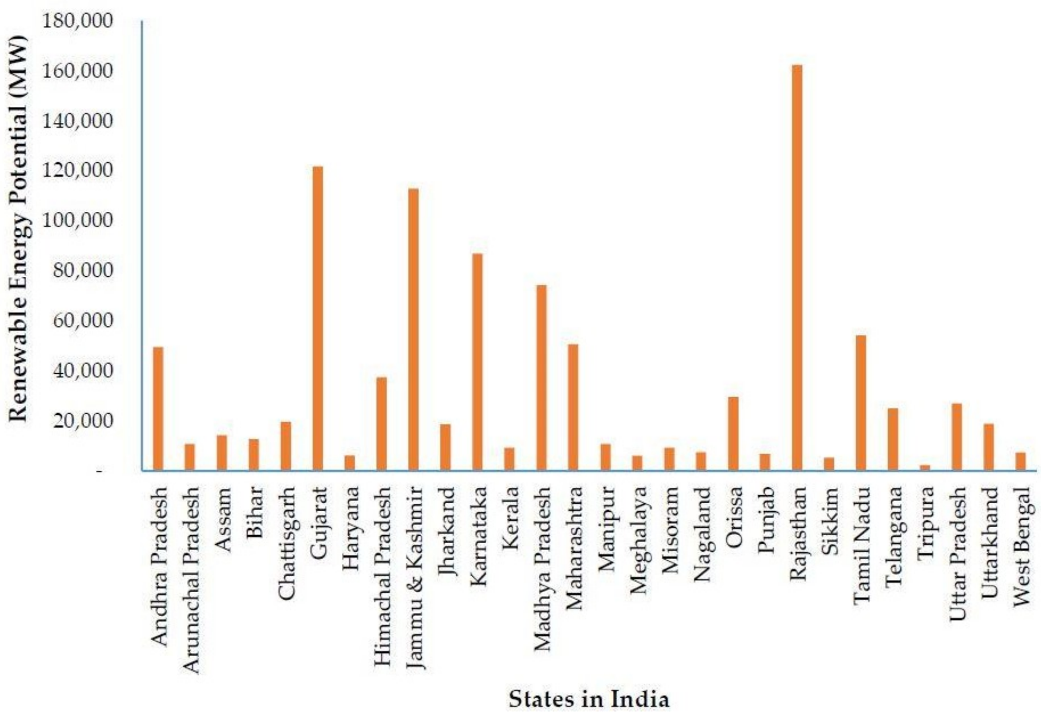


Figure 2.11 the renewable energy potential of various states

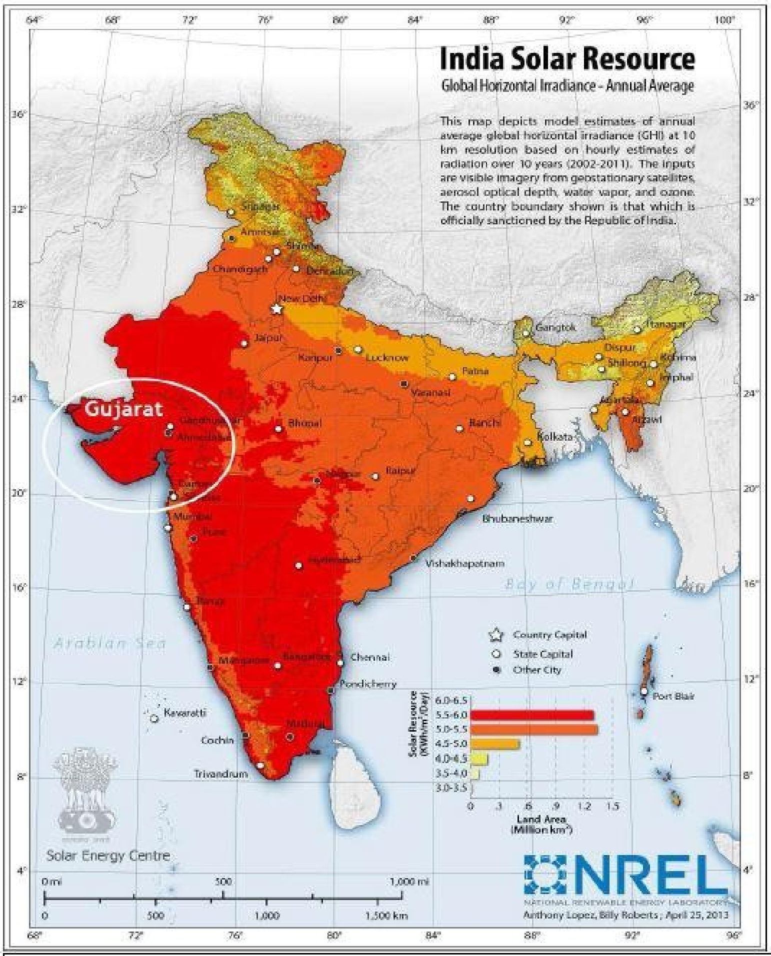


Figure 2.12 Annual average global horizontal irradiance map of India

Accordingly, the State Government Introduces the Gujarat Solar Power Policy 2015 with the following objectives:

- To promote green and clean power and to reduce the State's carbon emission
- To reduce dependency on fossil fuels for energy security and sustainability
- To help reduce the cost of renewable energy generation
- To promote investment, employment generation and skill enhancement in the renewable energy sector to promote productive use of barren and uncultivable lands.
- To encourage growth of local manufacturing facilities in line with the 'Make In
- India' programme.
- To promote research. Development and innovation in renewable energy.

2.4.1 State organizations/boards

2.4.1.1 Gujarat Energy Development Agency (GEDA)

GEDA is the state nodal agency involved in the promotion of renewable energy technology in the state of Gujarat. It Sponsor, co-ordinate and promote research programmes or projects and pilot investigations in the area of new and renewable sources of energy. It provides technical and financial assistance for the formulation of programmes, designs, and projects meant for extension of renewable energy development in the state

2.4.1.2 Gujarat Electricity and Regulatory Commission (GERC)

The Gujarat Electricity Regulatory Commission was constituted in 1998 under provisions of Electricity Regulatory Commissions Act, 1998. GERC has the authority to regulate the electricity sector in the state of Gujarat in a transparent, effective and efficient manner so as to safeguard the interests of consumers. GERC has been taking effective steps in promoting renewable sources of energy.

2.4.1.3 Gujarat Energy Transmission Corporation (GETCO)

GETCO was set up in May 1999 and is registered under the Companies Act, 1956. Role of GETCO in Gujarat is to plan, acquire, establish, construct, erect, lay operate, run, manage power system network in all its aspects and extra- high voltage (EHV), high voltage (HV) lines. That are connected Sub- Stations, including cable wires, accumulators, plants, motors, meters, apparatus, computers and materials connected with transmission , supply of electrical energy, communication and metering equipment , to undertake for and behalf of others, the erection, operation, maintenance, management of extra high voltage, high voltage lines and associated sub-stations, equipment, apparatus, cables and wires.

2.4.1.4 Gujarat Urja Vikas Nigam Ltd (GUVNL)

As a part of Power Reform Process, the Electricity Act, 2003, was passed by the Central Government and Gujarat Electricity Industry (Re-organization & Regulation) Act, 2003, was passed by the Government of Gujarat to restructure the Electricity Industry with an aim to improve efficiency in management and delivery of services to consumers. GUVNL As a part of Power Reform Process, the Electricity Act, 2003, was passed by the Central Government and Gujarat Electricity Industry (Re- organization &Regulation) Act, 2003, was passed by the Government of Gujarat to restructure the Electricity Industry with an aim to improve efficiency in management and delivery of services to consumers.

Accordingly, erstwhile Gujarat Electricity Board (GEB) was reorganized effective from 1st April 2005 into Seven Companies with functional responsibilities of Trading, Generation, Transmission, and Distribution etc.

The Gujarat Urja Vikas Nigam Limited was incorporated as a Govt. of Gujarat Company since 100% shares in the other six companies are held by GUVNL. The GUVNL is engaged in the business of bulk purchase and sale of electricity, Supervision, Co-ordination, and facilitation of the activities of its six Subsidiary Companies.

2.4.2 Problems faced by solar power in gujarat

Although Gujarat is shining and prospecting in the deployment of solar energy, there are some obstacles that are hurdles for further development. Some of the problems identified are as follows:

1. Cost of Land: Cost of land in Gujarat is quite higher. And hence it becomes difficult for developers to make their project economically feasible at the competitive tariff rate prevailing in Gujarat.
2. Artificial Price Reduction: Cost of PV module makes the major cost

of the solar project. But many developers have an opinion that price reduction of PV module is artificial and it is due to inventory stock due to the economic slowdown. And as soon as the economy will recover and inventory supply will exhaust prices will boost up and increase.

3. Rupee-Dollar exchangeability: Most of the components of solar panels are being imported and continuous fluctuation in rupee-dollar exchangeability is one of the major problems that creates a problem to plan large projects and execute them.

4. Long process: Government of Gujarat in spite of so much of development of in the field of solar have still not come up with the single window clearance solution. Without single window execution of the project on time is difficult. It takes longer time for getting different approvals and then final approval of power purchase agreement.

2.4.3 Lessons Learnt from the Literature on Gujarat's Renewable Energy Scenario

2.4.3.1 Recent Developments

This section provides a summary of the recent developments in various renewable energy project in the Gujarat state. Major developments during the years 2008–2018 are given. Also, the generation trend of various energy resources in Gujarat, along with an example, are presented in Table. Gujarat started its growth in solar power generation from 2008 after the revision of state solar policy.

- In 2009, Gujarat Solar Power Policy was revised, which led to a capacity addition of 1000 MW.
- The introduction of JNNSM in 2010 significantly increased solar projects in Gujarat.

- JNNSM approved the installation of 365 MW capacity in Gujarat. Further, it approved 351 MW of concentrating solar panel projects in Gujarat.
- In 2012, the installed capacity was 604.89 MW, as the government of Gujarat (GoG) initiated canal-top solar power projects on the riverbanks.
- Several rooftop solar schemes and programs were launched between the years 2012–2013.
- In 2015, the state solar installed capacity was 1000.02 MW, and Gujarat contributed 23% of total rooftop solar projects in India.
- In 2018, the installed capacity of solar projects in Gujarat had reached 1766 MW as of 31 October, with the successful framework of policies at the state and national level for solar projects. These developments include the already commissioned power plants, projects the are under commissioning stage and the planned projects.

2.4.3.2 Prospects and Implications

Finally, through the lessons learned from the extensive policy and framework reviews and the literature surveys, key findings and implications are present,

- The solar plant capacity planned to be installed by JNNSM does not meet the requirements of the National Action Plan on Climate Change (NAPCC).
- Gujarat provides gross metering and a feed-in tare for rooftop projects.
- Government of Gujarat with GEDA has implemented many solar projects, like installation of solar street lighting and standalone systems on main roads and solar PV on rooftops and solar/LED- based track signals on main roads.
- Gujarat government provides net metering rooftop solar grid-interactive systems; installing them will reduce the consumer’s utility bill.

- Gujarat announced the Wind Solar Hybrid Power Policy in 2018 for optimal usage of land and grid, which will improve the production in Upcoming years.

2.4.3.3 Intelligent Monitoring and Optimization Facility

The government of Gujarat in 2004 established the State Load Dispatch Centre (SLDC) in order to ensure the power system operation. “SLDC is liable for managing real-time operations for grid control and dispatch of electricity within the state to ensure secure and economic operation”. Some of the critical functions of SLDC are system operation and control, scheduling/rescheduling of generation dispatch of loads, fault detection and restoration, and metering and data collection. A typical snapshot of SLDC control is presented in. With time, SLDC has taken many initiatives to improve its capacity, not only by integrating state of the art technology, but also expanding its system based on the need for increasing load demands, network congestion, equipment replacement, or repair needs due to age and fault detection.

2.4.4 Future Initiatives

Deregulation has promoted several beneficial circumstances for RE production. Solar and wind are the leading RE sources in Gujarat, whereas tidal and geothermal are under development. The estate has many plans for the advancement of RE generation. Planned projects have to be implement properly in order to accomplish the targeted power by the end of 2022. The current and future install capacity of RE resources as per MNRE’s 2017 report was shown in Figure. Outcomes of key policy and planning undertaken by the Gujarat Government for meeting the RE integration targets are given below.

- Gujarat has set its target to install 22.6 GW of electricity by 2022 from RE sources, where the current installed capacity is 7.6 GW.

- The state has set a target to install 1000 MW of solar and 2000 MW of wind projects every year to meet the renewable purchase obligation (RPO) of 17% by 2022.
- Old and conventional generation plants are to be phased out, and new plants with more capacity are to be installed.
- Gujarat has also outlined a plan for the next three years from 2019, under which the state will produce 15,000 MW energy, out of which 10,000 MW would be from solar and 5000MW from the wind. Thus, the state would increase the renewable energy generation to 53% of total energy production, where it is currently 28%.
- For encouraging wind and solar power projects, the state has introduced a wind-solar hybrid power policy 2018. Through this policy, the government is expected to produce 30,000 MW of energy by the year 2030 and the government will also provide wasteland for 40-year leases to set up these hybrid parks.
- “Government of India has set a target to achieve 5 GW of energy from o shore wind projects by 2020”.
- The government is to set up a 1000MWmid-sea wind plant near Pipavav. Solar parks of 5000MW at Dholera, 700 MW at Radha Nesda, and 500 MW at Harshad will also be developed.
- Small hydropower projects of installed capacity 53 MW are under construction along the Canal of Narmada River through SSNM. The state would produce 25 MW of power from small hydro plants by the year 2022, tentatively.
- The MNRE has a target of producing 288 MW from biomass power by the year 2022. MNRE has taken initiatives to promote biomass power and bagasse cogeneration in the country. Waste to energy projects is also being set up to develop energy from industrial and agricultural waste.

2.5 Case study

2.5.1 Implementation of solar energy in urban planning

Analysis of $SAFAR_n$ as a solar potential metric &Improvement of simulation tools

2.5.1.1 Research aims

To provide more support for the key actors of urban planning regarding solar energy implementation. This study is divided into two parts focusing on SAFARn metric and solar energy building assessment tool.

2.5.1.2 Suitable Area to Floor Area Ratio (SAFARn)

The aim of this first part of the study is to bring further knowledge to the solar potential metric SAFARn, which was introduced by Kanters & Wall (2014). In their study, Kanters & Wall (2014) partly looked into the effect of an early urban planning design decisions, where form (based on a southern Sweden building typology), density, orientation and roof type were examined.

The first step of this part of the study looks into a case study in Hyllie, Malmö of an already planned urban district. The aim is to test the SAFARn-method on real case buildings, chosen according to their different surrounding context and to investigate the relationship between solar potential, building form and density. Additionally, the potential for solar electricity production and the subsequent load coverage were investigated.

In the second step of this part, the research project aims to examine the effect of the surroundings on the solar potential (SAFARn) in a theoretical urban setup, typical for cities in southern Sweden (Skåne) and similar to the buildings selected in the Hyllie case study. Parameters such as street width, neighbouring building height and buildings' facade surface materials are examined. The results should enhance the knowledge of how surroundings affect buildings' suitable area for installing PV panels and provide helpful insights for taking solar energy into account during planning phase.

2.5.1.3 Solar energy building assessment tool

The primary aim of this second part of the study is to develop a Grasshopper-based building assessment tool for solar energy design during early design phase, which provides visual and numerical information about solar energy generation, load coverage, system size and placement, necessary for assessing the solar potential of a building. The second part of this study part aims to demonstrate the tool by the use of a step-by-step process, where an assessment of a theoretical building within an urban setup featuring a diverse surrounding context is performed.

2.5.1.4 Scope and limitations

This study focuses on investigating the solar potential metric SAFAR, which is primary dependent on predetermined solar irradiation thresholds. Even though the metric SAFAR is aimed to be adaptable for international purposes, the chosen thresholds were adapted to the context of Southern Sweden (Skåne region) where this study was focused on. The results of this study can be mainly applicable in regions with similar landscape and climate characteristics. However, the pre-determined solar irradiation can be adapted according to the location and all simulations can be executed as long as the correct weather data is applied. Therefore, the methodology of this solar potential study could be used all over the world.

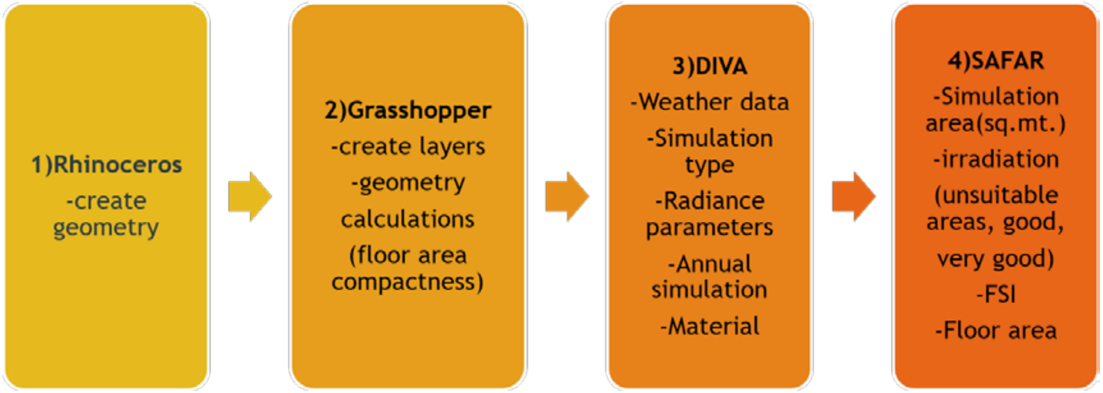
The research limits its scope to investigating solar potential for solar photovoltaic (PV) systems and does not take into consideration other types of solar systems. Therefore, the research results regarding SAFAR can be applicable mainly in assessing solar potential for PV systems. However, with some modifications, the results regarding solar energy building assessment tool could also be applied in other than PV systems.

The Grasshopper-based solar design tool developed in this study is able to calculate the hourly production per panel for a pre-defined period of time. The hourly results are especially useful when calculating the financial benefit of a photovoltaic solar energy system. However, this study does not encompass financial aspects of the solar energy systems and does not implement any calculations regarding the feasibility of the system, which creates a gap for future research in the study field.

Another limitation of the research is its focus on residential buildings, as an analysis of different purpose buildings might require some adjustments and deliver different results. Moreover, due to the time limitations of this project, the script could not be developed to its full potential in order to determine the best setup of the PV panels. Even though the purpose of the study was to demonstrate and test the tool, due to the time limit, no alterations or optimizations in the building design were made in order to provide more thorough overview of the tool.

