Position paper on:

Low Carbon Resource- Efficient Affordable Housing

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We would also like to thank Ar. Parag Udani for his contribution in translation of the research brochure in Gujarati language. This would hopefully help us reach a wider audience and better communicate our research findings and recommendations to the engineers and commissioners of various cities within the state of Gujarat.

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List of Abbreviations

AAC- Autoclaved Aerated Concrete

AHP- Affordable Housing In Partnership

BLC- Beneficiary Led Construction

BOQ- Bill of Quantities

BR- Brick

BSUP- Basic Services to the Urban Poor

CLSS- Credit Link Subsidy Scheme

COP- Conference of the Parties

DCR- Development Control Regulation

DU- Dwelling Unit

EPS – Environmentally Productive Space

FAR- Floor Area Ratio

GDCR- General Development Control Regulations

KPMG- Klynveld Peat Marwick Goerdeler (accounting firm)

MC- Monolithic Concrete

MMGY- Mukhya Mantri Gruh Yojana

PMAY- Pradhan Mantri Awas Yojana

PPP- Public Private Partnership

PV- Photo Voltaic

RCC- Reinforced Cement Concrete

RMC- Rajkot Municipal Cooperation

RUDA- Rajkot Urban Development Authority

SDC- Swiss Agency for Development and Cooperation

SDG- Sustainable Development Goals

1. Introduction

India is rapidly urbanising and cities are challenged by urban growth and continuing poverty. About 40% of the population in 2030 would be living in urban areas as against 30% currently.[1] This exponential growth in urban population will result in increasing demand for urban amenities like housing, energy, transport, water and waste disposal. The Government of India has launched many national programmes like Housing for All, Smart Cities Mission, Atal Mission for Urban Rejuvenation and Urban Transformation etc. to steer economic growth and meet demands of rapid urbanisation in the country. One of the flagship programme of the Government of India is Housing for All by 2022. The target is 20 million affordable houses in a time span of less than 6 years.[2]

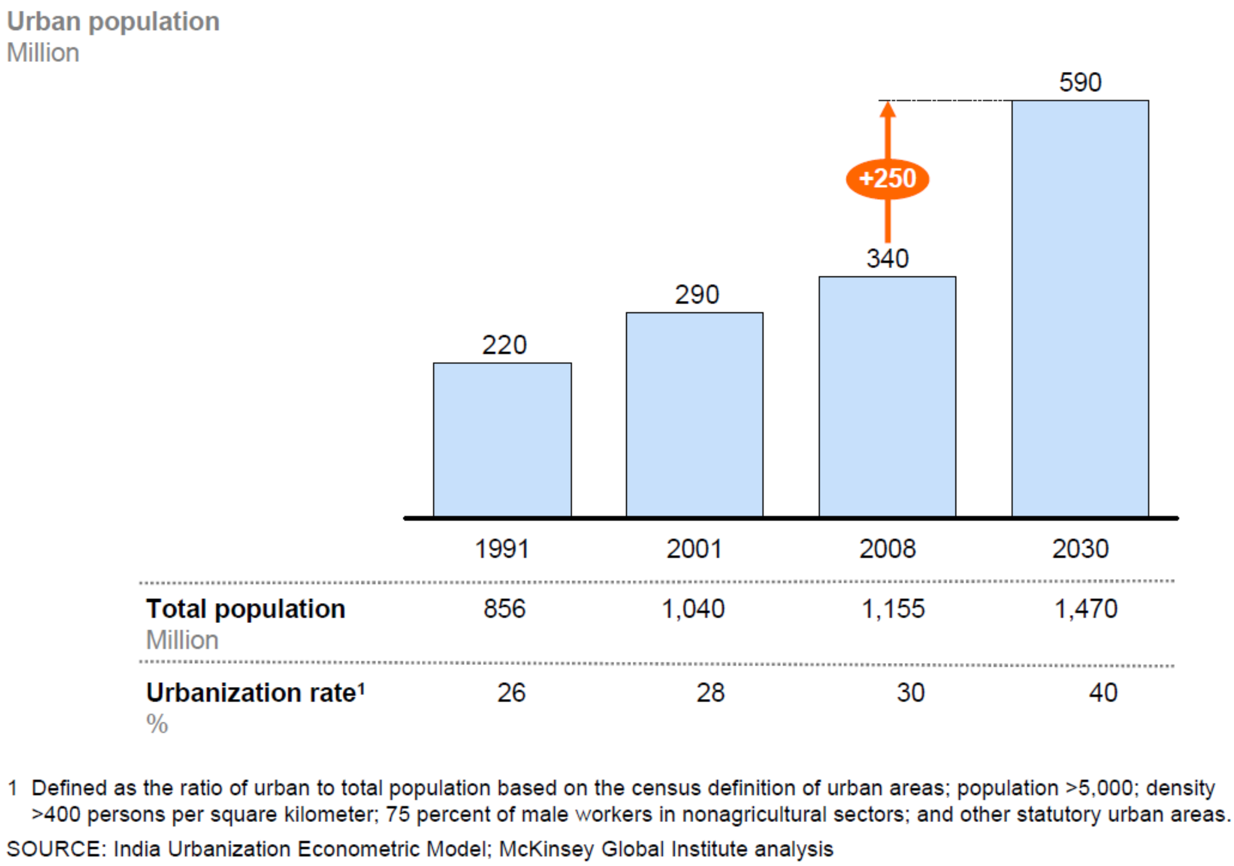
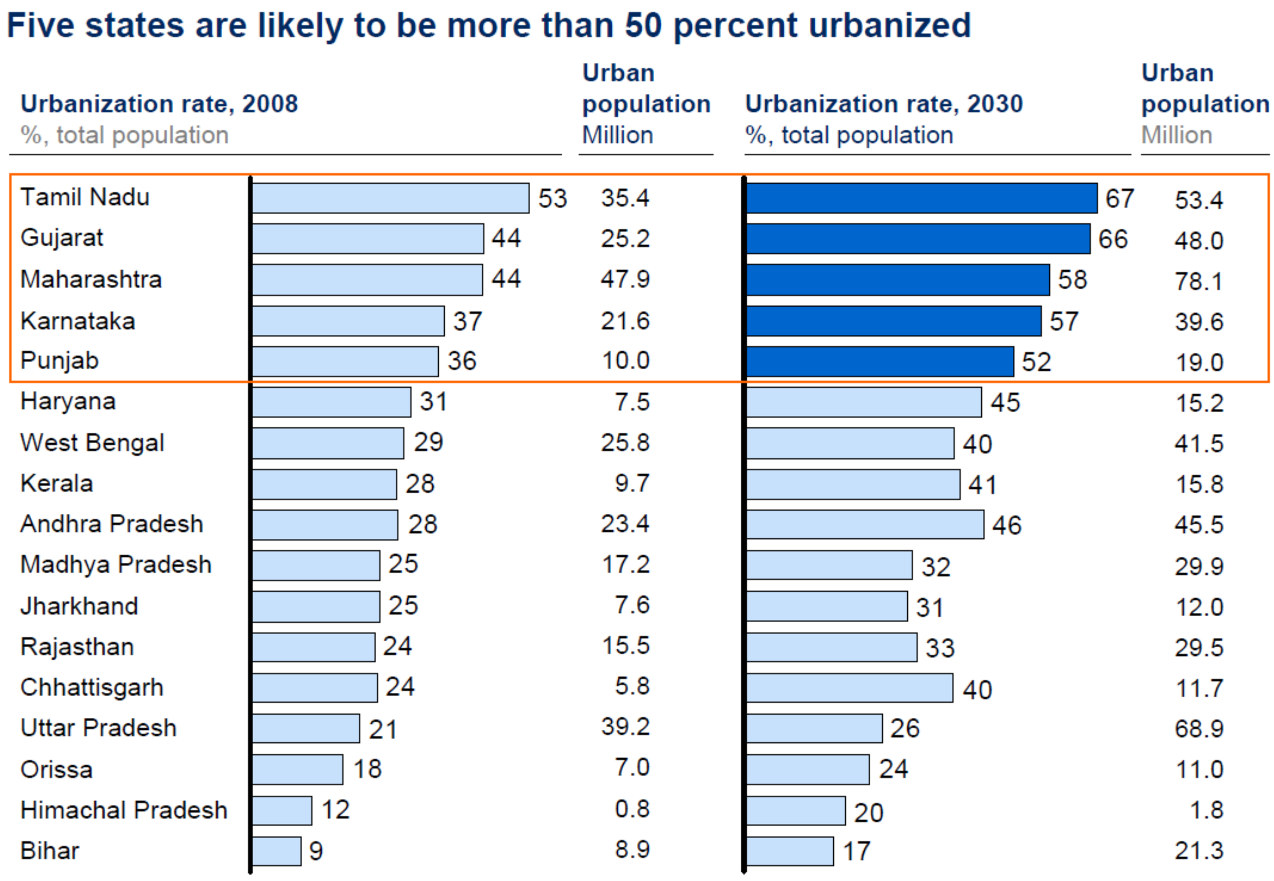


Figure 1 Projected Urbanisation in India

[1] India's Urban Awakening: Building Inclusive cities, sustaining economic growth, Mckinsey Global Institute
[2] http://www.thehindu.com/news/national/housing-for-all-by-2022-government-plans-20-million-houses-for-urban-poor/article7326997.ece

The rapidity and scale of urban growth, urban regeneration and urban expansion, calls for urgent attention to affordable housing as this will be the chief determinant of the success of the Mission.



SOURCE: India Urbanization Econometric Model; McKinsey Global Institute analysis

Figure 2 Comparison of projected urbanization in various states of India

The current affordable housing shortage in Urban India (2012-2017) stands at 18.78 million dwelling units[3]. This is expected to increase to 44-48 million units by 2022[4]. It may be surmised that about half of the housing need would be met by self-build by owners or by small enterprises as the existing habitations of cities upgrade and redevelop to accommodate more and better homes; the other half may be met by public, private-public partnerships (PPP) and private builders undertaking large group housing projects.

[3] Ministry of Housing and Urban Poverty Alleviation, 2012
[4] KPMG, 2014

Given the magnitude and scale of affordable housing to be built, it becomes necessary to have a strategy to minimise the potential environmental impacts of this rapid and enormous scale of construction and to seize this opportunity to leapfrog into low carbon urban systems of habitation and transport, it provides an opportunity to explore the potential of low carbon and resource efficient construction. However, the current policy context is not very clear and there is a need to fill this gap of constructing environmentally sustainable housing

1.1 Sustainable Development Goals and COP 21

The Housing for All mission and the objective of developing low carbon and resource efficient housing also respond to the commitments made by the Government of India to adopt Sustainable Development Goals of the United Nations and to the commitment toward reducing carbon intensity of development made at COP 21 at Paris. The policies that enable the provision of affordable, safe and secure homes and housing neighbourhoods in cities are to be seen as pursuant of four particular goals of the SDGs – **SDG10 *Reduced Inequalities***, **SDG11 *Sustainable Cities and Communities***, **SDG12 *Responsible Production and Consumption***, and also **SDG13 *Climate Action***.

Affordable homes at locations of employment and economic opportunity with access to public transport and social amenities.

Livelihoods in an inclusive economy with energy equity, and environmental security - conserve water and air purity, recycle waste, enhance public space with greenery.

Use of low-carbon and resource-efficient modes of production for construction of housing and selecting building types for minimum operational energy.

Build-in robustness against infrastructure failure, shade outdoors against heat waves, intensify rain harvest and water efficiency. Minimize hard ground and motor vehicles for low UHI

Since housing for the majority of our urban populations, for current populations as well as the increases due to migration, would constitute a dominant proportion of the built fabric of cities, a low carbon and resource efficient affordable housing becomes an important strategy for Climate Action. The combination of low carbon construction with compact urban morphology and low carbon city transport produces low carbon urban development.

Figure 3 Affordability and Sustainability

Homes for low income households would necessarily be of a small size for the number of members in an average household. It will be the complementary habitability of the spaces adjacent to and around the dwelling unit, with the dwelling itself, that constitutes the liveability of the housing system. This aspect of environmental sufficiency in housing is to be considered under the development goal Sustainable Communities and Sustainable Cities.

The sustainability of cities requires a strong strategy for ensuring low carbon urban systems. The distribution of affordable housing across the fabric of the city and its location with respect to public transport systems determines the carbon footprint of intra city mobility. Spatial distribution of affordable housing is also related to income potential and is an instrument for the development goal of Reducing Income Disparities.

In summary, it may be said that a broad based and comprehensive urban development policy for affordable housing is a necessary tool for urban development that serves the need of the majority of citizens at the lower end of the economic pyramid. City Master Plans and Development Control Regulations (DCR) have the potential for adjustment in order to attain the SDG and incorporate strategies toward low carbon urban living.

1.2 Position Paper – the context of Rajkot city and Gujarat State

The preparation of this Position Paper has been commissioned by the Swiss development Agency (SDC) as a complementary research study to the CapaCITIES project. The CapaCities project for India, supported by the Swiss Agency for Development and Cooperation(SDC) is for strengthening the capacities of city authorities to plan and implement measures for reducing greenhouse gas emissions and for coping with the effects of climate change. The project is being implementedin four target cities namely Rajkot, Siliguri, Coimbatore and Udaipur.

The context of this research has been the city of Rajkot in Gujarat. The Municipal Corporation of Rajkot has an active Affordable housing program. The Govt. of Gujarat uses the following income based criteria for affordable housing schemes:

Parameter	EWS	LIG-1	LIG-2	MIG-1
Carpet area (sq. mtr.)	25-30	31-40	41-50	51-65
Layout	2 room, kitchen, bathroom, toilet	1bedroom, 1 hall, kitchen, bathroom, toilet	1bedroom, 1 hall, kitchen,(study room, children room/dining area optional) bathroom, toilet	2 bedroom,1 hall kitchen, bathroom, toilet, (study room, children room/dining area optional)
Maximum selling price per unit (that includes all costs of construction but will not include maintenance deposit, registration and insurance)	Up to Rupees 3,00,000/-	Up to Rs. 7,50,000/-	Up to Rupees 11, 00,000/- (if specifications are better or jantri rate is more than Rs. 12000/- sq. mtr.	Up to Rupees 22,50,000/-
Annual Family Income	Less than Rs. 1,00,000/-	Rs. 1,00,000/- to 2,50,000/-	Rs. 1,00,000/- to 2,50,000/-	Rs. 2,50,000/- to 5,00,000/-

Figure 4 Income based criteria for affordable housing, Source:MMGY

Similarly, the state of Gujarat has been actively pursuing the Housing for All mission. This position paper, therefore, presents a perspective on the potential of the resource and energy efficiency at the city as well as the state level. It discusses these potentials being also guided by the objectives of the SDGs and that of low carbon development according to COP21.

The resulting Position Paper covers the following aspects:

1. The trends of urbanization and the demand for affordable housing at the State level and development in the cities.

2. The need and importance of low carbon and resource efficiency in housing
3. Analysis of the present situation of affordable housing in the state and with particular reference to the CapaCITIES partner city as a representative case
4. Evaluation of its potential in addressing the issue of low carbon and resource efficient construction
5. Recommendations – technical and policy

2. Scope of Work

SDC has its ongoing CapaCITIES project. As part of the project, SDC will support complimentary research studies and policy papers, which are related to the core project, but are not directly addressed by the Implementing Agency. Housing for All, especially affordable housing will be implemented by the Municipal Corporations of the cities. In view of the growing attention and focus, it is imperative to understand the policy context and opportunity for developing low carbon and resource efficient affordable housing. This assignment is to undertake a short study to develop a policy position paper.

The implementation of the Housing for All programme has been slow so far[5]. Gujarat is one of the states which has seen an early start to the programme. The position paper would be based in the context of urbanization in Gujarat, particularly that of Rajkot, which is also one of the partner cities of the CapaCITIES project. The position paper covers the following aspects:

1. The trends of urbanization and the demand for affordable housing at the State level and development in the cities.
2. The need and importance of low carbon and resource efficiency in housing
3. Analysis of the present situation of affordable housing in the state and with particular reference to the CapaCITIES partner city as a representative case
4. Evaluation of its potential in addressing the issue of low carbon and resource efficient construction
5. Recommendations – technical and policy

[5] http://indianexpress.com/article/business/economy/one-year-of-housing-for-all-pradhan-mantri-awas-yojana-a-dream-by-2022-2874246/

3. Objective

The objective of the paper is to raise various relevant issues relating to low-carbon, resource efficient affordable housing and generate further discussion on them by presenting our point of views, observations, comments, directions and considerations giving a wider policy outlook.

4. Methodology

4.1 The affordable housing context in Gujarat state

1. Collecting information on various trends of Urbanization and demand of Affordable Housing at the state level and in the city of Rajkot, in order to assess the scale and geographic distribution of demand in Gujarat state over the next decade or so.
2. Visits to ongoing and recently completed affordable housings in Ahmedabad and Rajkot, in order to study the range of housing types being currently provided.

4.2 Technical Data

1. Gathering data of various schemes and programmes on affordable housing in the state of Gujarat-under the Central Govt. schemes as well as State Govt. schemes and trends of housing provision by non-state agencies.
2. Collecting technical construction data of various Housing projects in Rajkot and Ahmedabad to evaluate and project material resource consumption in Housing at the state level for the next decade or so. This would enable an assessment of Embodied and Operational energy conservation opportunities at the gross state level for the next decade.
3. Study of RUDA GDCR 2031 and building bye laws in other cities of Gujarat, to establish the implications and potential of these on energy efficiency.