2.5.1.5 Grasshopper-based script for SAFARn simulations

The working process started with the creation of a Grasshopper-based script that was used to perform the solar irradiation simulations. Grasshopper was the backbone of the script, connecting the geometry created in Rhinoceros to the simulation tool DIVA. Furthermore, all visual and numerical results were exported into familiar file formats .csv (Excel) and .jpeg (any image viewer). SAFAR assessment workflow is presented in Figure



1) Rhinoceros

To create the models, the process could begin by importing a CAD, a SketchUp file, or they could directly be modelled in Rhinoceros. In this study, the buildings were modelled in Rhinoceros, using meters as a measure unit and dividing each geometry into three layers for the building, the plot and the surroundings. Shading from the surrounding buildings has a great effect on the solar potential, especially in an urban context, therefore, their geometry must be assigned to a layer.

2) Grasshopper

Geometry layers: In order for the Grasshopper script to recognize the geometry of 3D models present in Rhinoceros, components that recognize the layer names were activated. Geometry calculations: After geometry identification, this component analysed the 3D geometry of the building to analyse and provided information on the floor area, FSI of the building, FSI of the surroundings and compactness. Furthermore, the script was able to perform geometry calculations for different envelope surfaces such as flat roof, pitched roof and facades.

3) DIVA

After the geometry was set and all related parameters were calculated, materials for the building, the ground and the surroundings, in order to account for shading were set. It is also

worth to mention that the calculation method for the solar irradiance considers reflections from any surrounding objects or buildings. The next step was to setup an annual solar irradiation simulation by performing an analysis grid of 0.5 x
0.5 m, location, simulation type, analysis period, and Radiance parameters.

4) Export

When the simulation was finished, the irradiation data was processed and divided between the roof and facade surfaces and SAFARn was calculated. Once this was done a colour mask was assigned corresponding to the pre-determined solar irradiation thresholds:

- White – unsuitable 0-650 kWh/m2a
- Green – reasonable 651-899 kWh/m2a
- Yellow – good 900-999 kWh/m2a
- Red – very good > 1020 kWh/m2a

The final step was to gather all generated results and export them as a .csv file which contains output information about SAFARn for different irradiation values on roof and facade, categorized irradiation values and areas on roof and façade, as well as floor area, FSI and compactness. Additionally, images from four different orientations were exported into a .jpeg file to provide a visual representation of where the suitable and unsuitable areas are on the building. The results were later processed in post- processing software (Excel) in order to calculate the PV potential of the buildings. The PV output was calculated using Equation 3, assuming the PV panels are placed horizontally on the roof and vertically integrated on the façade.

$$PVoutput = (E.A).\eta PV.\eta syst$$

Equation 3

E – The sum of all radiation values for each suitable surface over the year (kWh/m2a)

A – The net available area for PV (according to the usable surface area of 75%)

ηPV – module efficiency (%) $\eta syst$ – system efficiency (%)

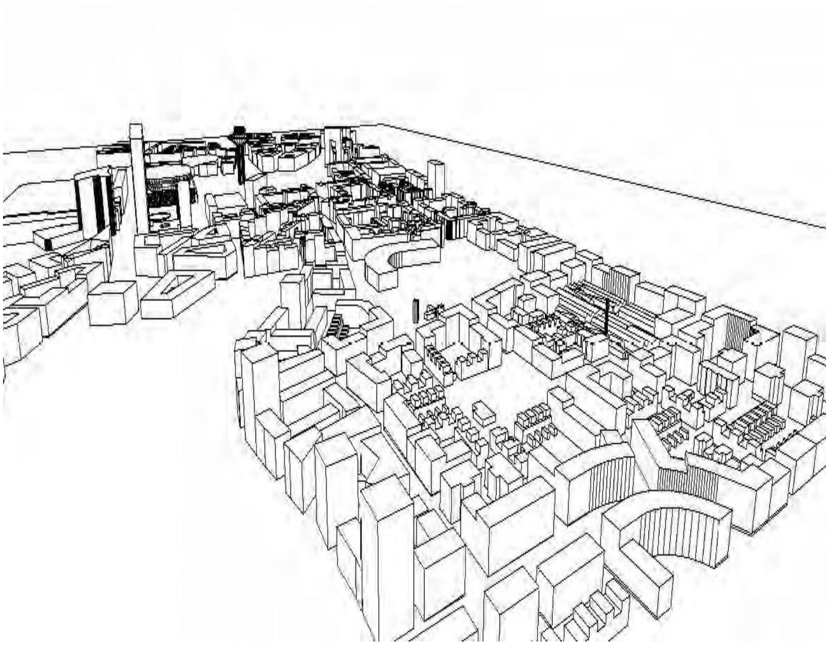


Figure 2.5.1.13 Hyllie's planned district

2.5.2 Hyllie case study

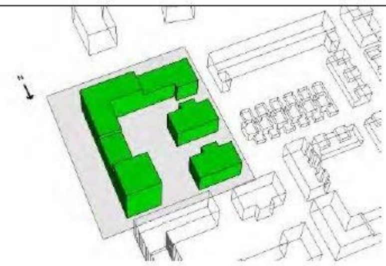
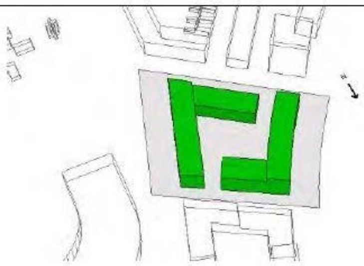
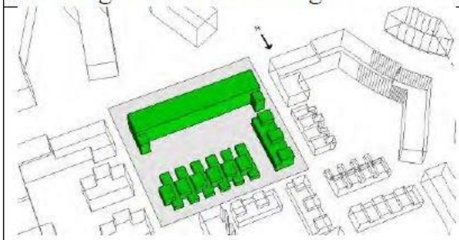
Hyllie (55° 34' N, 12° 58' E), a district in the city of Malmö, is going through a major development with many new planned multi-storey residential and commercial buildings (Hyllie, 2015). Most of the buildings that have been designed in the zoning plan have flat roofs and mainly follow a geometry with inner courtyards. The height of the buildings varies, but only in some cases exceeds 12 floors. (See

In this section, the focus will be on seven residential buildings, selected from the zoning plan (see Figure 2.13 and Figure 2.14), indicated with their plot names, which had a different surrounding

Figure 2.14 Plan view of Hyllie with the selected buildings

context, varying roof heights and building dimensions.

Figure 2.14 Plan view of Hyllie with the selected buildings

	
Building Ö15 Floor area: 11507 m^2 Surroundings:east and south: open space (buildings far away); west and north: buildings with similar height	Building Öö1 Floor area: 12099 m^2 Surroundings:south-east and north-west: open space; south-west and north-east: buildings with similar height
	Building Öö4 Floor area: 5322 m^2 Surroundings:south: open space (buildings far away); north, east and west: buildings with similar height

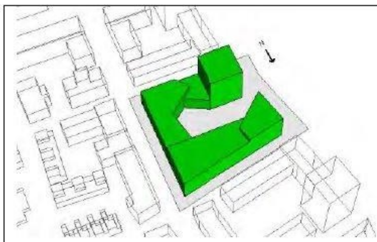
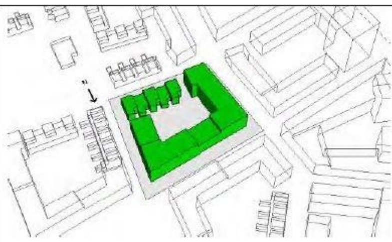
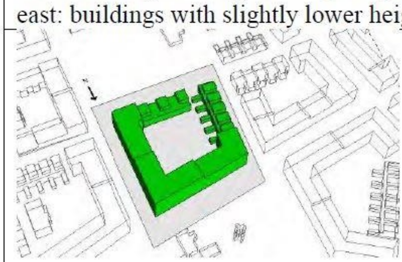
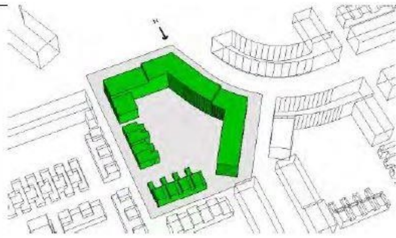
	
Building Ö2 Floor area: 13693 m^2 Surroundings:north and south: buildings with similar geometry; west: open space; east: buildings with slightly lower height	Building Ö7 Floor area: 7840 m^2 Surroundings:all directions: buildings with similar height
	
Building Ö10 Floor area: 10494 m^2 Surroundings:north and south: open space; west and east: buildings with similar height	Building Ö11 Floor area: 8301 m^2 Surroundings:south: open space; north, east and west: similar height buildings

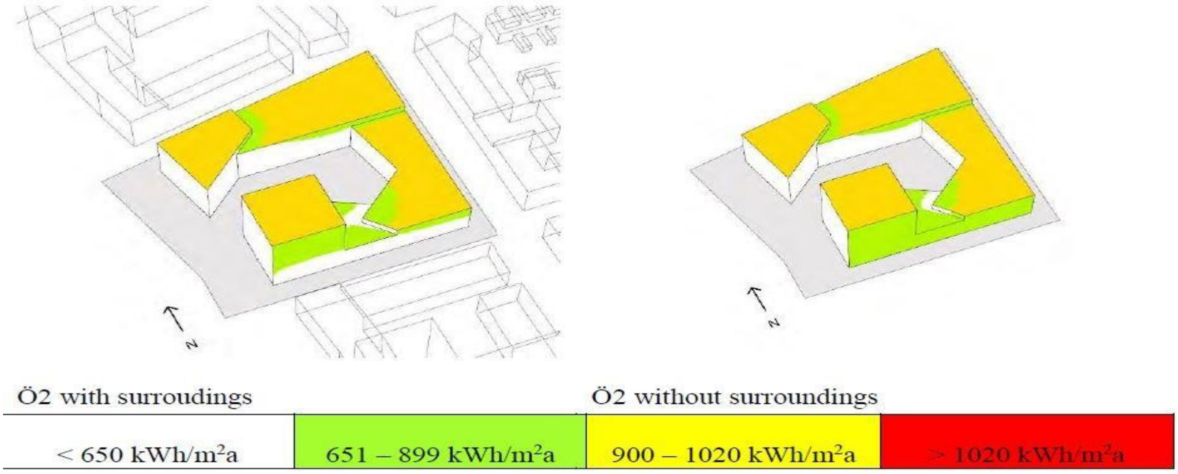
Figure 2.15 3D view of the seven buildings, Hyllie

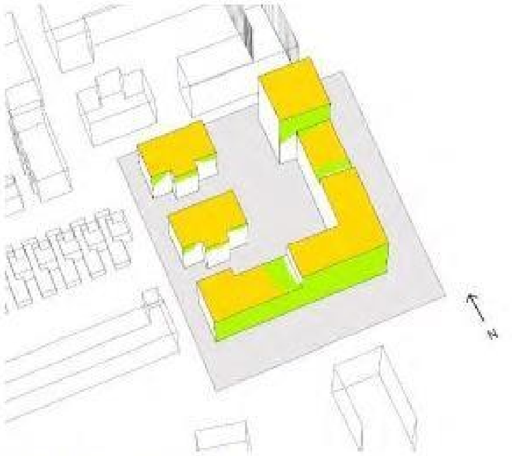
Using the Grasshopper-based script for SAFARn simulations, each building was examined in terms of suitable area for solar electricity harvesting, expressed by SAFARn, a visual representation of where the suitable and unsuitable areas are and an annual load coverage calculation for common and household electricity load, based on the PV output. Additionally, the buildings were simulated in two scenarios, with and without surroundings, in order to assess the effect of shading on the building envelope. The buildings' solar potential was also assessed on the basis of their compactness and their density.

2.5.2.1 Results and Discussion

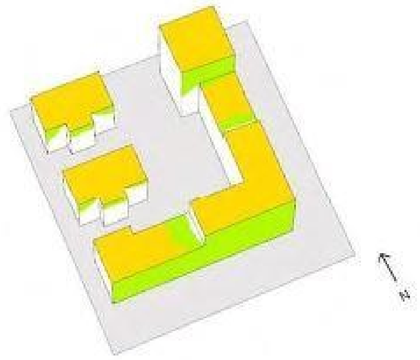
SAFARn solar potential metric was tested on seven cases located in Hyllie, Malmö and assessment of the relationship between solar potential, building form and density was done.

Figure 2.15 visualizes which areas of the buildings are suitable for solar panels, as well as the contribution of shading from the neighbouring buildings. For all buildings, the roofs affected by self-shading and the south-facing façades are indicated as suitable with irradiation over 650 kWh/m2a, and over 800 kWh/m2a for roofs which are generally not shaded. When the surroundings are omitted, the south facades are fully available, while the east and west facades are still result irradiation values under 650 kWh/m2a, therefore, indicated as unsuitable.

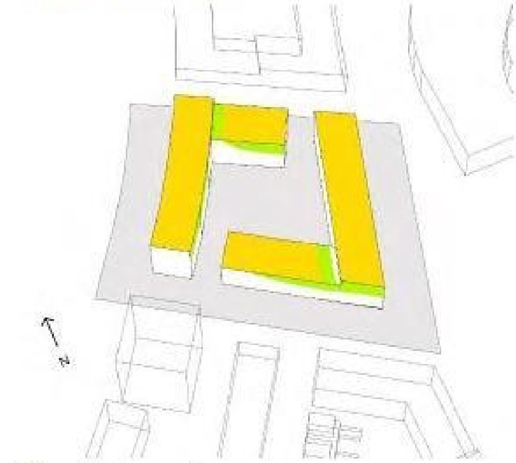




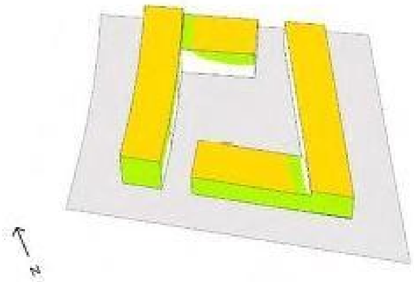
Ö15 with surroudings



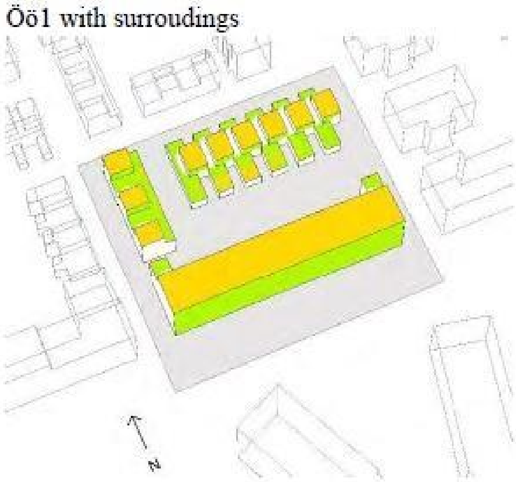
Ö15 without surroundings



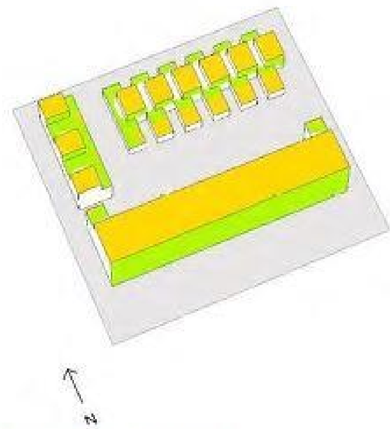
Öö1 with surroudings



Öö1 without surroundings



Öö4 with surroudings



Öö4 without surroundings

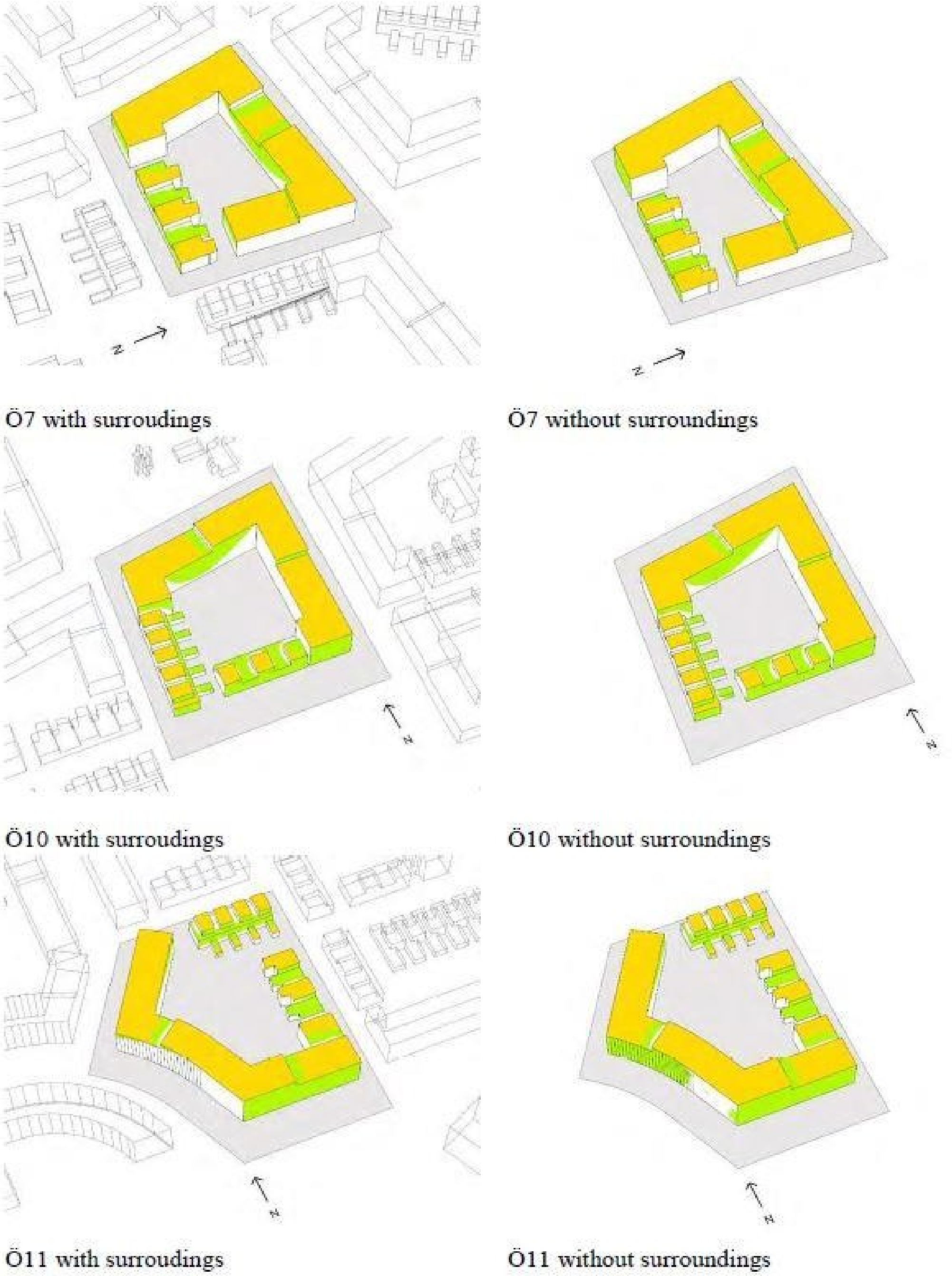


Figure 2.16 Visual representation on the suitable areas of all seven buildings

2.5.2.2 Inferences

In this research SAFARn solar potential metric was tested for the case of seven buildings in Hyllie, Malmö area in Southern Sweden. The results showed that only roof surfaces and south-facing facades or facades with an azimuth angle close to the absolute south could be considered suitable in this and similar latitude regions. However, due to the urban context the south façades were strongly affected. Moreover, the building density and compactness were identified as determining factors for the SAFARn metric. Based on the results obtained from SAFARn, a good

understanding was developed for some of affecting factors for the potential of a building to harvest solar energy. Additionally, a large potential for locally produced solar electricity was identified, as all buildings theoretically covered their common electricity need.
The research also examined the surroundings' effect on SAFARn and the results showed that larger street dimensions are more favorable for the overall solar potential of buildings. Additionally, it became evident that the façades are the most affected by the height of the surrounding buildings. A large difference between the solar potential between SAFAR650 and SAFAR800 was identified considering the roof surface, where the difference in solar potential and potential for load coverage was significantly affected by the surroundings. If 800 kWh/m2a as a suitable threshold for the roof was instead considered, surrounding buildings of no more than two floors higher than the examined building showed to be optimal for keeping the roof solar potential high. Furthermore, the study on different facade materials identified a significant contribution of high reflectance materials such as glazed facades and painted concrete. Other less reflective surfaces showed to have a slightly negative effect on the irradiation. The results of this study can be used to correctly determine the best building heights and street dimensions in order to optimize the solar potential of the building in an urban district.

In this examination a Grasshopper-based structure evaluation instrument for sunlight based energy plan during early plan stage was created and shown by surveying a hypothetical structure in different metropolitan environmental factors. The device is fit for performing expectations on sun oriented potential (SAFARn), giving the client a visual and mathematical yield of the outcomes, age of a sun based energy framework on any appropriate surface, giving adaptability and decision of framework arrangements. Moreover, the hourly PV yield could give helpful data on the genuine burden inclusion, just as to help with a monetary advantage computation of the chose framework. The tool was validated by comparing the output to the validated solar energy system modelling program SAM and the results indicated a slight overestimation of the script, which are due to the complexity of SAM as a tool, as well as simplifications adopted in the calculation method of the Grasshopper-based tool. The tool can be optimized by making it more user-friendly, also allowing for a simulation of each individual panel of the system in order to give a slightly more accurate result.

2.5.3 Solar infrastructure plan in rajkot city

2.5.3.1 Energy In Rajkot

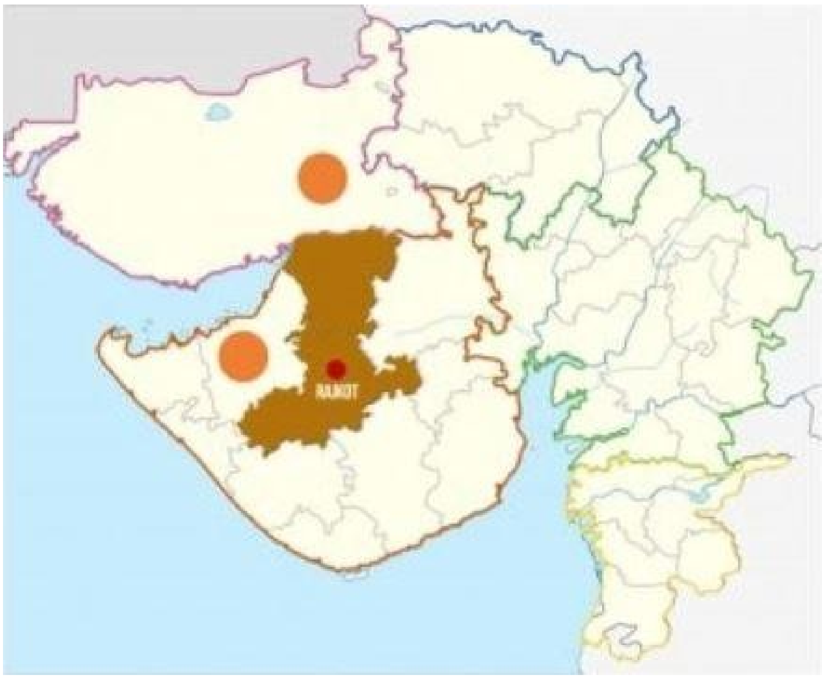


Figure 2.17 Source of power supply in Rajkot

Electricity in Rajkot is generated through Kutch and Jamnagar

Thermal Power Station. Then it is transmitted to Rajkot via tension lines. There are different networks of different power capacity plants, and they are spreaded through PGVCL.

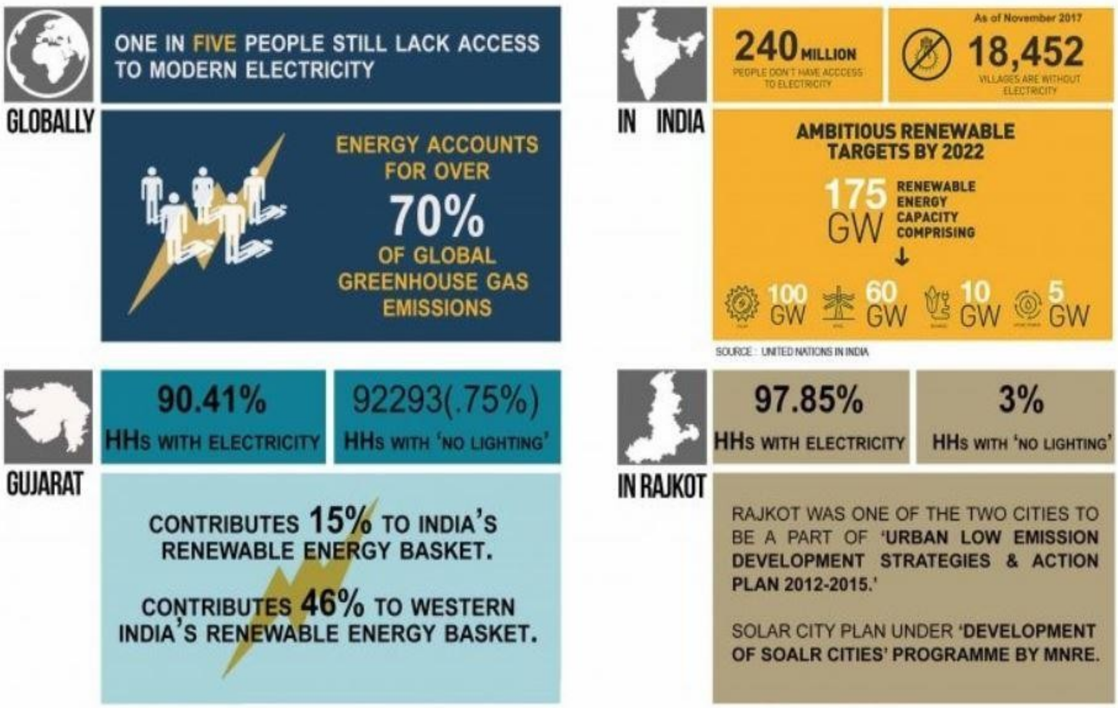


Figure 2.18 Energy scenario in Rajkot

2.5.3.1 Household survey analysis

To know the scenario of electricity (power) in Rajkot, household questionnaire included questions like

1. Are there any power cuts in Rajkot. If yes, how frequent?
2. Do you have power backup? If yes, what type- - Generator Invertor - Solar power - Others
3. Do you have any non- conventional source of energy installation like solar water heaters / solar panels?
4. Is there any difference in electricity bill after installation of solar panels?

As per the household survey, it was conduded that half of the Rajkot faces frequent power cuts for 20-30 minutes once in a week or month. Hence, people are dependent altemate like Kerosene, Solar for their energy needs.

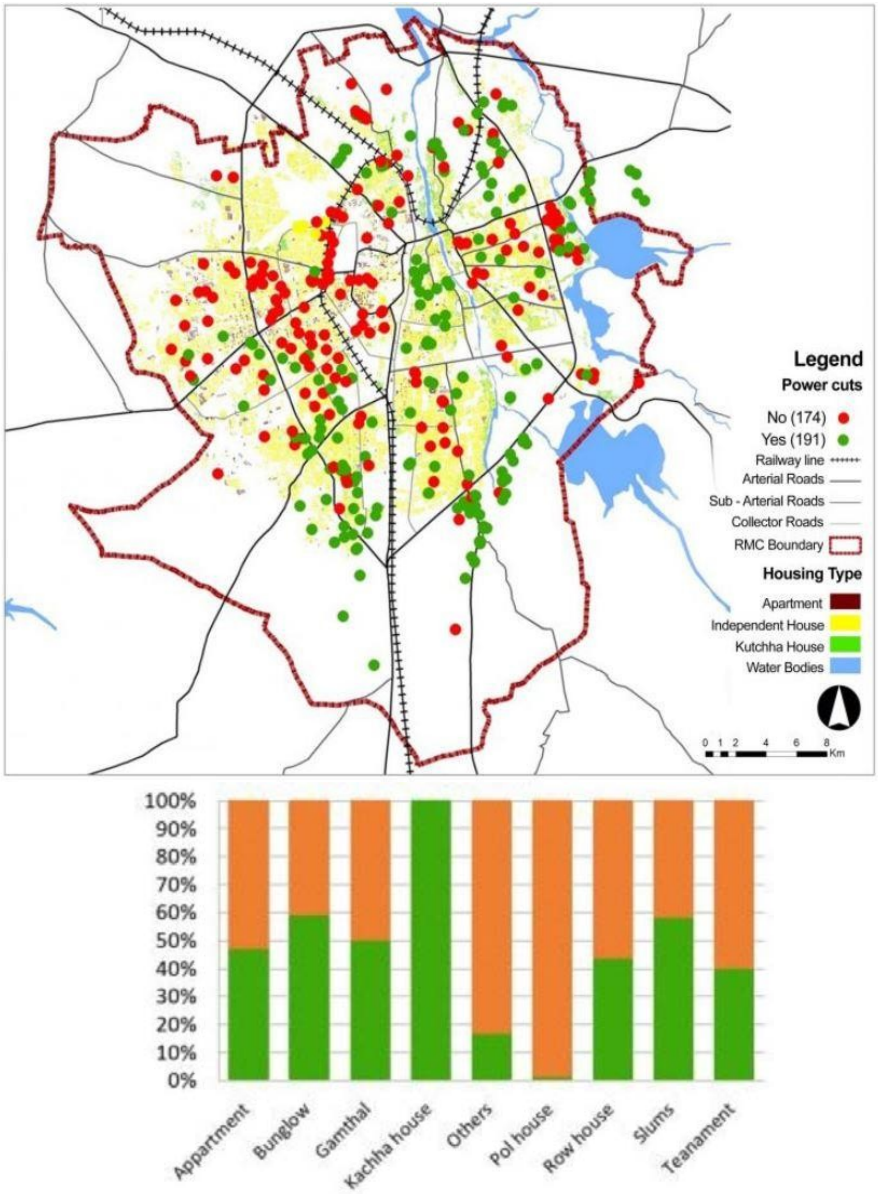


Figure 2.19 Typology wise power cuts

As per the household survey, power cut in each typology, various in pole housing due to the sample surveys taken.

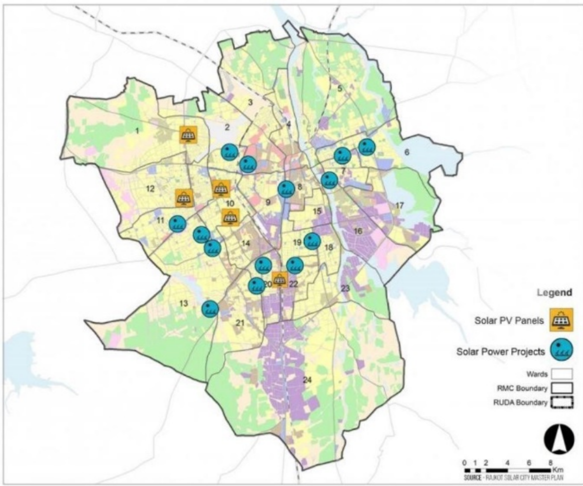


Figure 2.20 House hold survey map

The high potential of solar energy in the form of direct solar irradiance and energy saving efforts of rmc by making rajkot part of urban led programme enabled rajkot to become part of solar city programme under mnre. The target was 10% reduction in projected demand of convention- al energy at the end of five years, through a combination of enhanc- ing supply from renewable energy sources (solar) in the city and energy efficiency measures.

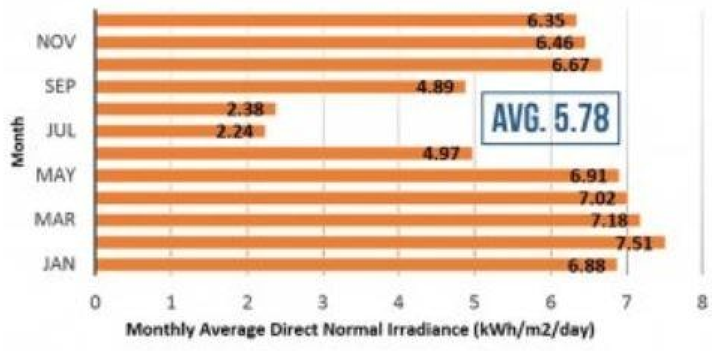


Figure 2.21 Monthly average direct normal irradiance

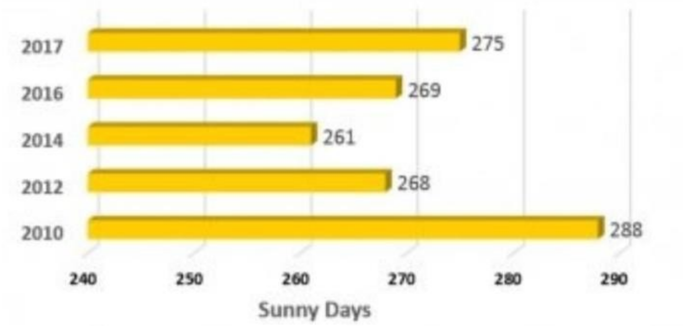
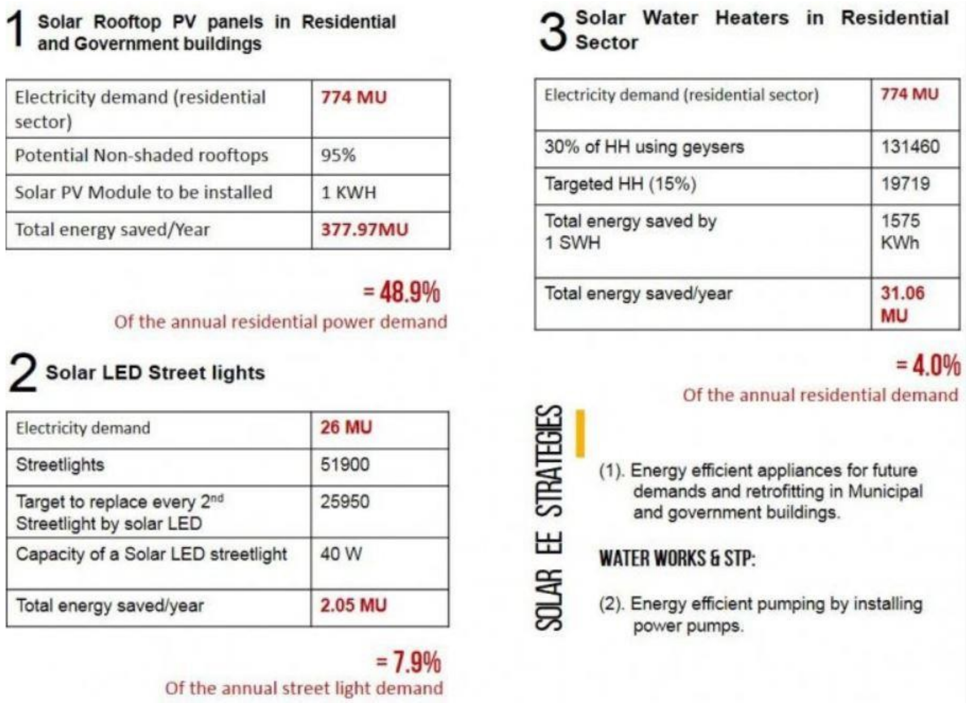


Figure 2.22 Year wise sunny days



1 Solar Rooftop PV panels in Residential and Government buildings

Electricity demand (residential sector)	774 MU
Potential Non-shaded rooftops	95%
Solar PV Module to be installed	1 KWH
Total energy saved/Year	377.97MU

= 48.9%
Of the annual residential power demand

2 Solar LED Street lights

Electricity demand	26 MU
Streetlights	51900
Target to replace every 2nd Streetlight by solar LED	25950
Capacity of a Solar LED streetlight	40 W
Total energy saved/year	2.05 MU

= 7.9%
Of the annual street light demand

3 Solar Water Heaters in Residential Sector

Electricity demand (residential sector)	774 MU
30% of HH using geysers	131460
Targeted HH (15%)	19719
Total energy saved by 1 SWH	1575 KWh
Total energy saved/year	31.06 MU

= 4.0%
Of the annual residential demand

Figure 2.23 Rajkot target in different sector

After looking at various Solar RE & EE Strategies adopted in the Rajkot Solar City Plan, the above following strategies have been prioritized that have the maximum implementation feasibility. And the potential of the total energy that can be saved has been calculated.

2.5.3.3 Case of RAIYA smart city

RAIYA from Rajkot has been chosen for the GREENFIELD AREA BASED DEVELOPMENT in the 100 Smart Cities Mission of India. Taking forward the initiatives of RAJKOT SOLAR CITY PLAN, the smart city plan for Raiya ABD & PAN city includes the following Solar Renewable Energy strategies-

1. Solar roof cover across key pedestrian pathways and 50 KM of cycle tracks.
2. 15% household each with KW solar roof top.
3. Each rooftop in affordable housing scheme will be equipped with 25 kW of solar cells resulting into 1390 kW of clean energy
4. Solar LED street lights

Figure 2.24 Existing master plan of RAIYA smart city

Being a greenfield development with Central &State funding, Raiya proves to be the best site for magnifying energy saving efforts through active & passive solar strategies that could serve as the lighthouse project of achieving the target of increasing the Renewable energy share.