4.3 Framework for evaluation

The project will be evaluating the potential of Low Carbon resource-efficient housing at following 3 levels:

- Building Level
- Neighbourhood Level
- City Planning Level

4.4 Overview for Policy

The studies and findings of the specific cases as described above provide a basis for arriving at energy consumption and potential energy savings in affordable housing per capita and per unit of built area. This will enable a projection of CO_2 emissions of the affordable housing sector in the coming decade for the state of Gujarat. The objective of this position paper is to arrive at the gross carbon emissions reduction potential, if appropriate policy measures are taken.

Suggestions for amendments in GDCR would be made for policy consideration at the State level.

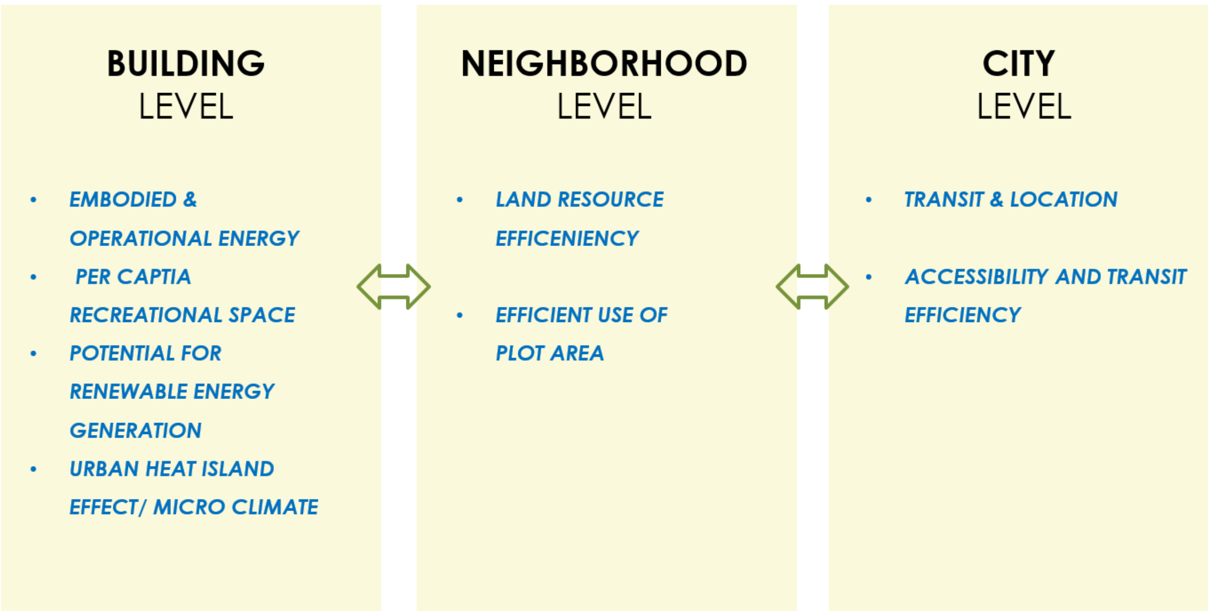
5. Existing Policies and Programmes

Following is a list of various Schemes that currently run under Rajkot Municipal Corporation Housing Department :

1. **BSUP** – Basic Services to the Urban Poor
2. **RAY** - Rajiv Awas Yojana
3. **MMGY** - Mukhya Mantri Gruh Yojana
4. **AHP** - Affordable Housing in Partnership (PMAY)
5. **PMAY** - Pradhan Mantri Awas Yojana (PPP)
6. **PMAY** - Pradhan Mantri Awas Yojana (AHP-Untenable Category)

6. Potential of low carbon resource-efficient Affordable housing

This study has evaluated the potential of Low Carbon resource-efficient housing on various parameters over 3 scales: Building level, Neighbourhood level and City level. The parameters studied and the inter-relationship is shown in the following figure:



Nine affordable housing projects in Rajkot have been analysed for these parameters. The results of the analyses are described in the following sections:

6.1 Building level parameters

6.1.1 Embodied and Operational Energy

Embodied energy and operational energy are two components of overall life-cycle energy of a building. Life cycle energy of a building is sum of energies spent during its life cycle in stages, namely, pre-and post-construction activities (such as raw material extraction, transport, manufacture, assembly, installation, renovation, refurbishment etc.), during building occupancy (energy consumed by heating and cooling systems, lighting, equipment and appliances etc.) as well as during demolition and disposal.

a) Embodied Energy

One of the more comprehensive definitions of embodied energy is that it “comprises of the energy consumed during the extraction and processing of raw materials, transportation of the original raw materials, manufacturing of building materials and components and energy use for various processes during the construction and demolition of the building" (Cited in Dixit, Fernandez-Solis, Lavy, Culp, 2014).

Embodied energy in a building has two primary components, direct energy and indirect energy (Cited in Dixit, Fernandez-Solis, Lavy, Culp, 2014).

- *Direct energy*: Total energy consumed in onsite and offsite operations, such as construction, prefabrication, assembly, transportation & administration etc.

- *Indirect energy*: Energy consumed in manufacturing the building materials, in renovation, refurbishment and demolition processes of the buildings etc. Thus, it can be further subdivided into the following:
    - Initial embodied energy: Energy consumed during the production of materials and components, which includes raw material procurement, building material manufacturing and finished product delivery (transportation) to the construction site.
    - Recurrent embodied energy: Energy used in various maintenance and refurbishment processes during the useful life of a building.
    - Demolition energy: Energy expended in the processes of a building's deconstruction and disposal of building materials.

In the present study, only the initial embodied energy part of indirect energy is considered for the embodied energy analysis.

The 8 projects[6] studied were compared based on Embodied Energy per sq.m. of built up area (MJ / m²). The results of the analysis of embodied energy for the 8 projects is shown in (Figure 5). The ***key findings*** of the analysis are:

- **Steel and cement are the highest contributors to building embodied energy (70 %– 90%)**
- **Walling materials shares around 10% – 25% of embodied energy.**
- **Use of AAC instead of burnt brick can reduce embodied energy around 10 - 20% for the same building.**
- **If the walling material remains the same, there is an increase in embodied energy around 40% with an increase in height from mid-rise to high-rise (as shown in Error! Reference source not found.: from S+7 to S+11).**
- **Monolithic concrete construction results in 10% increase in embodied energy compared to burnt brick wall construction**

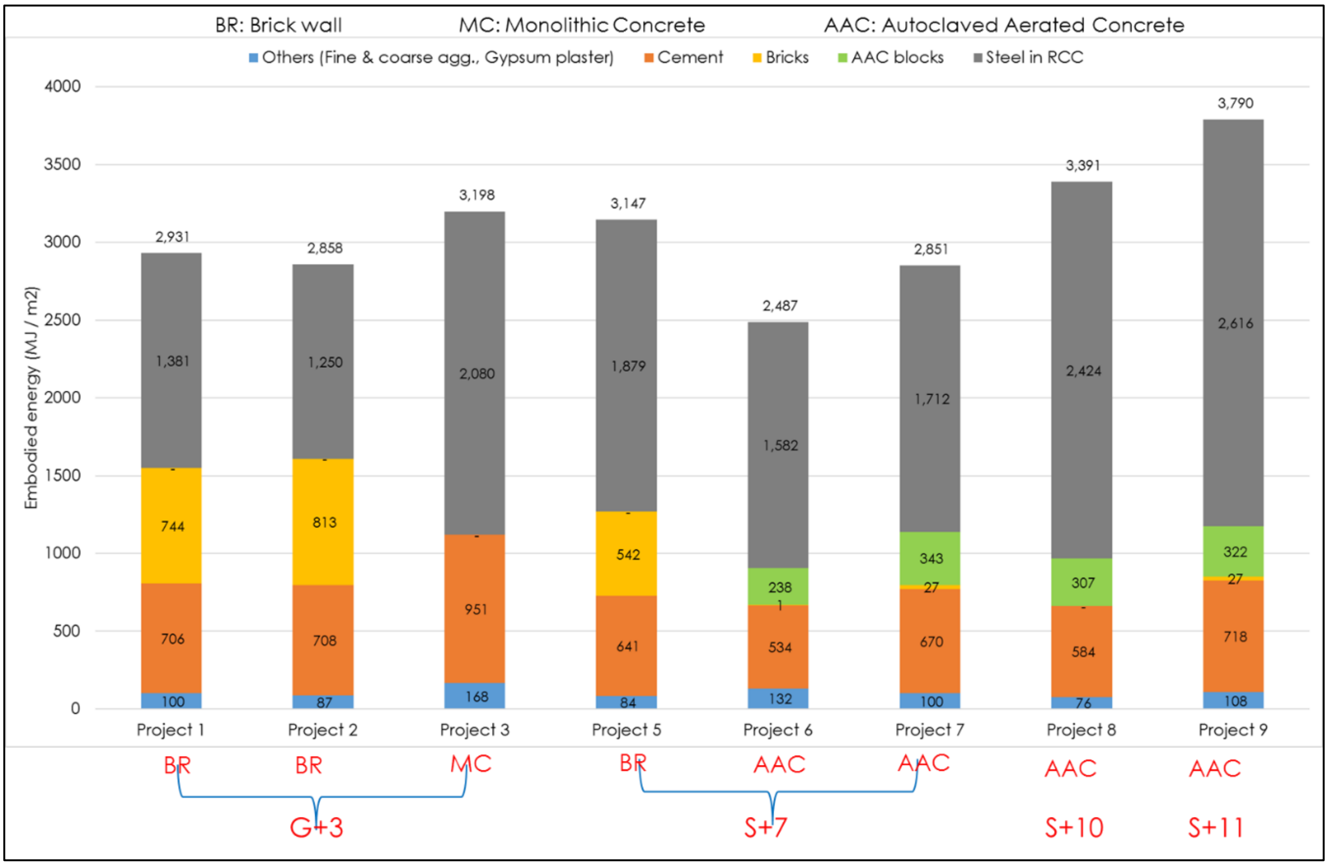


Figure 5 Comparison of Embodied Energy of 8 affordable housing projects

[6] While 9 affordable housing projects in Rajkot were studied, one of the projects, viz, Bishop House, was excluded from the analyses on embodied and operational energy. This was done as there were special concerns in its construction leading to wide deviation in embodied energy results.

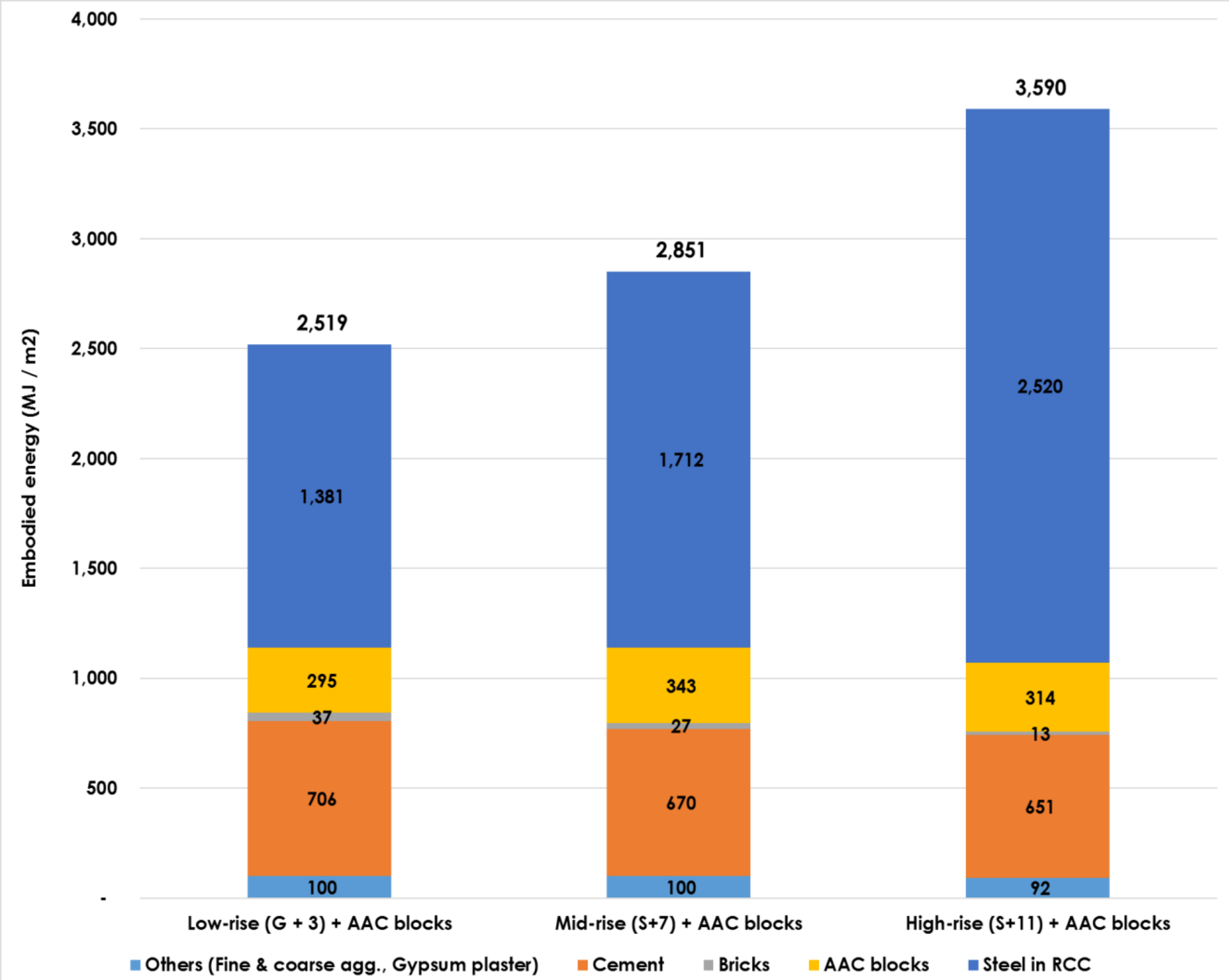


Figure 6 Average Embodied energy in the 3 typologies

A higher embodied energy also translates into higher carbon emissions (as most of the energy used for production of building materials comes from fossil fuels). An analysis was carried out to find the CO_2 emissions from a building due to the major construction materials used. In this analysis, only manufacturing emissions is considered. The analysis was carried out in the following way:

- 3 building projects, one each of low-rise (G+3), mid-rise (S+7), high-rise (>S+8), were selected from among the 9 case study projects. Kittipara, Smart GHAR III and Smart GHAR I were the projects chosen for the different height categories respectively.
- As AAC is the lowest embodied energy walling material, this was considered as the walling material. While Smart GHAR III and I used AAC as the walling material, none of the low-rise buildings studied used AAC. Hence, the actual

brick construction for Kittipara was replaced with AAC for the purpose of this analysis[7].

- CO_2 emissions for the 3 projects was calculated based on the consumption of the major building materials i.e., cement, steel, brick and AAC blocks.

Figure 7**shows that given the same walling material, the taller the buildings are, greater will be the CO_2 emissions, due to higher steel and cement content. As we go from low-rise to mid-rise and high-rise buildings, CO_2 emissions will increase around 15% and 35% respectively.**