Figure 2.25 Arial view of RAIYA smart city

Making room for maximum Solar Access by exploring the potential of planning mechanisms like TP SCHEMES where power energy is not seen in silos but in an integrated manner through

1. Passive solar planning strategies (Orientation of plots).
2. Active solar planning strategies - Rooftop Solar potential - Solar LED street lights
3. Solar Parks
4. Solar junctions (solar trees)
5. Energy efficient strategies.

2.5.3.4 Proposed scenario of RAIYA smart city

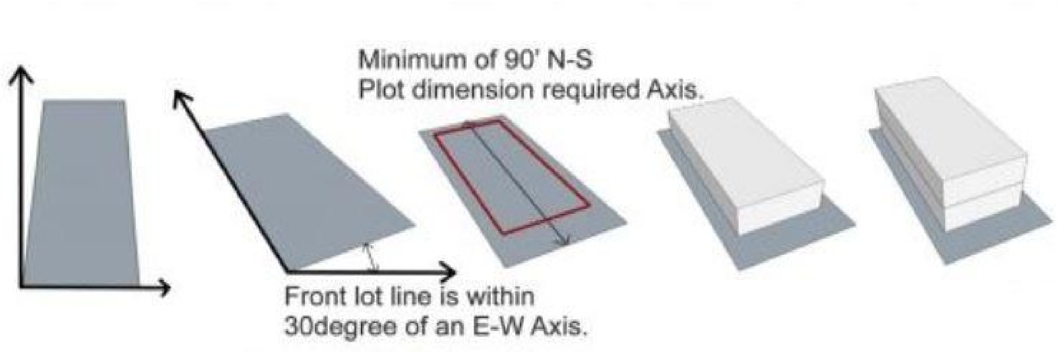


Figure 2.26 Existing Study and Proposed plot orientation

As orientation of plots and hence built within the plot depends on the orientation of roads. Therefore while planning out the roads, roads were taken within the 30 degree of E-W axis of Raiya and then plotting was done. To have shade free rooftop space for atleast one 1KWH PV panel setup, the minimum plot size was taken as 100 sqmts.

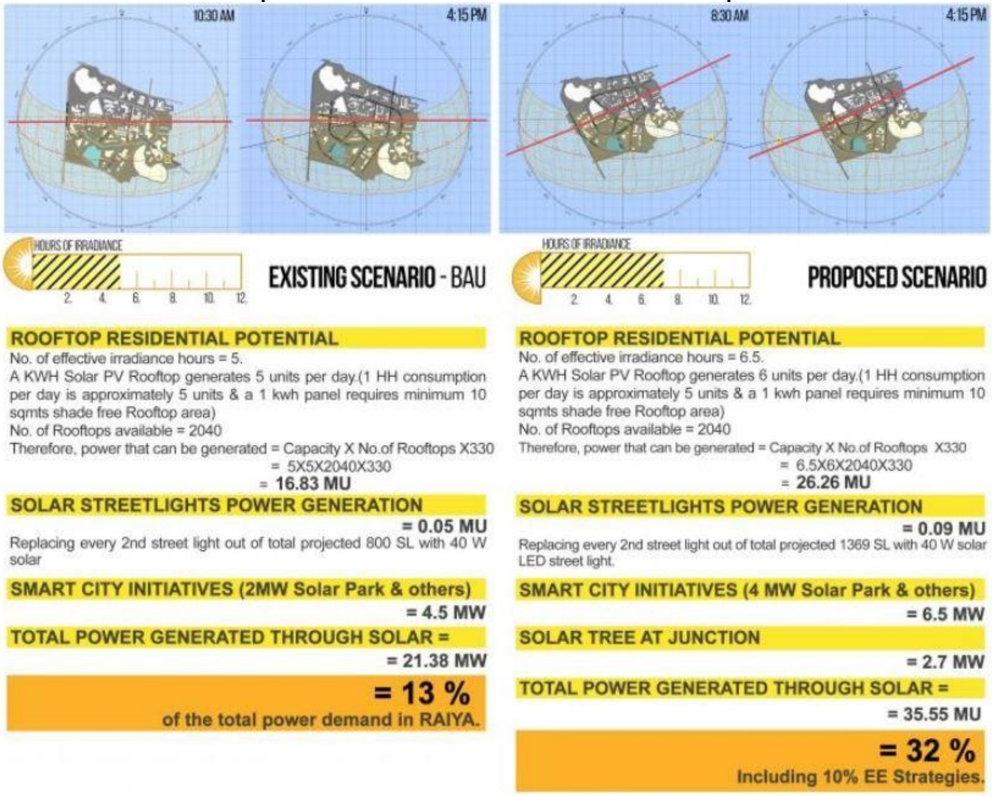
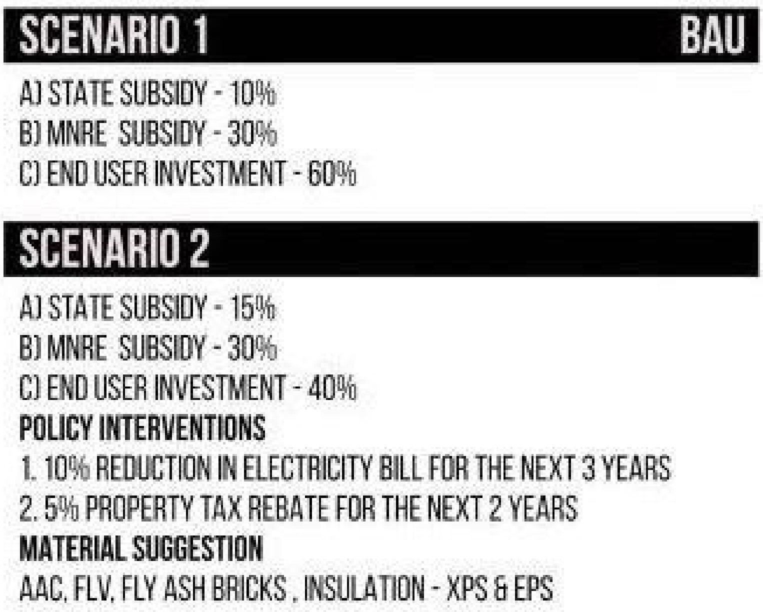


Figure 2.27 Proposed scenario of Raiya

Figure 2.28 Proposed policy interventions



2.5.3.5 Inferences

A study was done using the model of existing Raiya master plan built up- - Firstly, BAU front plot line in alignment with E-W axis Secondly, rotating the front plot line within 30 degree of E-W axis. In the BAU, effective hours of Solar Irradiance was found out to be 5 hours. And, in the proposed case, the hours of effective irradiance increased upto 6.5 hours. The power that can be generated through a Solar PV Panel depends directly on the hours of effective irradiance. And hence, the power generated through rooftop PV panels increases when the orientation of plot line is changed in the proposed scenario as shown in the table.

3.RESEARCH METHODOLOGY AND DATA COLLECTION

To enhance this research each of objectives using specific techniques and tools. This research based on secondary and primary qualitative evidence and has been conducted in two phases based on the objectives of the research and each part adopts different method as required. Also, because the results are interconnected, the research is conducted in successive manner where each part was completed before commencing the next.

3.1 Research methodology

3.1.1 Analyze literature review:

Literature review will be broadly divided in five parts: energy scenario of globally, India, Gujarat and Vadodara and case studies.

3.1.2 Data collection:

- To assess the energy consumption pattern in the household sector, under each income class of households.
- Industry survey will be done to assess the energy requirement in all types of industries operating. To assess the energy consumption pattern in Commercial and Institutional sectors.
- Detailed energy inventory will be collect and analyze for understanding the energy need of the Municipal sector.

3.1.3 Data analysis:

- The analysis of existing resources; energy consumption across various sectors; inventories; and demand projections of various energy-infrastructure requirements and current issue are based on-the data collection.

- Review of Renewable Energy and Energy Efficiency programs and policies

3.1.4 Data source identification:

- Data will be collected in two phases; primary data and Secondary Data.
- Primary data is regarding city profile and their perception.
- Primary data will be collected through a self-administered questionnaire to be filled by different sector. Questionnaire will be mainly focusing on information such as problems in power cut, then have any power back up, have any non-conventional source of energy and difference in electricity bill after installation of solar panels.
- Secondary data will include study of demography, land use and master plan of city.

The sample size of this study area was formed through simple sampling. The areas where the flyover impact is more comparatively other areas of study.

3.1.5 Out comes:

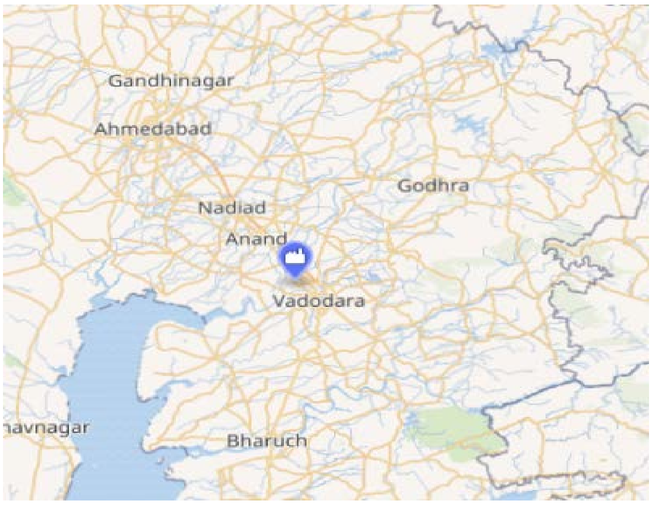
- Based on the data analysis various issues and gaps can be identified and recommendations and improvement strategies and policies can be identified and bringing solar Energy and Energy Efficiency interventions in different sectors can be formulated.
- Propose model of passive solar techniques based on data analysis.

3.2 STUDY AREA

Vadodara is the third largest and one of the most populated cities in the Indian state of Gujarat. The city is well connected with air, road and railways. Vadodara has witnessed establishment of medium and large scale industries. With great strides in economic field, the city has giant industrial complexes and public undertaking like Gujarat Refinery, Indian Petrochemicals, Gujarat State Fertilizers, Heavy Water Project, Oil & Natural Gas Commission etc. Vadodara Municipal Corporation was formed in year 1966.It has now total coverage area of 160 sq. kilometers with total population of 18.17 lac.

GIPCL Vadodara Gas based Power Station is gas turbine based combined cycle power plant. It is located at Dhanora village in Vadodara, Gujarat. The power plant is run by state-owned Gujarat Industrial Power Corporation Limited (GIPCL).

Vadodara Municipal Corporation has started **implementing Energy**



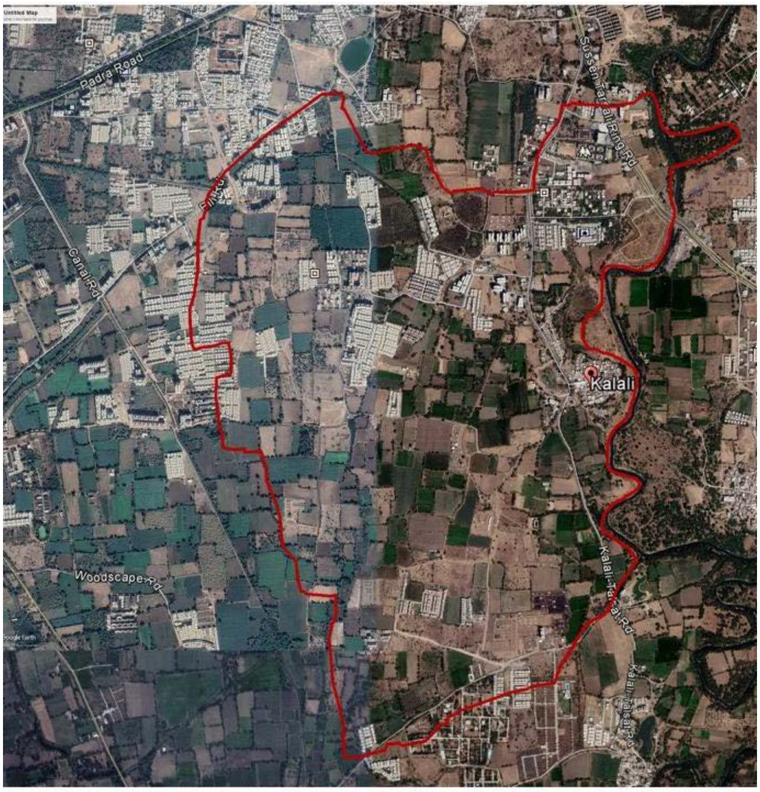
conservation measures in Street Light Service since 1992. Energy efficiency measure is considered in project planning phase and material inventory phase which result into no additional investment for energy efficiency after project implement.

3.3 Primary data

3.3.1 RESEARCH LOCATION : (KALALI)

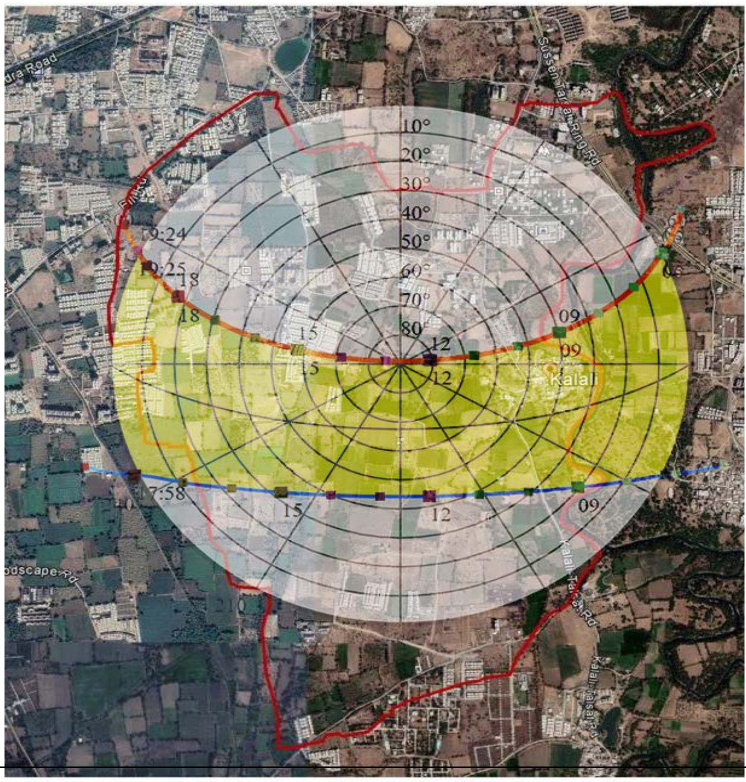
GOOGLE EARTH IMAGE OF EXISTING SITE :

Figure 3.2 existing site



SUNPATH DIAGRAM OF EXISTING SITE :

Figure 3.3 Sunpath diagram with existing site



EXISTING LANDUSE

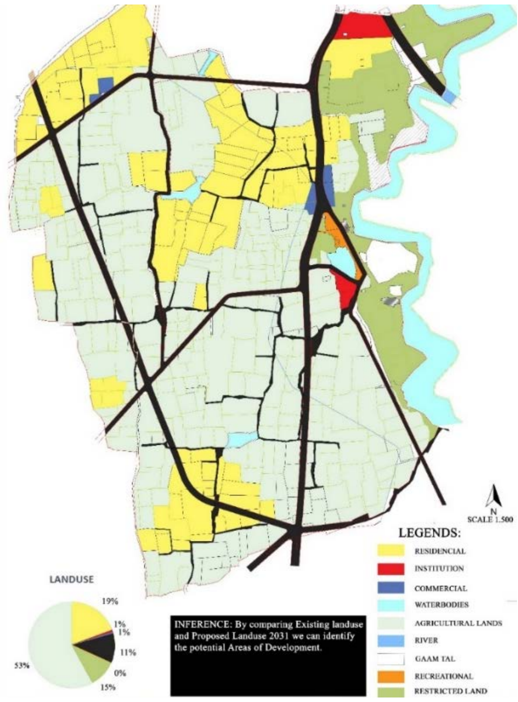
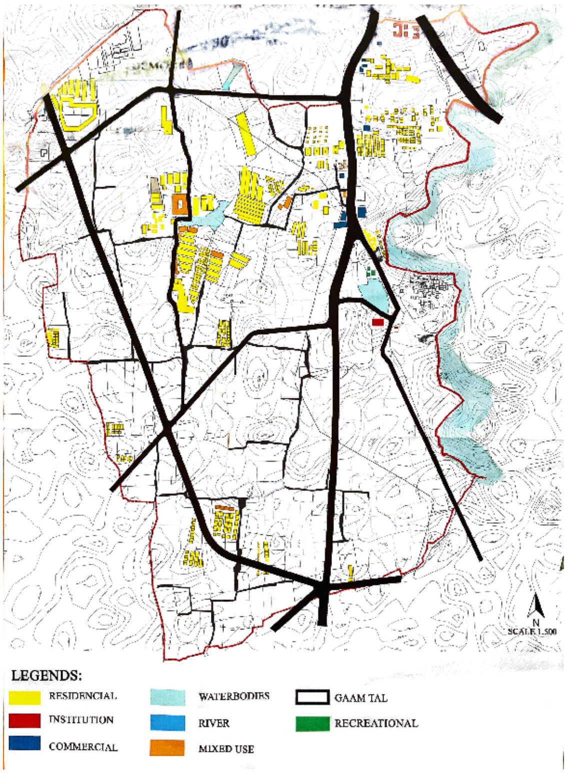


Figure 3.4 existing land use of kalali

EXISTING BUILDING USE

BUILDING HEIGHT

Figure



3.5 building use of kalali

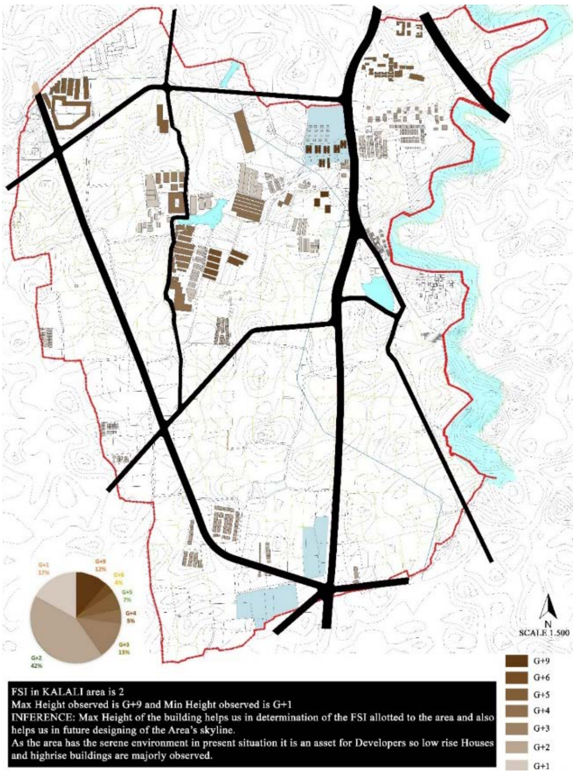


Figure 3.6 building height of kalali

3.3.2 Data Collection

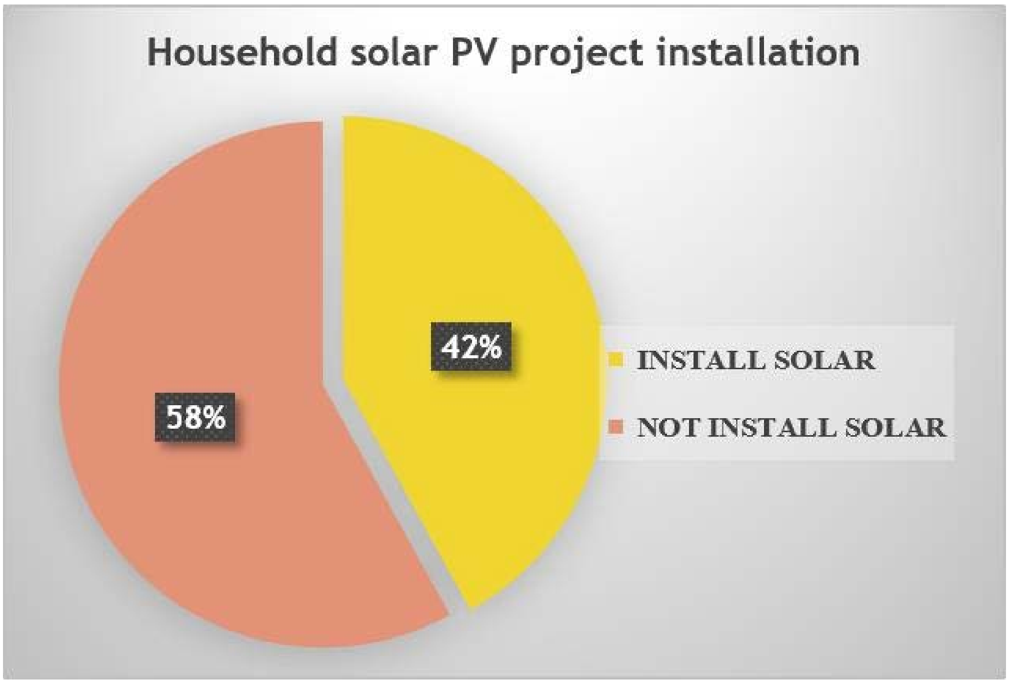


Figure 3.7 Household solar PV project installation

It is inferred from the data survey that 58% population has no installation of solar panel whereas 42% have.