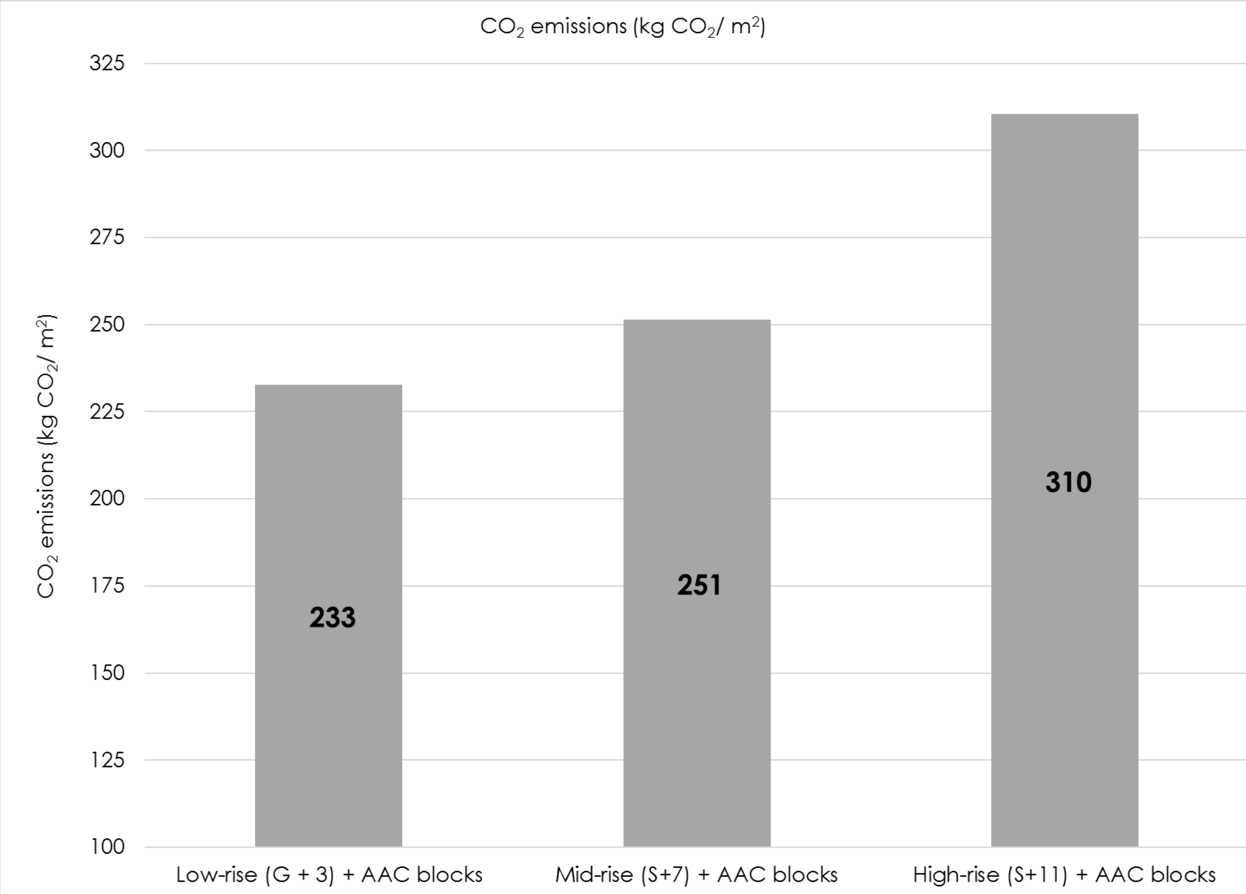


Figure 7 CO_2 emissions per m^2 built-up area from low-rise, mid-rise and high rise buildings

The CO_2 emissions will be higher if we use brick and monolithic concrete as walling material instead of AAC blocks[8].

[7] A direct replacement of brick with AAC was done for this analysis. Ideally, replacing brick with AAC would also result in structural revision and reduce steel and cement content. This has not been considered in this analysis.
[8] Due to limited range of building examples with brick and monolithic concrete as walling material, this analysis was not carried out for these materials.

The following table shows the CO_2 emissions from the planned affordable housing units planned at city level (Rajkot) and state level (Gujarat) for different height categories, if AAC is the walling material.

	No. of affordable housing DUs planned	Total built-up area in sqm [9]	CO_2 emissions (in million tonnes)		
			Low-rise buildings	Mid-rise buildings	High-rise buildings
Rajkot	76,241[10]	30,50,000	0.71	0.82	0.95
Gujarat	9,78,000[11]	3,91,20,000	9.10	10.52	12.00

Building these units as low-rise instead of high-rise would result in 1.35 times less CO_2 emissions. This can be in turn, further reduced with the use of low-carbon building materials.

b) Operational Energy

Operational energy can be defined as the amount of energy consumed to satisfy the demand for-

- Thermal comfort, i.e. heating, cooling and ventilation,
- Visual comfort, i.e., lighting, and
- Running other equipment and appliances for common and individual amenities.

However, in this study the analysis on operational energy is limited to:

- Energy consumed for thermal comfort at the flat-level:
  At the flat level, cooling and ventilation is the major consumer of electricity. Monitored data in multi-storey residential flats in the hot-dry climate of India show that air-conditioning and fans, i.e. equipment for thermal comfort, consumes between 33% - 65% of the annual electricity consumption of any flat. The balance is used for lighting and other individual (flat-level) equipment like refrigerators,

[9] (taking 40 m^2 / DU)
[10] Affordable housing units planned by Rajkot Municipal Corporation between 2016 – 2022.
[11] Source: http://timesofindia.indiatimes.com/city/ahmedabad/guj-needs-9-78l-affordable-houses/articleshow/57456646.cms

washing machine, electric geysers, kitchen appliances, television, computers etc. (Source: BEEP, 2014).

- Energy consumed in common building-level services (water-pumping and lifts): Electricity consumption of these common equipment is quite significant. This has been considered in this study as these are affected by building height.

b.1) Energy consumed for thermal comfort at the flat-level:

In India, operational energy in residential buildings for thermal comfort is mostly associated with running of cooling equipment, viz., fans, evaporative coolers and air conditioners. In this study, energy used to cool the building is interpreted through the number of uncomfortable hours in a flat in the absence of such cooling equipment. The assumptions made were:

- Lesser the number of uncomfortable hours, lesser will be the energy used to cool the flat.
- Uncomfortable hours are the hours where inside air temperature is above 30°C.

Inside air temperature in residential buildings is affected by the building envelope. Hence, uncomfortable hours are evaluated for different envelope options for 8 projects. If the number of uncomfortable hours were more, then the operation energy of that building would also be more.

The comparison of uncomfortable hours for different projects are presented in the Figure 8.

The analysis shows that:

- **Monolithic concrete construction results in highest number of uncomfortable hours in a year.**
- **Combination of AAC blocks + casement window + overhang (chhajja) results in an additional 1500 comfortable hours in comparison to the base case. Peak internal temperature can be brought down by 3°C - 4°C. In hot climates like that of Rajkot this would mean that the peak summer temperature inside the flats can be reduced to 36°C - 37°C when outside temperature is around 42°C.**

It must be mentioned here that if the windows were provided with external movable shading, the most rudimentary example of which are bamboo "chiks", the peak inside temperature could be brought down further to around 32°C - 33°C and the number of

uncomfortable hours reduced even further. At this temperature, thermal comfort can be achieved by running ceiling fans instead of resorting to evaporative coolers or ACs.

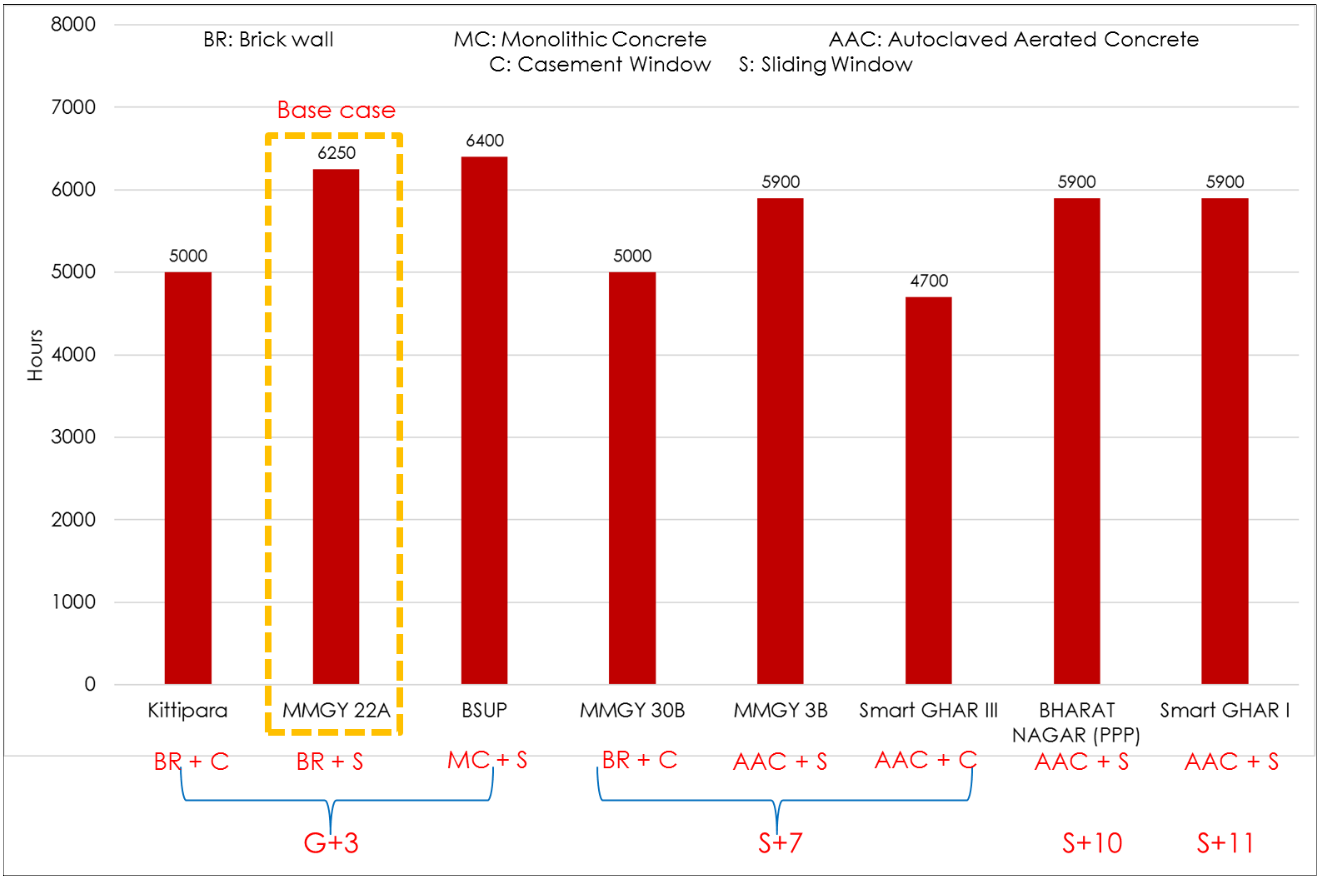


Figure 8: Comparison of Uncomfortable hours/year – Project wise

b.2) Energy consumed in common building-level services (water-pumping and lifts):