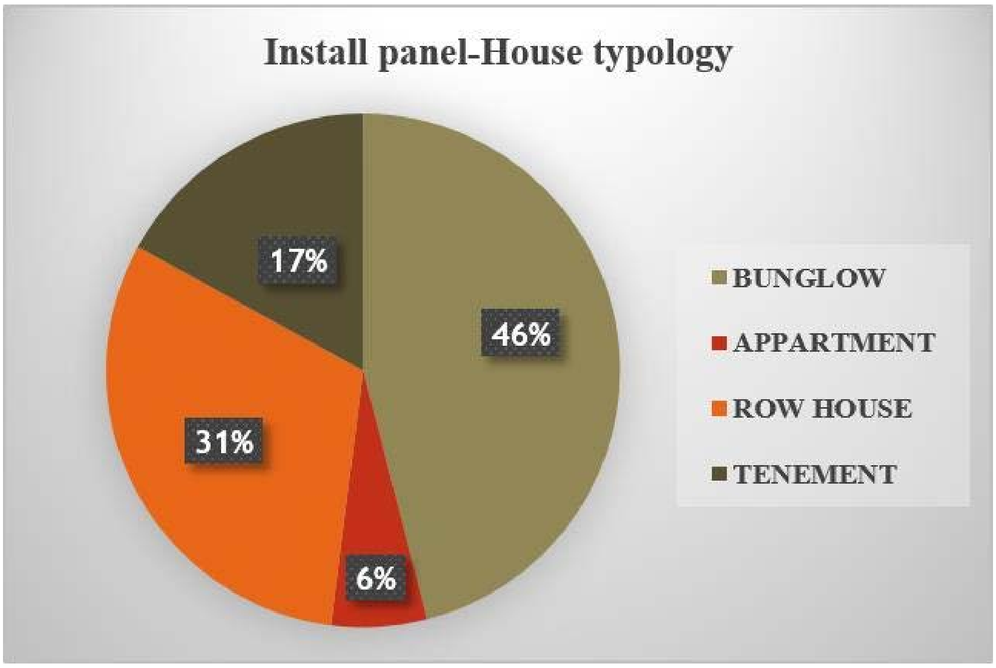


Figure 3.8 install panel -house typology

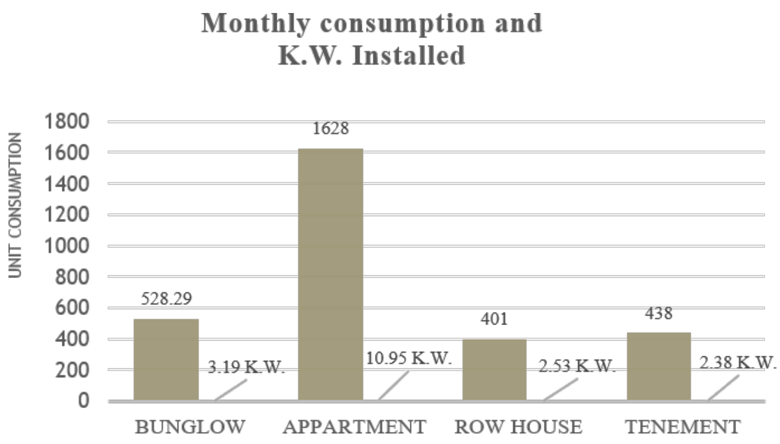


Figure 3.9 Monthly consumption and K.W.installed

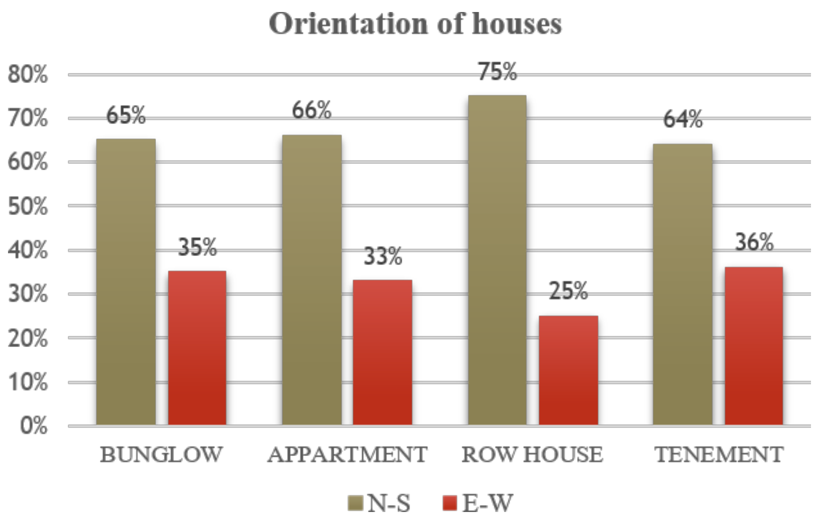


Figure 3.10 Orientation of Houses

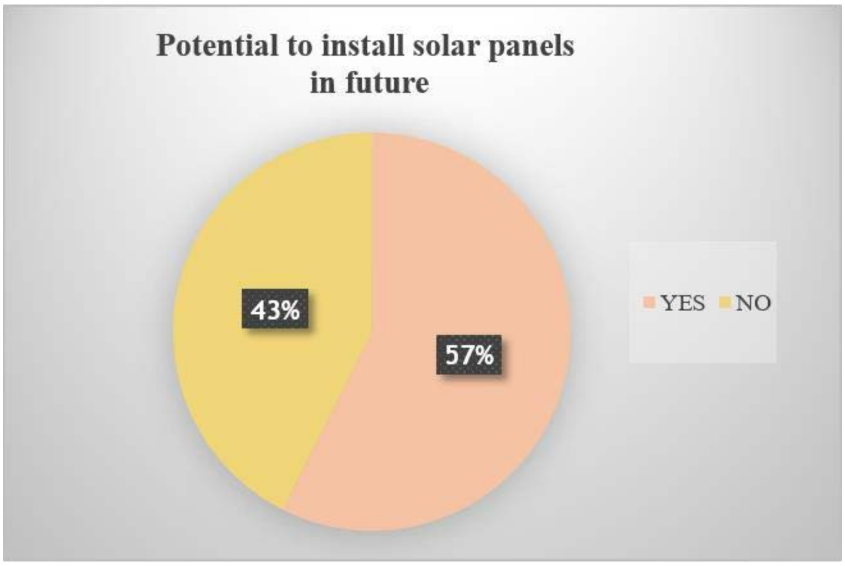


Figure 3.11 Potential to install solar panels in future

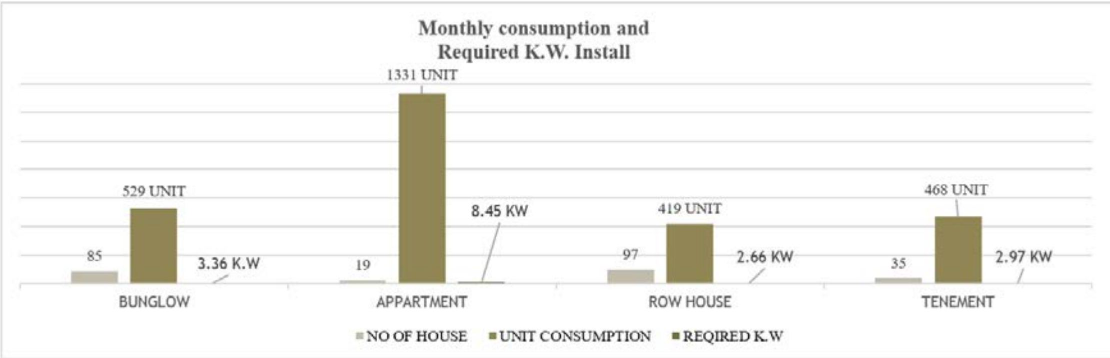


Figure 3.12 Mothly consumption ad required k.w. Istall

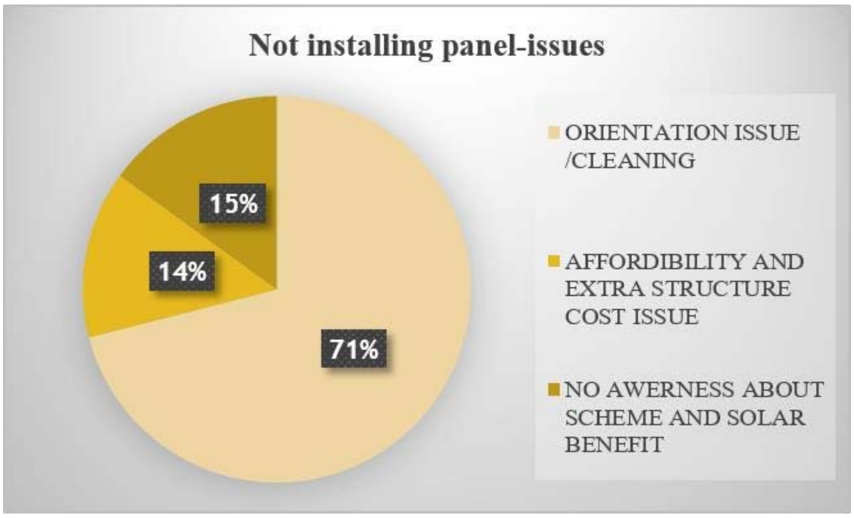


Figure 3.13 Issues of not installing PV project

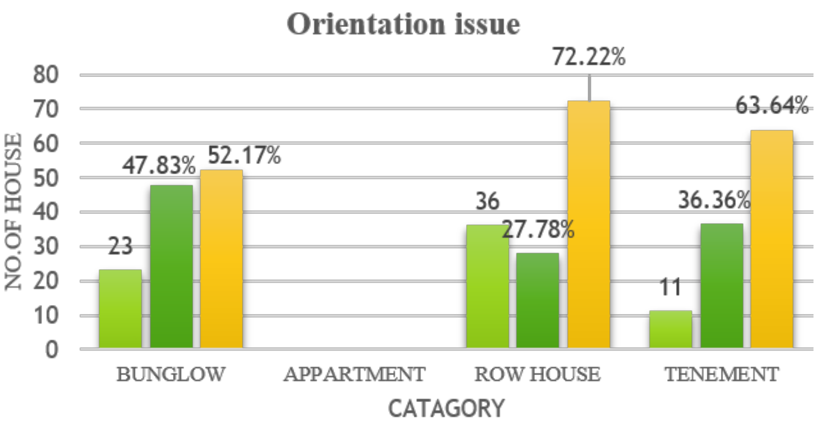


Figure 3..14 Orientation issue of not installing solar

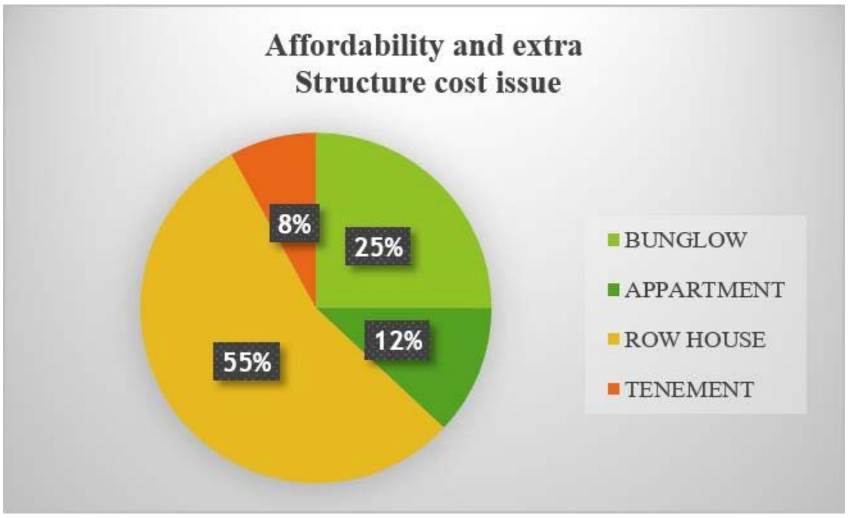


Figure 3.15 Affordability issue of not installing solar

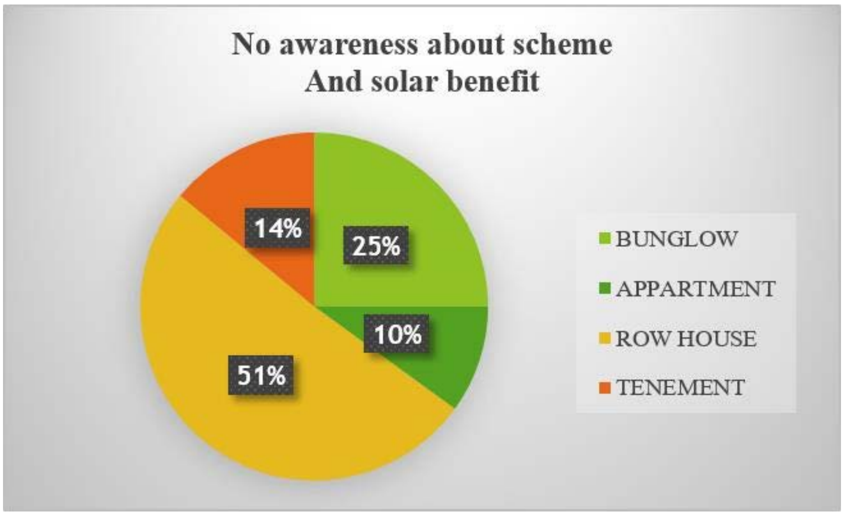


Figure 3.16 No awareness about scheme and solar benefit

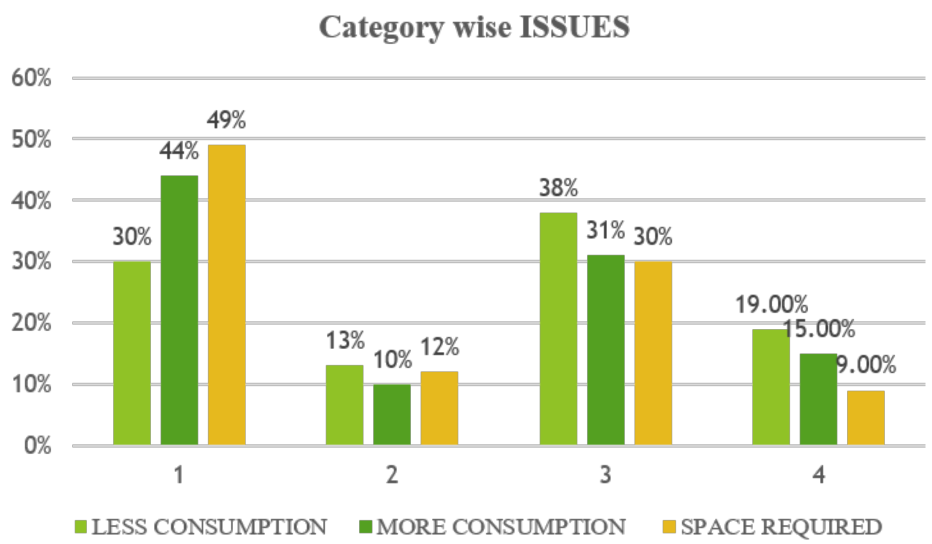


Figure 3.18 Category wise issues

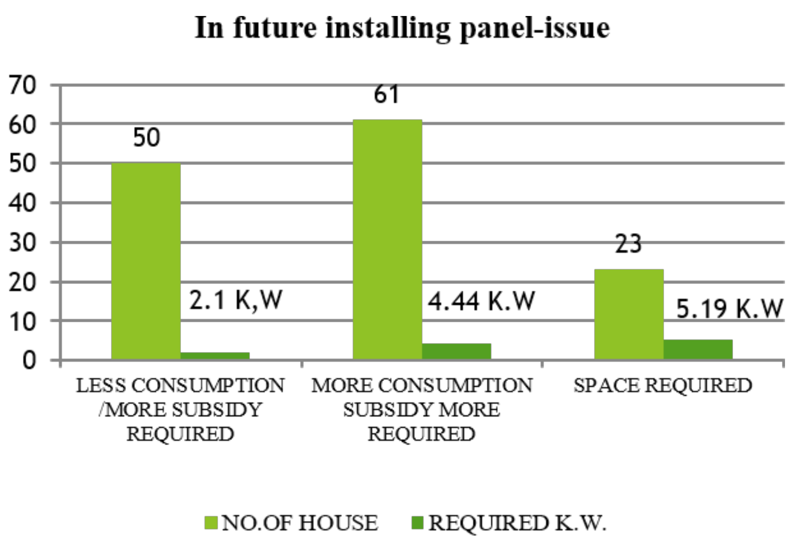


Figure 3.19 Issue of in future installing PV project

It can be inferred from all the above graphs that households in general require moresubsidy from government to install solar roof panels in their households.