The following assumptions used in energy calculations for water pumping and lifts:

- Water pumping energy calculated per DU assuming
  - Water requirement = 1000 Litre/DU/ day
  - Total head = Static head + Frictional losses (20% of static head)
  - Pumping efficiency of 30%
- Lift energy calculated per DU assuming
  - Gear-less PMD and VVVF non-regen type
  - Load (8 persons) 544 kg; Motor rating 5.6 kW; Speed 1m/s; Stand-by power 24 W; 70% efficiency
  - No. of trips per DU = 10

The project comparison of energy used for water-pumping and lifts is shown in

Figure 9 Comparison of Common services energy per DU per year

. As can be seen from the graph, energy for water-pumping and operation of lifts is proportional to the number of floors of the building or building height. Low-rise buildings use less energy for water-pumping and do not have the requirement of lifts for vertical transport. Figure 10 shows the average energy consumed for these common services for low-rise (G+3, S+4), mid-rise (S+7) and high-rise (S+10, S+11) buildings. It should be noted that operation of lifts has become more efficient over the years, in comparison to the efficiency of water pumps.

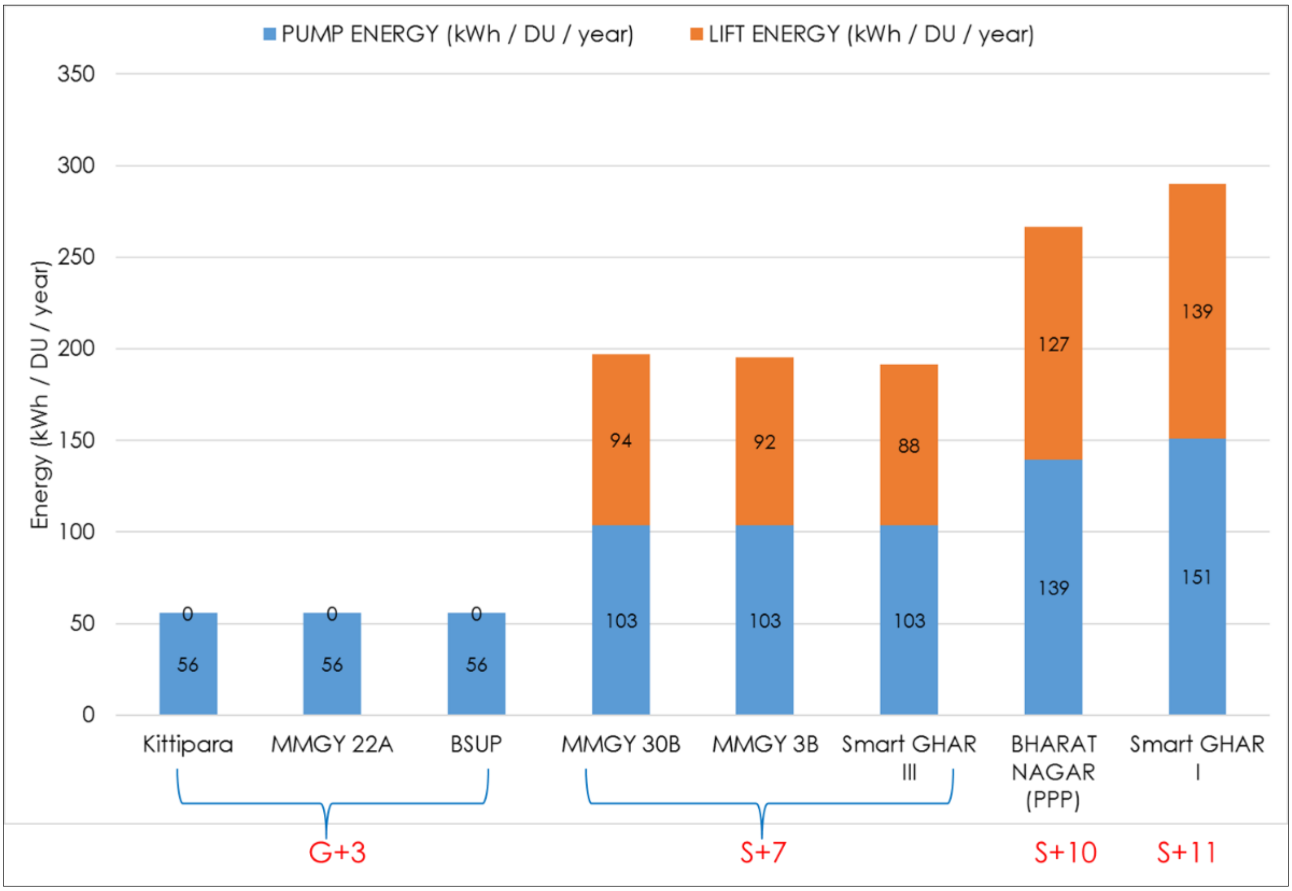


Figure 9 Comparison of Common services energy per DU per year

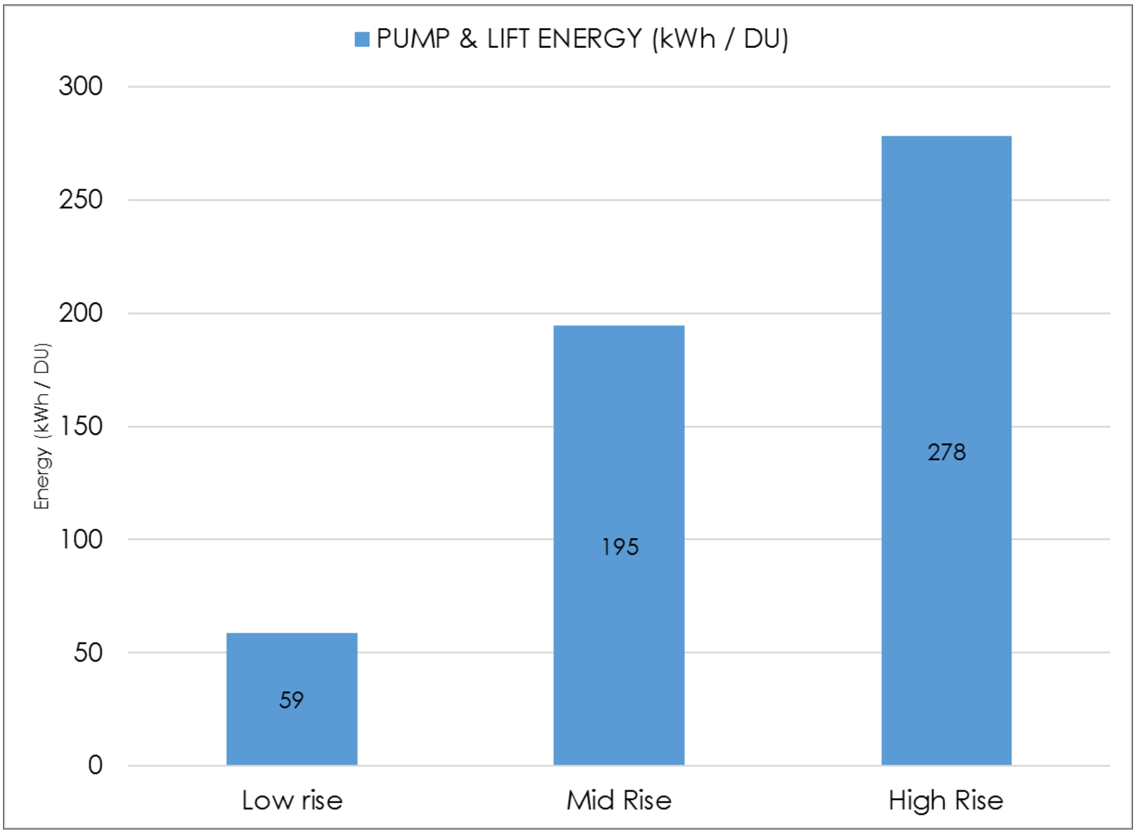


Figure 10: Comparison of pump and lift energy as per building height

It is clear from the above figures that there is an increase in common service energy consumption (pump + lift) by 4 to 5 times as we go from low-rise to high rise. Hence, low rise affordable housing projects are energy efficient than medium and high rise projects as far as common service's energy consumption is concerned.

c) Maintenance cost of common services

Maintenance, and the cost incurred because of it, is an important consideration in affordable housing projects. The maintenance cost in medium and high rises is more than low rises due to greater dependency on mechanical systems for operation, transport and safety.

The table below gives likely operational and maintenance cost per dwelling unit (DU) in a year in medium rise buildings, incurred due to common services like water pumping, lifts, firefighting etc.