3.4 SECONDARY DATA

3.4.1 POLICY AND NORMS ANALYSIS

3.4.2 Gujarat roof top solar power policy 2021

3.4.2.1Preamble

The Government of Gujarat ("State") recognizes the growing impacts of climate change at local and national levels and has taken various policy initiatives to mitigate the impact.

The State is having a significant potential of solar energy resource due to its topography and has witnessed the deployment of both large scale and distributed solar PV systems indigenously. Since the inception of the Solar Policy in 2009 and the subsequent revision in 2015 and 2019, the State has installed over 3,200 MW of solar PV technology across all segments until 2020.

To align with India's ambitious solar PV capacity expansion program, the State envisages to accelerate the deployment of solar power by means of implementation of large-scale projects, small scale distributed systems, establishment of ultra-mega solar parks. These targets will be achieved by introducing new mechanism that will support consumers, businesses and developers in the sector.

3.4.2.2 Vision

The State intends to meet its sustainable development goals by advancing the development of solar energy in a manner that would position it as a mainstream source of energy supply as well as a primary contributor to the national target of 100 GW Solar Capacity by 2022 as part of India's Global Commitment.

3.4.2.3 Objectives

Accordingly, the State Government introduces the "Gujarat Solar Power Policy 2021" with the following objectives:

- To rapidly scale up the State's solar energy capacity in order to contribute to India's overall renewable energy targets keeping in mind India's commitments under international climate agreements.
- To reduce the dependence on fossil fuels and further energy security in the State. 3.3 To further the Sustainable Development Goals (SDG) of Gujarat.
- Employment generation and skill enhancement and promotion of local manufacturing facilities.
- To establish core technical competence in professionals by promoting research, development, deployment and innovation in the solar energy sector.
- To spread awareness about solar power technologies amongst all the electricity consumers.
- To create an investment friendly environment that can provide a win-win situation for all stakeholders in the Power sector.

3.4.2.4 Operative period

This policy will come into effect from the date of its notification and shall remain in operation for a period up to 31st December 2025.

The Solar Power Systems (SPS) installed and commissioned during the Operative Period shall become eligible for the benefits and incentives declared under this Policy, for a period of 25 years from their date of commissioning or for the life span of the SPS, whichever is earlier.

3.4.2.5 Capacity installation

The capacity installation targets for the DisComs shall be based on the renewable power purchase obligation (RPO) defined by the Gujarat Electricity Regulatory Commission (GERC), from time to time. The minimum size of a MW-scale project shall be 1 MW and that for KW-scale project shall be 1 KW.

3.4.2.6 Eligible entities

Any individual or company or body corporate or association or body of individuals, whether incorporated or not, or artificial juridical person shall be eligible for settingup of SPSS, either for the purpose of captive use and/ or for selling of electricity tothe Distribution Licensee or Third Party whether or not under the renewable energy certificate (REC) mechanism subject to provisions of this policy and in accordance with the Electricity Act-2003, as amended from time to time.

The entity desiring to set upa solar power project shall submit a proposal, withrequisite details to the State Nodal Agency (SNA), as may be specified by the SNA, for qualifying for the benefits/facilitation under this Policy.

3.4.2.6 Projects for residential consumers

Solar Projects set up by residential consumers on their rooftop / premises shall be allowed irrespective of consumer sanctioned load. Incentives under existing schemes can me availed by consumers as per the provisions of the scheme.

- Solar Projects can also be set up by a developer on the rooftop

/ premises of a residential consumer for generation and sale of power to such consumer in the same premises (Third Party Sale) for which the developer and consumer shall enter into a lease agreement and/or power sale agreement.

- In case of Residential Consumers, the Energy Accounting shall be carried out on Billing Cycle basis.
- Surplus Energy generated from the solar project after set off on billing cycle basis shall be purchased by respective DisCom at the following rates.
- In case of self-owned systems and SURYA Gujarat scheme consumers: At Rs.2.25 / unit for the first 5 years from commissioning of project and thereafter for the remaining term of the project at 75% of the simple average of tariff discovered and contracted under competitive bidding process conducted by GUVNL for non-park based solar projects in the preceding 6-month period, i.e. either April to September or October March as the case maybe, from the commercial operation date (COD) of the project.

  In case of Third-Party Sale covered under Clause - At 75% of the simple average of tariff discovered and contracted under competitive bidding process conducted by GUVNL for Non-park based solar projects in the preceding 6- month period, i.e., either April to September or October to March as the case may be, from the commercial operation date (COD) of the project. Such rates shall be declared by GUVNL on six monthly basis and shall be applicable under the connectivity agreement to be executed by DisComs.
- Excess drawl by consumer from the grid, if any, after giving shall be charged by DisCom at applicable tariff of respective category of consumer as determined by Hon'ble GERC from time to time.
- No transmission and wheeling charges and losses shall be

applicable as solar power is generated and consumed in the same premises.

- No Banking charges shall be applicable on solar power consumed by Residential Consumers.
- Cross subsidy and additional surcharge shall not be applicable for self- consumption. However, Cross subsidy and additional surcharge for projects under third party sale shall be applicable.
- Consumers and DisComs shall comply with the provisions of applicable regulations, standards and codes notified by various authorities such as GERC and CEA on aspects like metering, connectivity and safety.

3.4.2.7 RATE LIST –"Surya Gujarat Rooftop Yojana"

Table 3.1 RATE LIST -Surya Gujarat Rooftop Yojana 18-19

Table 3.2 RATE LIST -Surya Gujarat Rooftop Yojana 19-20

RATE LIST OF 2018-19						
kW Capacity	Rate Per kW	Original Price	30 % Subsidy (STATE GOV.)	FIX Subsidy (CENTRAL GOV.)	Total Subsidy	Net Payable Amount After Deducting Subsidy
1.000	₹ 48,300	₹ 48,300.00	₹ 14,490	₹ 10,000	₹ 24,490	₹ 23,810
2.000	₹ 48,300	₹ 96,600.00	₹ 28,980	₹ 20,000	₹ 48,980	₹ 47,620
3.000	₹ 48,300	₹ *1,44,900.00*	₹ 43,470	*₹ 20,000*	*₹ 63,470*	*₹ 81,430*
4.000	₹ 48,300	₹ 1,93,200.00	₹ 57,960	₹ 20,000	₹ 77,960	₹ 1,15,240
5.000	₹ 48,300	₹ 2,41,500.00	₹ 72,450	*₹ 20,000*	₹ 92,450	₹ 1,49,050
6.000	₹ 48,300	₹ 2,89,800.00	₹ 86,940	₹ 20,000	₹ 1,06,940	₹ 1,82,860
7.000	₹ 48,000	₹ 3,36,000.00	₹ 1,00,800	*₹ 20,000*	₹ 1,20,800	₹ 2,15,200
8.000	₹ 48,000	₹ 3,84,000.00	₹ 1,15,200	₹ 20,000	₹ 1,35,200	₹ 2,48,800
9.000	₹ 48,000	₹ 4,32,000.00	₹ 1,29,600	*₹ 20,000*	₹ 1,49,600	₹ 2,82,400
10.000	₹ 48,000	₹ 4,80,000.00	₹ 1,44,000	₹ 20,000	₹ 1,64,000	₹ 3,16,000

RATE LIST OF 2020-21						
kW Capacity	Rate Per kW	Original Price	40 % Subsidy For Upto 3 kW	20% Subsidy For More Than 3 kW	Total Subsidy	Net Payable Amount After Deducting Subsidy
1.000	₹ 41,991	₹ 41,991.00	₹ 16,796	₹ 0	₹ 16,796	₹ 25,195
2.000	₹ 41,991	₹ 83,982.00	₹ 33,593	₹ 0	₹ 33,593	₹ 50,389
3.000	₹ 41,991	*₹ 1,25,973.00*	*₹ 50,389*	*₹ 0*	*₹ 50,389*	*₹ 75,584*
4.000	₹ 40,993	₹ 1,63,972.00	₹ 49,192	₹ 8,199	₹ 57,390	₹ 1,06,582
5.000	₹ 40,993	₹ 2,04,965.00	₹ 49,192	₹ 16,397	₹ 65,589	₹ 1,39,376
6.000	₹ 40,993	₹ 2,45,958.00	₹ 49,192	₹ 24,596	₹ 73,787	₹ 1,72,171
7.000	₹ 40,993	₹ 2,86,951.00	₹ 49,192	₹ 32,794	₹ 81,986	₹ 2,04,965
8.000	₹ 40,993	₹ 3,27,944.00	₹ 49,192	₹ 40,993	₹ 90,185	₹ 2,37,759
9.000	₹ 40,993	₹ 3,68,937.00	₹ 49,192	₹ 49,192	₹ 98,383	₹ 2,70,554
10.000	₹ 40,993	₹ 4,09,930.00	₹ 49,192	₹ 57,390	₹ 1,06,582	₹ 3,03,348

Table 3.3 RATE LIST -Surya Gujarat Rooftop Yojana 20-21

It can be inferred that & subsidy has been increased by government and at the same time the project costs have reduced this shows the government willingness in promoting renewable energy in its policies.

RATE LIST OF 2019-20						
kW Capacity	Rate Per kW	Original Price	40 % Subsidy For Upto 3 kW	20% Subsidy For More Than 3 kW	Total Subsidy	Net Payable Amount After Deducting Subsidy
1.000	₹ 46,827	₹ 46,827.00	₹ 18,731	₹ 0	₹ 18,731	₹ 28,096
2.000	₹ 44,203	₹ 88,405.00	₹ 35,362	₹ 0	₹ 35,362	₹ 53,043
3.000	₹ 43,331	*₹ 1,29,993.90*	*₹ 51,998*	*₹ 0*	*₹ 51,998*	*₹ 77,996*
4.000	₹ 42,308	₹ 1,69,230.80	₹ 50,769	₹ 8,462	₹ 59,231	₹ 1,10,000
5.000	₹ 42,090	₹ 2,10,449.00	₹ 50,508	₹ 16,836	₹ 67,344	₹ 1,43,105
6.000	₹ 41,382	₹ 2,48,292.00	₹ 49,658	₹ 24,829	₹ 74,488	₹ 1,73,804
7.000	₹ 41,382	₹ 2,89,674.00	₹ 49,658	₹ 33,106	₹ 82,764	₹ 2,06,910
8.000	₹ 41,382	₹ 3,31,056.00	₹ 49,658	₹ 41,382	₹ 91,040	₹ 2,40,016
9.000	₹ 41,382	₹ 3,72,438.00	₹ 49,658	₹ 49,658	₹ 99,317	₹ 2,73,121
10.000	₹ 41,382	₹ 4,13,820.00	₹ 49,658	₹ 57,935	₹ 1,07,593	₹ 3,06,227

3.4.2.8 Portal dashboard –"Surya Urja Rooftop Yojana 18-19"

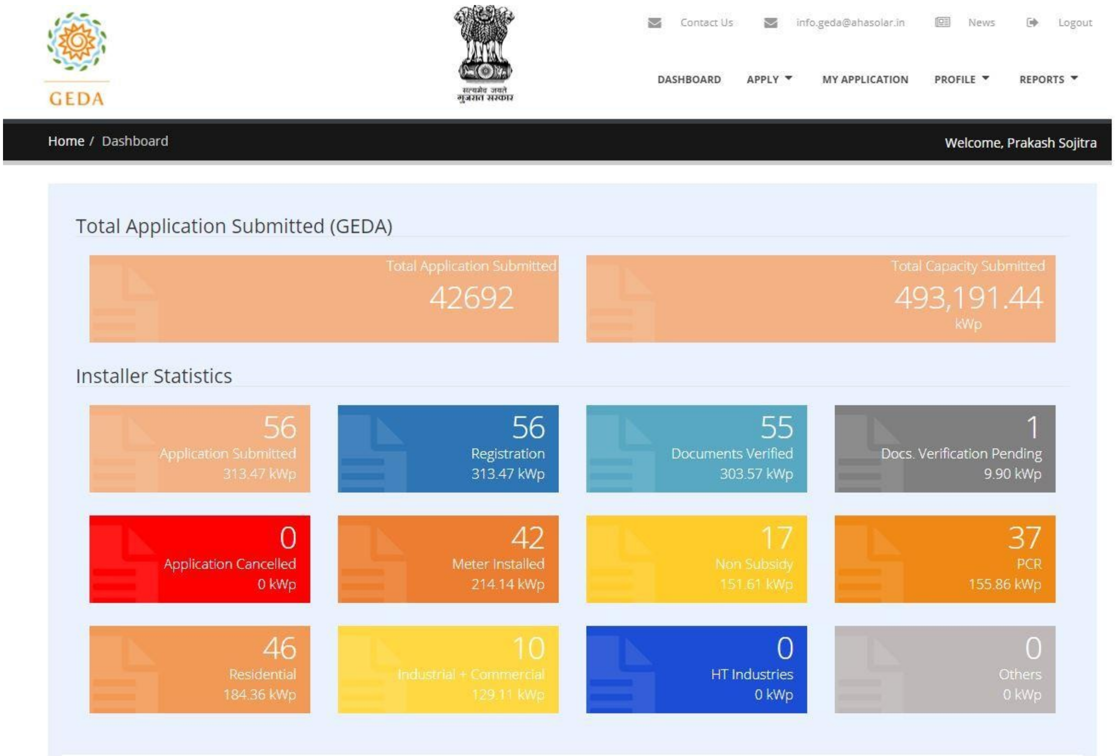


Figure 3.20 2018-19 government portal of GEDA

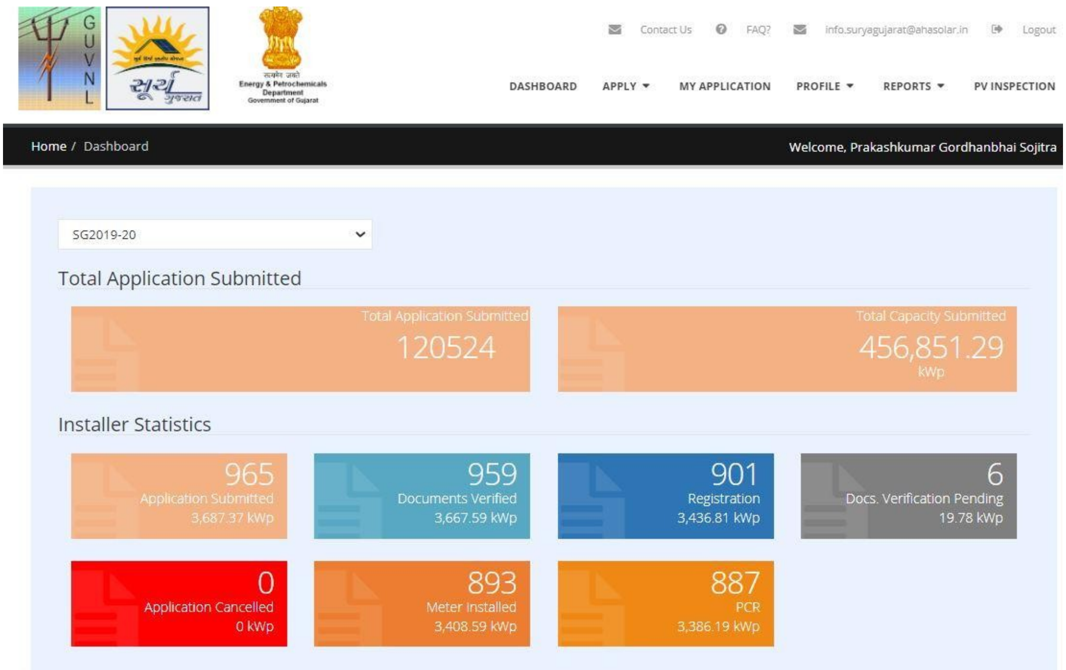


Figure 3.21 2019-20 government portal of GEDA

It is inferred that year on year even though subsidy has increased, the entire 600mw subsidy is still not capitalized by the citizens.

3.4.2.9 Comprehensive General Development Control Regulations – 2017

Table 5.2.1 Norms in cgdcr,2017 about pv project

Sr. No.z	Category of buildings/area	Area standards	Generation requirement *
Residential			
1	Plotted Housing	Greater than 1000 Sq. mt	Minimum 5% of connected load or 20W/sqft for "available roof space"**, whichever is less.
2	Group Housing	All proposals, as per Group Housing Norms	Minimum 5% of connected load or 20W/sqft for "available roof Space", whichever is less.
3	Educational, Institutional, Commercial ,Industrial ,Mercantile, Recreational	Plot size of 1000 sqmt and above	Minimum 5% of connected load or 20W/sqft for *"available roof space"*, whichever is less.
* Area provisions on roof top shall be @12 sq.mt per 1KWp, as suggested by Ministry of New and Renewable Energy. ** *"available rood area"* = 70 % of the total roof size, considering 30 % area reserved for residents' amenities.			

Source: Urban Development and Urban Housing Department

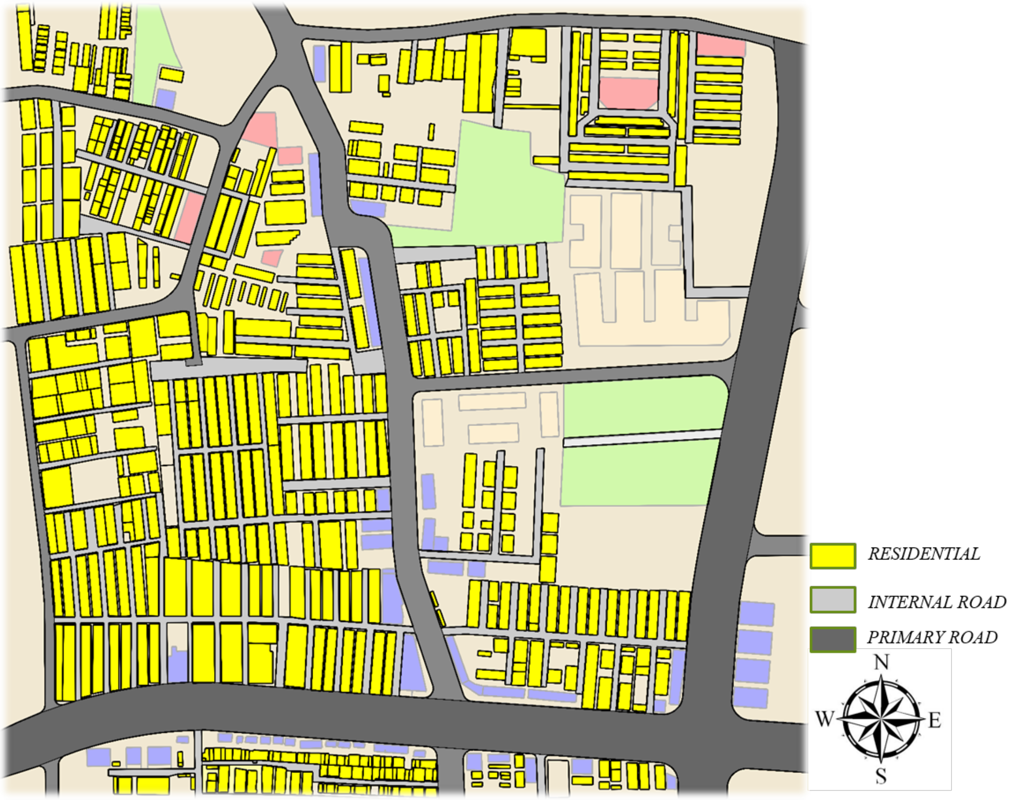
Reference case: Rajkot Urban Development Authority has revised its Building Bye Laws-General Development Control Regulations act (GDCR) in 2004 and included a clause for mandatory provision of Solar Assisted water heating System: New Building in the following categories in which there is a system or installation to supplying hot water shall be built unless the system or installation is also having an auxiliary solar assisted water heating system:

a) Hospitals and Nursing Homes b) Hotels, Lodges and Guests Houses c) Hostels of Schools, Colleges , Training Centers d) Barracks of armed forces, paramilitary forces and police e) Individual residential buildings having more than 150 Sq mt plinth area.

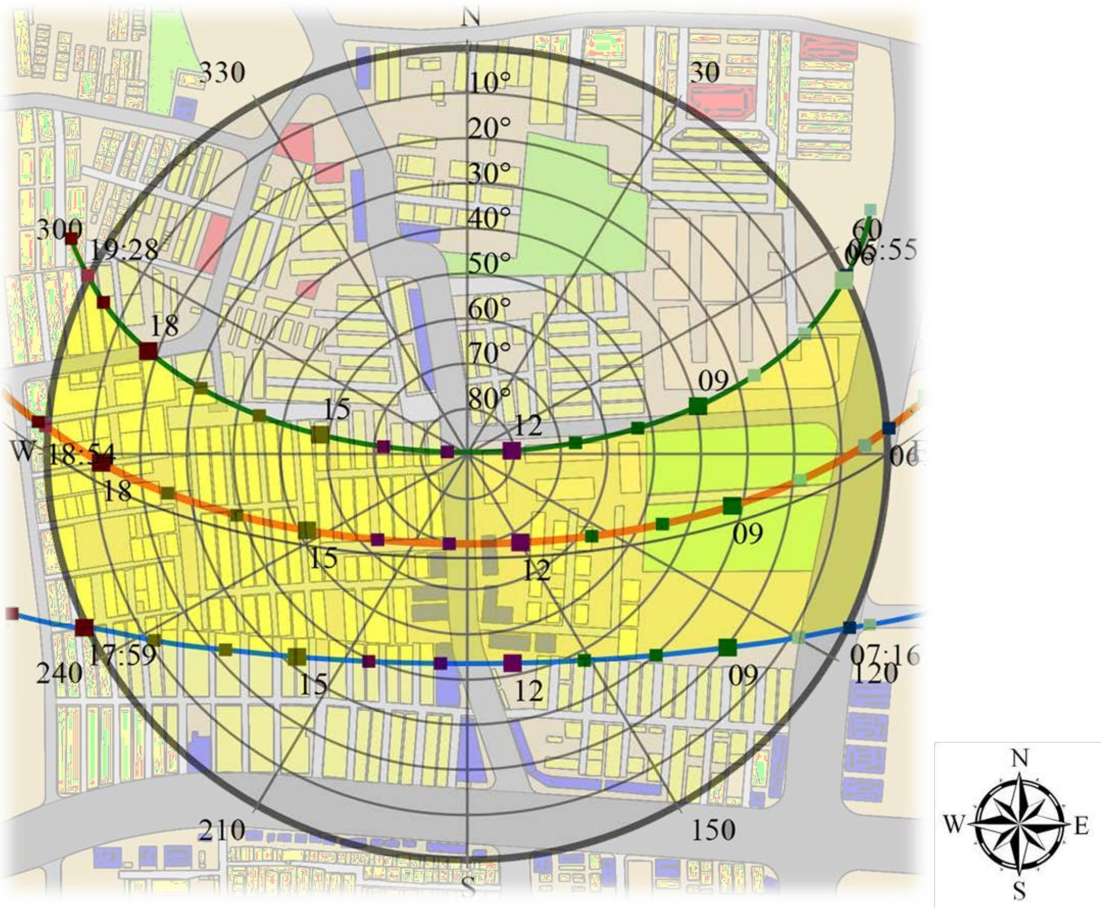
f) Functional Buildings of Railway station and Airport like waiting rooms , retiring rooms, rest rooms, inspection bungalows and catering units g) Community Centers, Banquet Halls, Barat Ghars, Kalyan mandaps and buildings for similar use.

3.5 Data Analysis, Representation and Findings

Figure 3.13 Landuse map of part of tp scheme




RESIDENTIAL
-APARTMENT
INTERNAL ROAD
PRIMARY ROAD
N
W
E
S


N
330
30
300
60
240
120
210
150
W
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10°
20°
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40°
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19:28
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17:59
07:16
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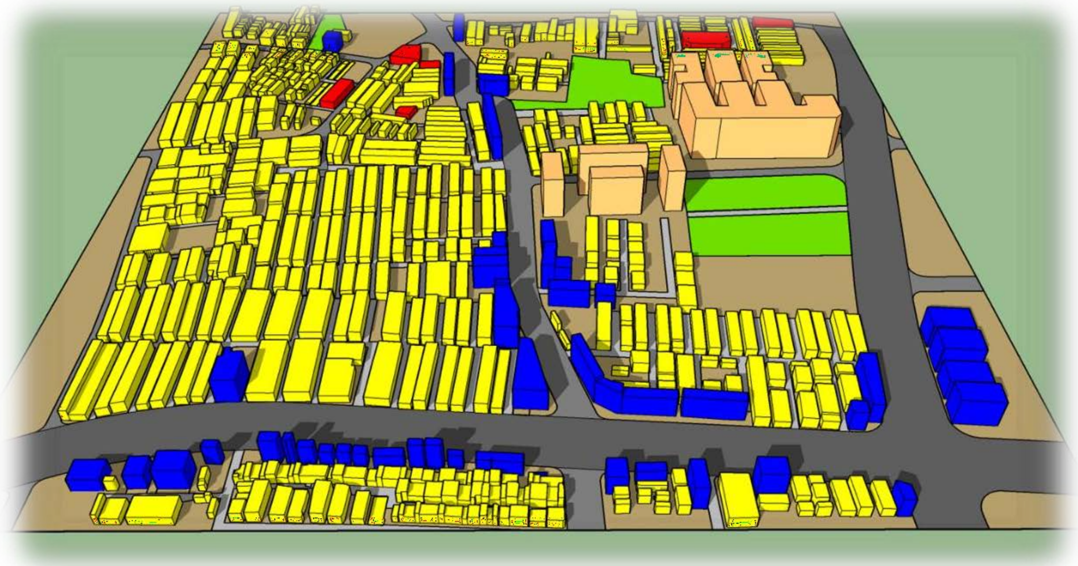
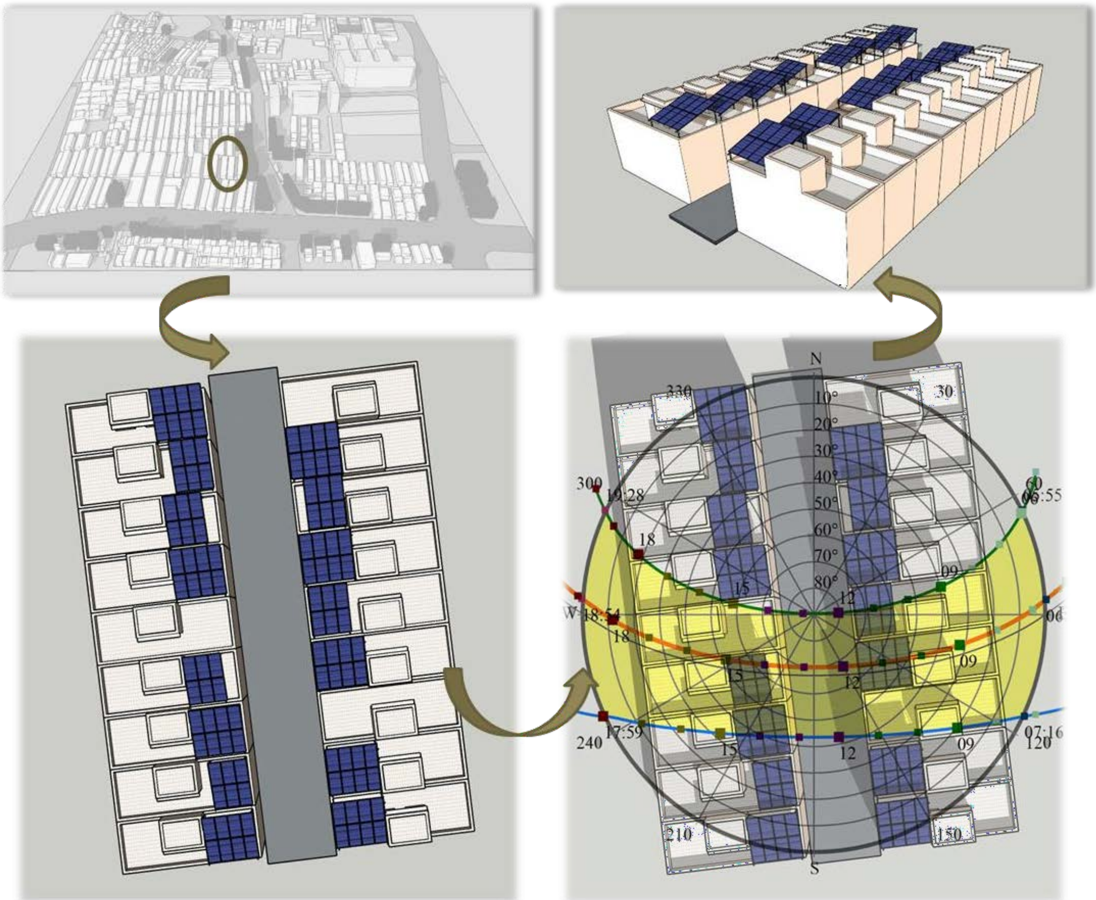




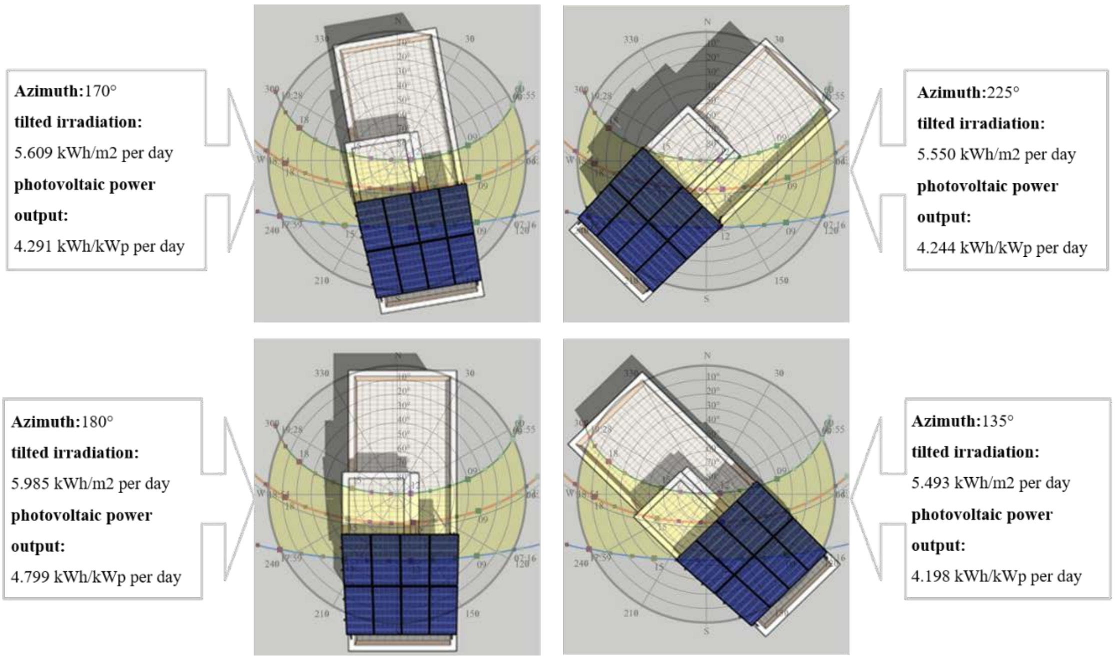
The study highlights that the row house in tp scheme is oriented 10 degrees away from desired north south axis.

It is identified that is the house is not aligned to north direction which creates the following problems:

Firstly, the rooftops are in complete shade of the adjoining building and thus tapping of solar energy is harnessed.

Secondly, due to misaligned of the building, the generation of solar energy is less compared to its maximum potential output.

3.5.1 Single unit solar analysis:

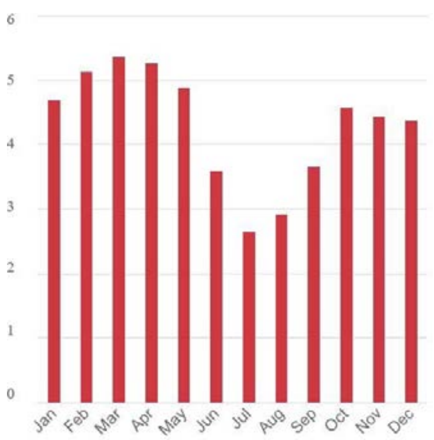


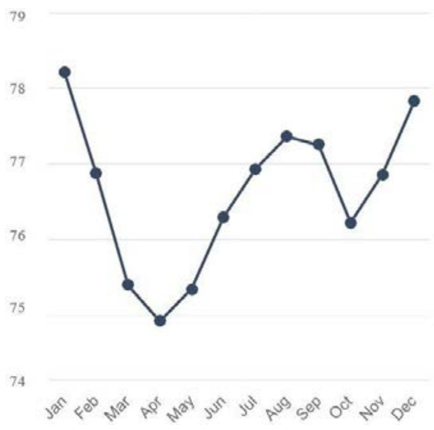
3.5.2 PV electricity: Monthly statistics

Theoretical estimate of solar electricity production by a photovoltaic system without considering the long-term ageing and performance degradation of PV modules and other system components.

Month	**GTI** Monthly sum kWh/m^2 per day	**GTI** Daily average Wh/m^2	**PVOUT specific** Monthly sum kWh/kWp per day	**PVOUT specific** Daily average Wh/kWp	**PVOUT total** Monthly sum MWh	**PVOUT total** Daily average kWh	**PR** %
Jan	6.011	6011	4.700	4700	0.437	14.101	78.2

Feb	6.677	6677	5.131	5131	0.431	15.394	76.9
Mar	7.094	7094	5.348	5348	0.497	16.043	75.4
Apr	7.045	7045	5.278	5278	0.475	15.833	74.9
May	6.471	6471	4.875	4875	0.453	14.626	75.3
Jun	4.716	4716	3.598	3598	0.324	10.793	76.3
Jul	3.449	3449	2.653	2653	0.247	7.959	76.9
Aug	3.790	3790	2.932	2932	0.273	8.795	77.4
Sep	4.733	4733	3.656	3656	0.329	10.967	77.2
Oct	6.004	6004	4.576	4576	0.426	13.728	76.2
Nov	5.796	5796	4.454	4454	0.401	13.362	76.9
Dec	5.617	5617	4.371	4371	0.407	13.113	77.8
Yearly	**5.609**	**5617**	**4.291**	**4298**	**4.699**	**12.893**	**76.5**





4.PROPOSAL AND RECOMMENDATION

4.1 Hypothetical model for a part of tp scheme

Based on the findings of the research guidelines which will form the policies and efforts needed on aspects of the solar rooftop policy which will further improve the physical, social and economic areas have been recommended in this concluding chapter. Also, further scope for the research is outlined.