Table 1: Maintenance cost per DU in a year in mid and high rise buildings

Parameter	Annual Cost/DU (INR)
Electricity consumption for lifts & pumps, taking 250 kWh / DU / year from analysis shown earlier in this section (@ Rs. 5 per kWh,)	~ 1250
Lift: replacement fund Assumptions: ➢ Capital cost of a lift @ Rs. 20 lakh ➢ A lift is assumed to be replaced in 20 years ➢ 1 lift is assumed to serve maximum 30 flats (Based on actual lift cost in RMC Smart GHAR I BOQ)	~ 3500
Lift: maintenance cost Assumptions: ➢ Annual maintenance cost is 3% of the capital cost (Based on actual lift cost in RMC Smart GHAR I BOQ)	~ 2000
Fire-fighting system (FFS) replacement fund Assumptions: ➢ FFS is assumed to be replaced in 20 years (Based on fire-fighting system cost given in RMC Smart GHAR I BOQ)	~ 700
Fire-fighting maintenance cost Assumptions: ➢ Annual maintenance cost is 5% of the capital cost (Based on fire-fighting system cost given in RMC Smart GHAR I BOQ)	~ 700
DG set replacement fund Assumptions: ➢ DG set is assumed to be replaced in 6 years (Based on actual DG set cost in RMC Smart GHAR I BOQ)	~ 700
DG set maintenance fund Assumptions: ➢ Annual maintenance cost is 3% of the capital cost (Based on actual DG set cost in RMC Smart GHAR I BOQ)	~ 120
Total	~ 9000

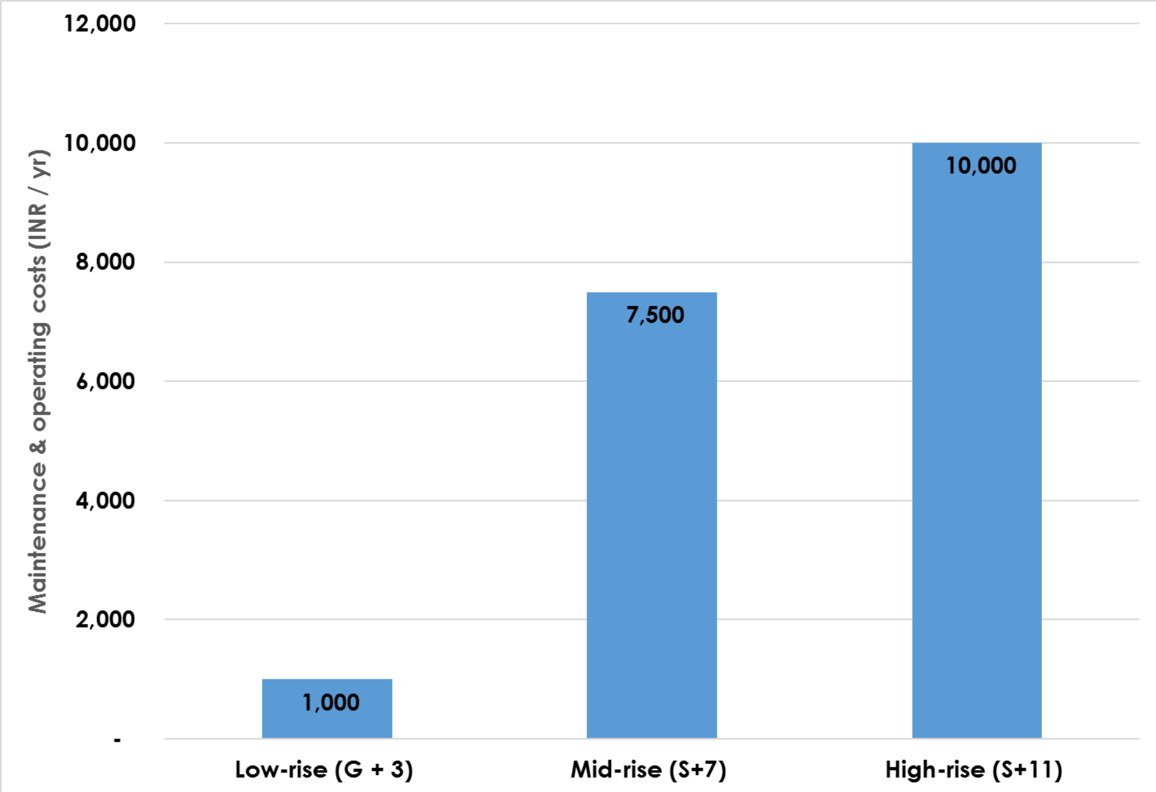


Figure 11 Average Maintenance cost in the 3 typologies

The annual maintenance cost would range from INR 7,500 to 10,000 in a year in medium and high-rise buildings. This cost would be very nominal in low-rise buildings with no requirement of lifts, firefighting and DG sets.

6.1.2 Renewable Energy (solar) potential

One of the easiest and readily available RE technology that could be used in affordable housing is rooftop Solar PV technology. Available roof area on the terrace of buildings can be used for solar PV panel installation. Solar energy generated at building level can be used within the building or can be exported to grid.

Methodology for calculating solar energy potential

For this study, potential rooftop solar energy that could be generated in all projects has been estimated using "RETScreen" Software. Thereafter, the solar fraction of each project has been calculated. Solar fraction is the indicator used to represent the solar energy share and, for the purpose of this study, can be defined as the percentage of the total energy required by the building that can be generated by the rooftop PV potential of the same building.

Energy Performance Index (EPI) of a typical dwelling unit is calculated to be around 30 – 40 kWh / m² / year. (not including the common services like water pumping and lift energy). EPI of a dwelling unit, including water pumping energy and lift energy (where applicable), is estimated to be in the range of 35 – 50 kWh/ m² / year.

The comparison of solar fraction of all projects is presented in the Figure 12.

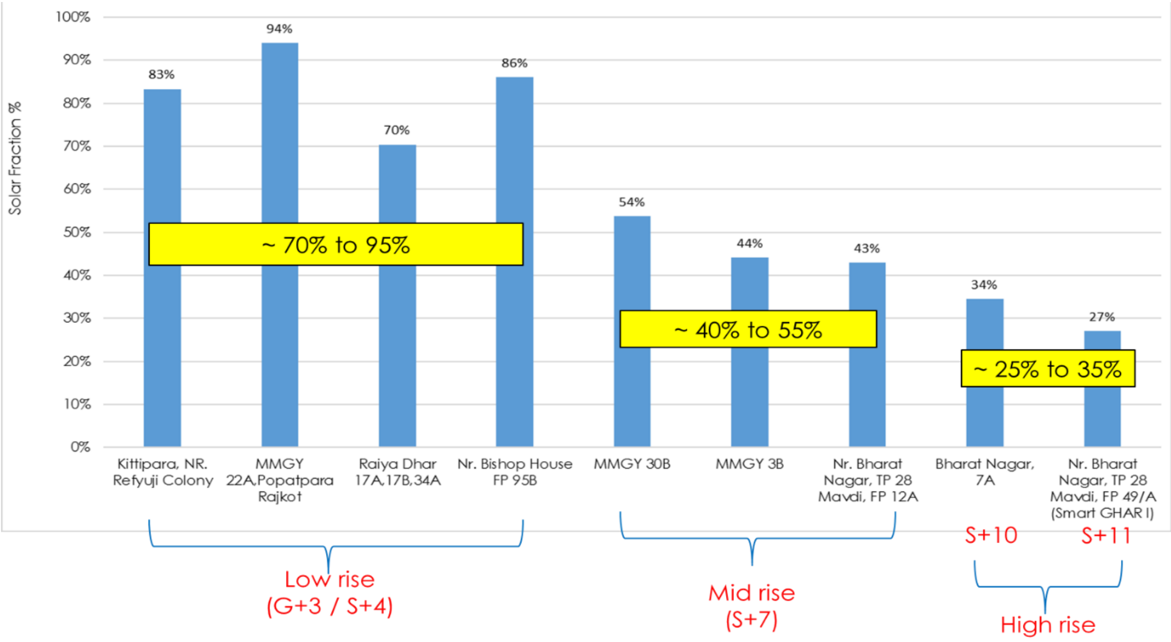


Figure 12: Solar PV potential – Project wise[12]