After an elaborate literature survey and research, the following definition can be adopted for ideal town planning scheme:' town planning scheme means a master plan, local plan or scheme as defined in section 2 of the Regional, Town and Country Planning Act [Chapter 29:12], **that is designed in accordance to the solar path of the particular site to maximize solar efficiency of roof top solar panels of the buildings residing inside the tp scheme.**

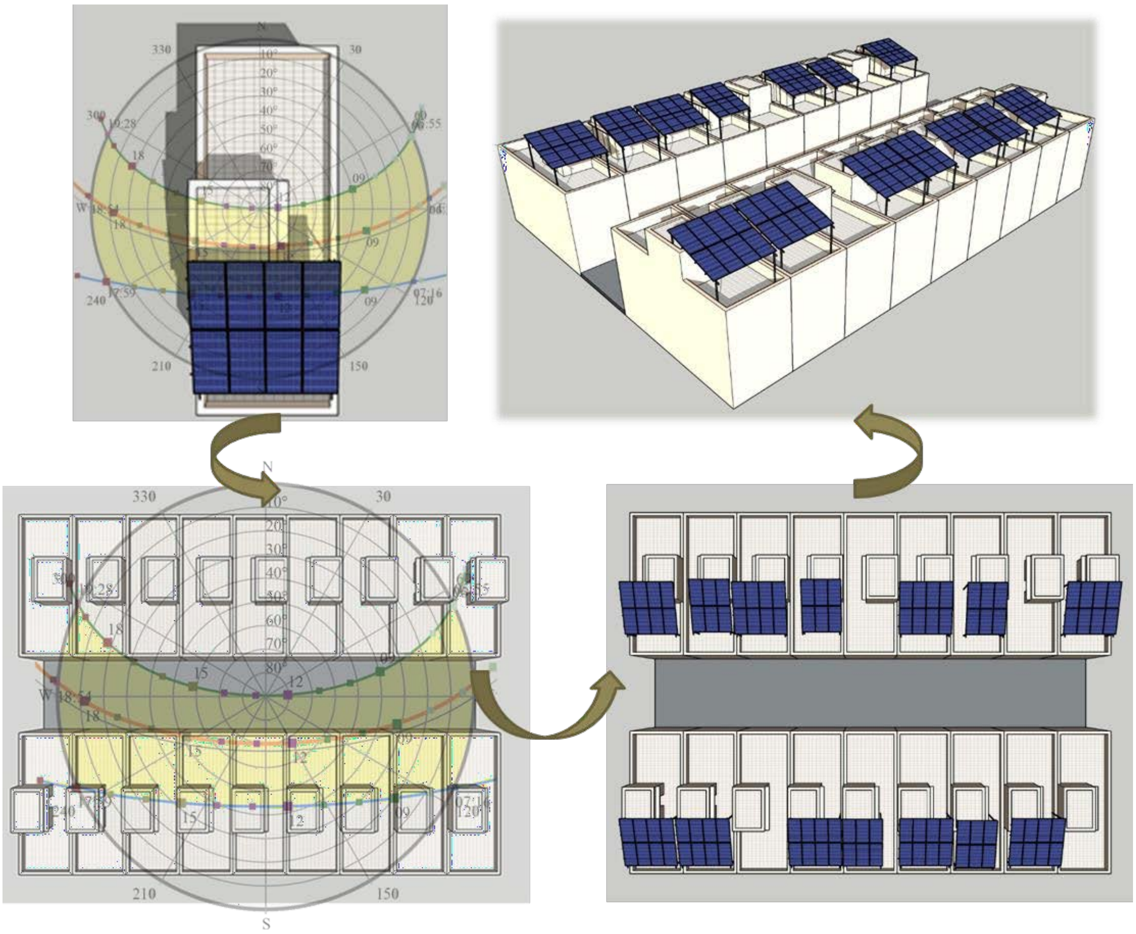
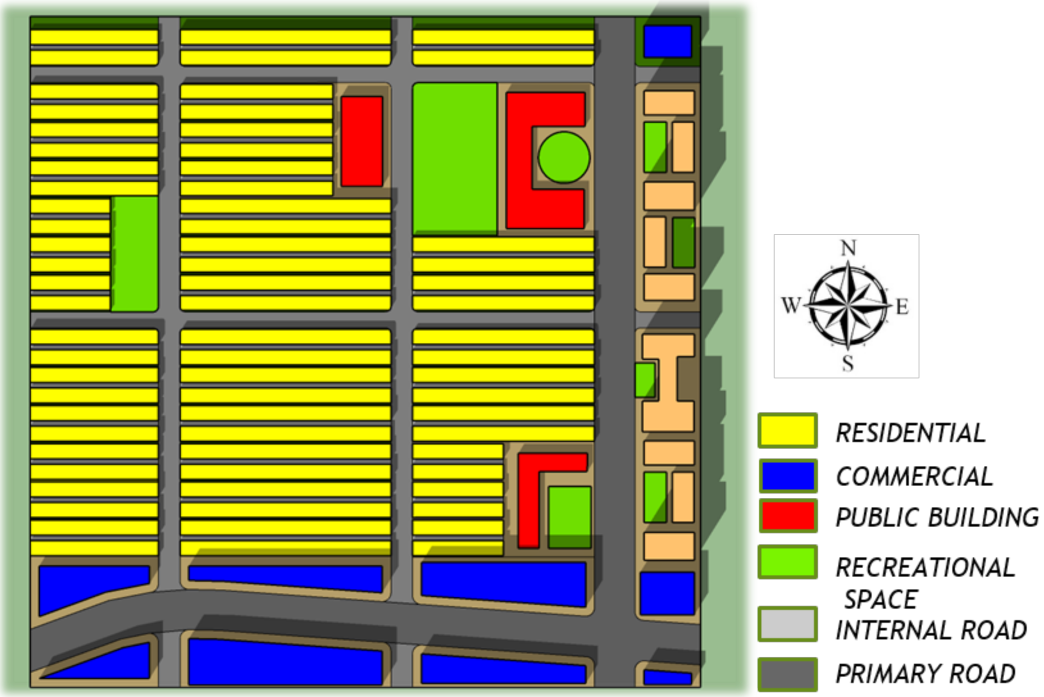
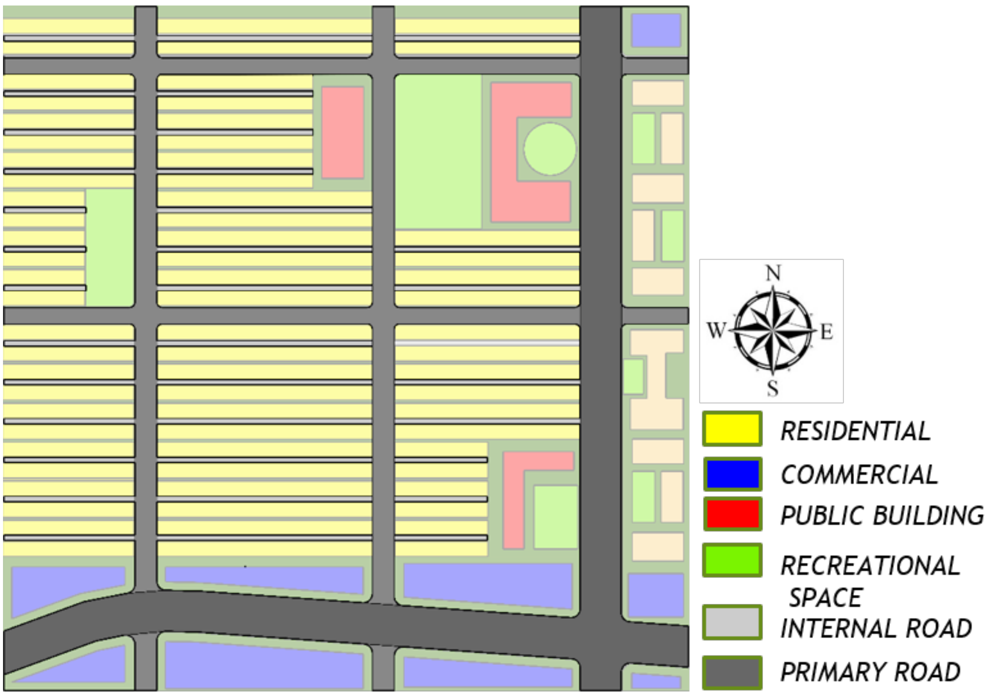


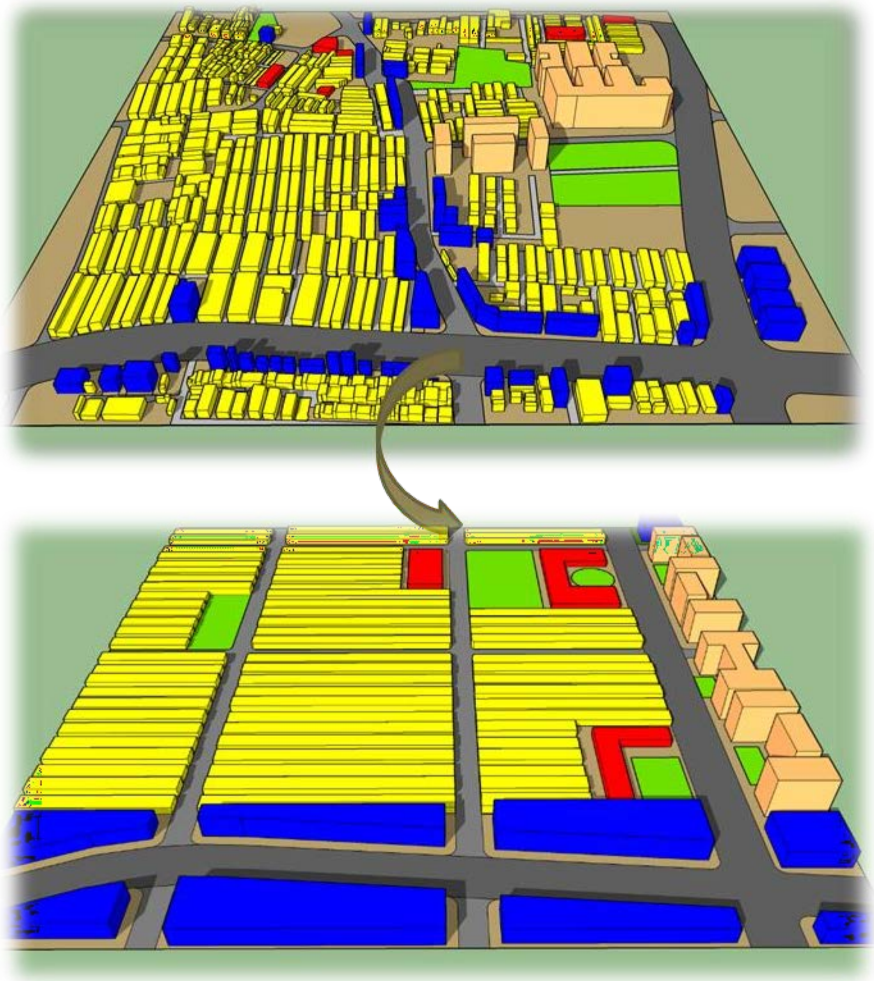
Table 7.1.1 Proposed PV power project output – long-term averages

Month	GTI Monthly sum kWh/m^2 per day	GTI Daily average Wh/m^2	PVOUT specific Monthly sum kWh/kWp per day	PVOUT specific Daily average Wh/kWp	PVOUT total Monthly sum MWh	PVOUT total Daily average kWh	PR %
Jan	6.228	6228	4.881	4881	0.454	14.644	78.4
Feb	6.870	6870	5.292	5292	0.445	15.875	77.0
Mar	7.232	7232	5.452	5452	0.507	16.356	75.4
Apr	7.285	7105	5.317	5317	0.479	15.952	74.8
May	6.485	6485	4.883	4883	0.454	14.648	75.3
Jun	4.718	4718	3.598	3598	0.324	10.795	76.3
Jul	3.457	3457	2.660	2660	0.247	7.979	76.9
Aug	3.819	3819	2.955	2955	0.275	8.865	77.4
Sep	4.798	4798	3.708	3708	0.334	11.125	77.3
Oct	6.149	6149	4.686	4686	0.436	14.059	76.2
Nov	5.994	5994	4.616	4616	0.415	13.848	77.0

Dec	5.829	5829	4.559	4559	0.424	13.678	78.2
Yearly	**5.895C**	**5724**	**4.799**	**4384**	**4.793**	**13.152**	**76.6**







Existing scenario

No.of effective irradiance =5.609 kWh/m2 per day

1 khw solar pv rooftop generates =4.291 kWh/kWp per day

There fore power that can be generated

= capacity x unit generates x 300 sunny days

=1 X 4.291 X 300 = 1287.03 Units

Proposed scenario

No.of effective irradiance =5.985 kWh/m2 per day

1 khw solar pv rooftop generates =4.799 kWh/kWp per day

There fore power that can be generated

= capacity x unit generates x 300 sunny days

=1 X 4.799 X 300 = 1439.07 Units

As orientation of plots depends on the orientation of roads planned under a tp scheme, to achieve a solar efficient plot, foremost the tp scheme has to be planned effectively. Therefore while planning out the roads, roads were taken within the north –south axis of tp model and then plotting was done. Thus it can be concluded that if tp schemes are planned with priority to the orientation of its physical infrastructure such as roads, the residential and commercial plots will automatically align in accordance of maximum solar efficiency. Further research in the planning of tp scheme can be carried out to maximize solar efficiency as well as in the field of loss of energy in transmission.

4.2 Policy level implementation and recommendations

It is proposed to change the 1kw and 2 K.W. subsidy from 40% to 50% and for 3K.W. and 4K.W. the subsidy has been changed from 20% to 40% to incentivize maximum usage of the subsidy given by government under solar roof top policy.

Table 7.2.1 Existing rate list of rooftop policy 20-21

RATE LIST OF 2020-21						
kW Capacity	Rate Per kW	Original Price	40 % Subsidy For Upto 3 kW	20% Subsidy For More Than 3 kW	Total Subsidy	Net Payable Amount After Deducting Subsidy
1.000	₹ 41,991	₹ 41,991.00	₹ 16,796	₹ 0	₹ 16,796	₹ 25,195
2.000	₹ 41,991	₹ 83,982.00	₹ 33,593	₹ 0	₹ 33,593	₹ 50,389
3.000	₹ 41,991	₹ *1,25,973.00*	₹ *50,389*	*₹ 0*	*₹ 50,389*	*₹ 75,584*
4.000	₹ 40,993	₹ 1,63,972.00	₹ 49,192	₹ 8,199	₹ 57,390	₹ 1,06,582
5.000	₹ 40,993	₹ 2,04,965.00	₹ 49,192	₹ 16,397	₹ 65,589	₹ 1,39,376
6.000	₹ 40,993	₹ 2,45,958.00	₹ 49,192	₹ 24,596	₹ 73,787	₹ 1,72,171
7.000	₹ 40,993	₹ 2,86,951.00	₹ 49,192	₹ 32,794	₹ 81,986	₹ 2,04,965
8.000	₹ 40,993	₹ 3,27,944.00	₹ 49,192	₹ 40,993	₹ 90,185	₹ 2,37,759
9.000	₹ 40,993	₹ 3,68,937.00	₹ 49,192	₹ 49,192	₹ 98,383	₹ 2,70,554
10.000	₹ 40,993	₹ 4,09,930.00	₹ 49,192	₹ 57,390	₹ 1,06,582	₹ 3,03,348

Table 7.2.2 Proposed rate list of rooftop policy 20-21

PROPOSED RATE LIST OF ROOFTOP POLICY							
kW Capacity	Rate Per kW	Original Price	50 % Subsidy For Upto 2 Kw	40 % Subsidy For Upto 4 kW	20% Subsidy For More Than 4 kW	Total Subsidy	Net Payable Amount After Deducting Subsidy
1.000	₹ 41,991	₹ 41,991	₹ 20,996	₹ 0	₹ 0	₹ 20,996	₹ 20,996
2.000	₹ 41,991	₹ 83,982	₹ 41,991	₹ 0	₹ 0	₹ 41,991	₹ 41,991
3.000	₹ 41,991	₹ *1,25,973*	₹ -	₹ *50,389*	₹ 0	*₹ 50,389*	*₹ 75,584*
4.000	₹ 40,993	₹ 1,63,972	₹ -	₹ 65,589	₹ 0	₹ 65,589	₹ 98,383
5.000	₹ 40,993	₹ 2,04,965	₹ -	₹ 65,589	₹ 8,199	₹ 73,787	₹ 1,31,178
6.000	₹ 40,993	₹ 2,45,958	₹ -	₹ 65,589	₹ 16,397	₹ 81,986	₹ 1,63,972
7.000	₹ 40,993	₹ 2,86,951	₹ -	₹ 65,589	₹ 24,596	₹ 90,185	₹ 1,96,766
8.000	₹ 40,993	₹ 3,27,944	₹ -	₹ 65,589	₹ 32,794	₹ 98,383	₹ 2,29,561
9.000	₹ 40,993	₹ 3,68,937	₹ -	₹ 65,589	₹ 40,993	₹ 1,06,582	₹ 2,62,355
10.000	₹ 40,993	₹ 4,09,930	₹ -	₹ 65,589	₹ 49,192	₹ 1,14,780	₹ 2,95,150

2.2.1.1 Rebate in property tax through Municipal Corporations and Municipalities should be provided to the users of solar panel especially in domestic sector as such area install solar panel.

2.2.1.2 For awareness Rigorous publicity campaign, training programme and business meets should be organized for various stake holders e.g. architects, engineers, builders & developers, financial institutions, NGOs ,etc by the local area body or state government to increase awareness within the citizens.

2.2.1.3 The government should start a sustained campaign on Solar panel through print media, radio and television and should be printed as adverts in property tax bill.

2.2.1.4 The local area body should promote the establishment of information centers in major area of the city with a view to make solar energy products and information easily available.

2.2.1.5 Government Order with regard to construction of energy efficient solar buildings should be issued at least in Government and public sector infrastructure in accordance with ECBC: 2006.

Table 7.2.3 Proposed norms in cgdcr

Sr. No.	**Category of buildings/area**	**Area standards**	**Generation requirement ***
Residential			
1	**Individual residential houses**	**Greater than 50 Sq mt plinth area**	Minimum 3kw or 0.1kw/sq.mt "available roof space"**, whichever is less.
2	**Residential building (for common facilities)**	**All building**	Minimum 3kw or 0.1kw/sq.mt "available roof space"**, whichever is less.

	* Area provisions on roof top shall be @12 sq.mt per 1KWp, as suggested by Ministry of New and Renewable Energy. ** *“available rood area”* = 70 % of the total roof size, considering 30 % area reserved for residents’ amenities.

APPENDIX

THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

Masters in Urban and Regional Planning (MURP)

QUESTIONNAIRE (households)

SURVEY FORM FOR HOUSEHOLD SOLAR ROOFTOP

1. Name	
2. Address	
3. Location	LONGITUDE:……………………………. LETITUDE:………………………………….

4. Which type of residence in you are living?

- ☐ Bangalow
- ☐ Raw house
- ☐ Apartment
- ☐ Tenement

5. Which type of residence in you are living?

☐ East-West or similar East –West direction

☐ North-South or similar North – South direction

6. What is your average monthly electricity bill?

_______₹

7. What is your average monthly electricity consumption?

________Units

8. Do you have installed PV panels?

☐ Yes

☐ no

9. If yes, then how much KW solar PV plant you have installed?

_____________KW

10. How much units are generated in your PV plant?

_________Units

11. After installation of PV plant how much difference came in your electricity bill?

__₹

12. If no, then in future any plan to install solar PV panels?

13. If no, then reason for not installing solar PV plant?

☐ Affordability
☐ No awareness
☐ Orientation issue
☐ 4kw consumption need more subsidy
☐ 1-2 kw consumption more subsidy
☐ Any other

14. Suggestions/Comments for improving installation of solar pv project?

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- Fédérale de Lausanne (EPFL) Switzerland Romain Nouvel Hochschule für Technik Stuttgart, Germany Giuseppe Peronato Ecole Polytechnique Fédérale de Lausanne (EPFL) Switzerland Cristina S. Polo López University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Switzerland Cristian Roecker Ecole Polytechnique Fédérale de Lausanne (EPFL) Switzerland Alessandra Scognamiglio Photovoltaic Technologies Unit (UTTP-FOTO) ENEA, Italy Simon Stendorf Sørensen PlanEnergi, Denmark Tanja Siems Bergische Universität Wuppertal, Germany Katharina Simon Bergische Universität Wuppertal, Germany Daniele Vettorato European Academy EURAC Bozen/Bolzano, Italy Karsten Voss Bergische Universität Wuppertal, Germany: Approaches, Methods and Tools for Solar Energy in Urban Planning • MiguelAmado , FrancescaPoggi: Towards Solar Urban Planning: A New Step for Better Energy Performance • IRENA: REMAP RENEWABLE ENERGY PROSPECTS FOR INDI.