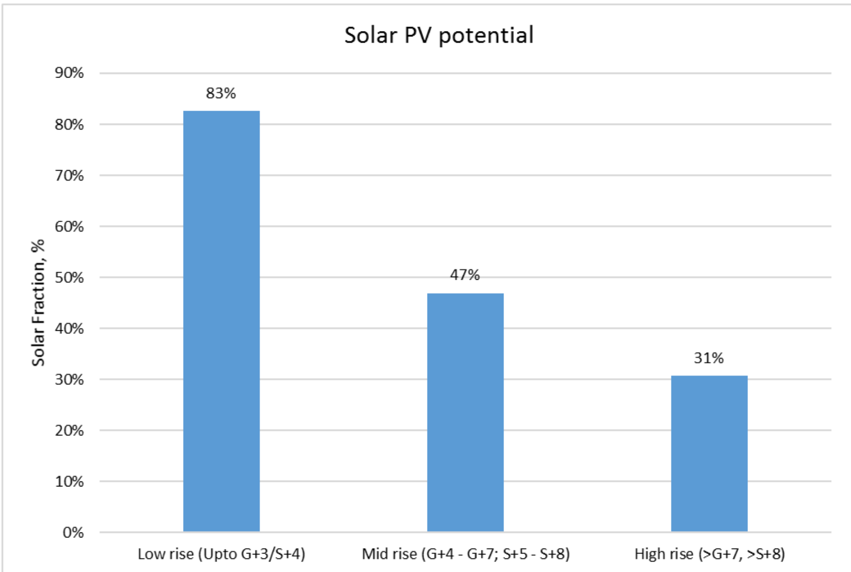


Figure 13 Average Solar PV potential for Low, Medium and High Rise Buildings

[12] The variations in solar fraction within low-rise, mid-rise and high-rise categories occur due to:

- Variations in roof-top area to built-up area ratio
- Variations in dwelling unit built-up area

6.1.3 Conclusion

The results show that:

80% of the electricity demand in a low-rise building can be met by rooftop solar energy.

- **A roof-top area to built-up area ratio of 1:3 to 1:3.5 affords the best solar energy potential. This is achieved in low-rise buildings. Mid-rise buildings have a roof-top area to built-up area ratio of 1:4 to 1:6. High-rise buildings have a ratio higher than 1:7.**
- **It is possible to meet 100% of the electricity demand from solar energy, with better design and hence lesser energy demand for cooling, in low-rise buildings. Better design here means using passive design strategies to improve thermal comfort and reduce the need for cooling energy, like external movable shading, optimum natural ventilation and optimum roof and wall insulation.**
- **As the height of the building increases, electricity consumption for common services increase, hence low solar potential was observed for high rise buildings.**

6.1.4 Recommendations:

- *Maximize* **Solar PV** *potential at roofs.*
- *Replace burnt brick with* **AAC/Hollow-core/fly ash block / Hollow burnt-clay brick** *to minimize embodied energy in construction.*

Hollow Core Blocks | AAC Blocks | Flyash Bricks | Hollow burnt-clay brick

- *Incentivize* **steel consumption below 22kg/sqm** *floor area(by rebates in property tax) to curtail embodied energy in structural systems.*
- *Minimize dependence on lifts and Booster Pumps. Choose G+4 walkup.*

➢ *Shade against direct sun.*

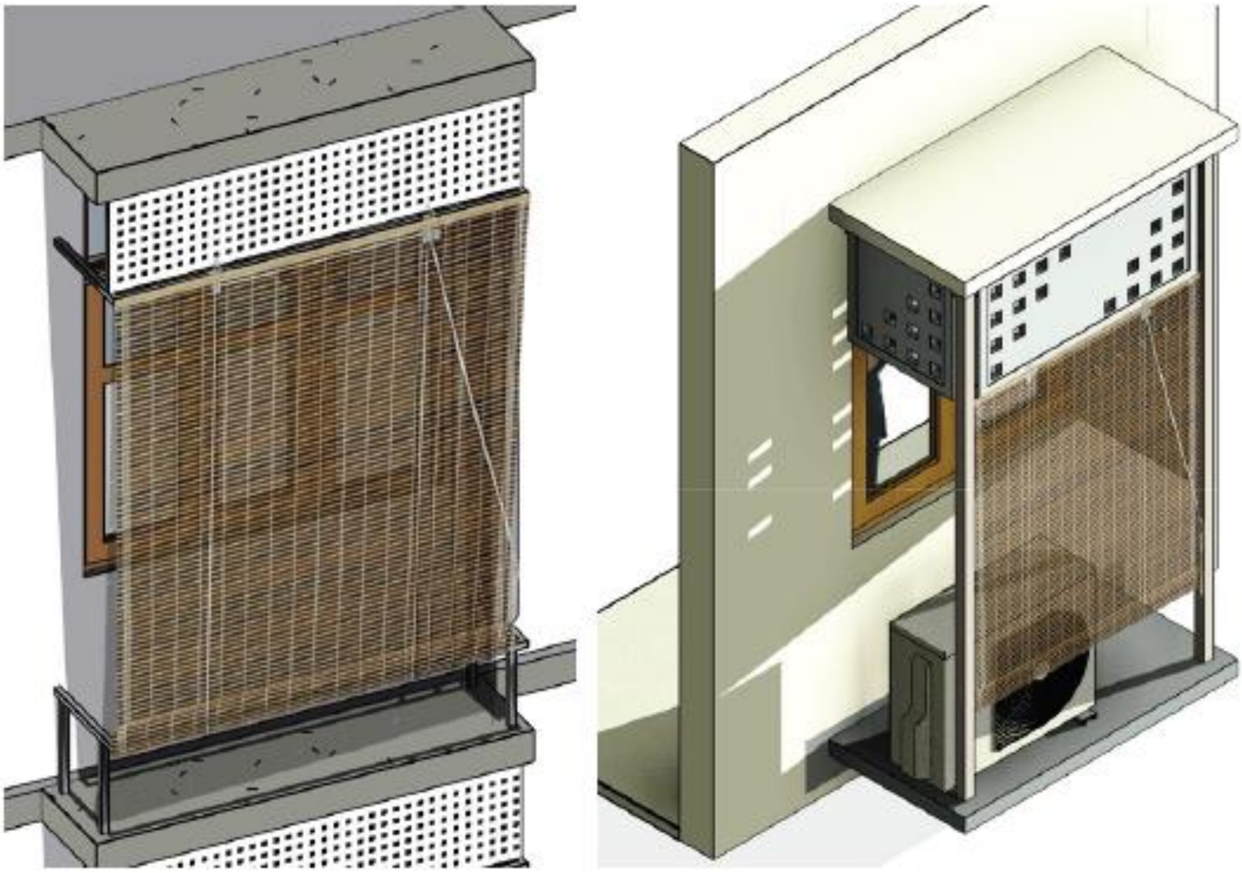


Figure 14 Avoid sun ingress from East & West, use External Shading Device

➢ *Ensure* **cross ventilation** *during nights and morning for all rooms.*

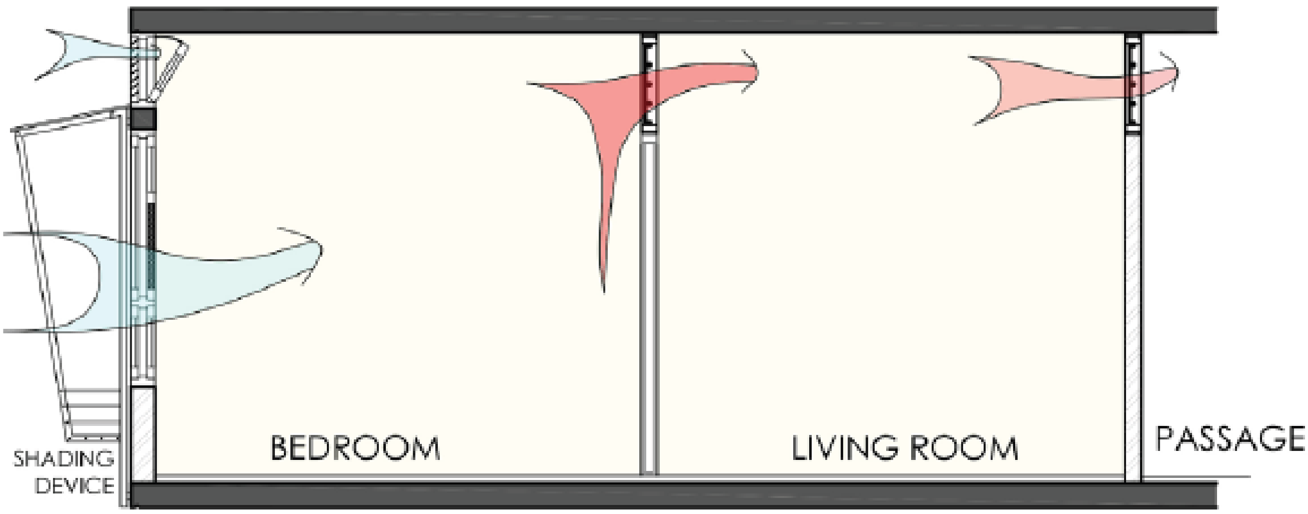


Figure 15 Cross Ventilation inside a House

➢ **Insulate roofs** *and finish rooftop with reflective material like china mosaic.*

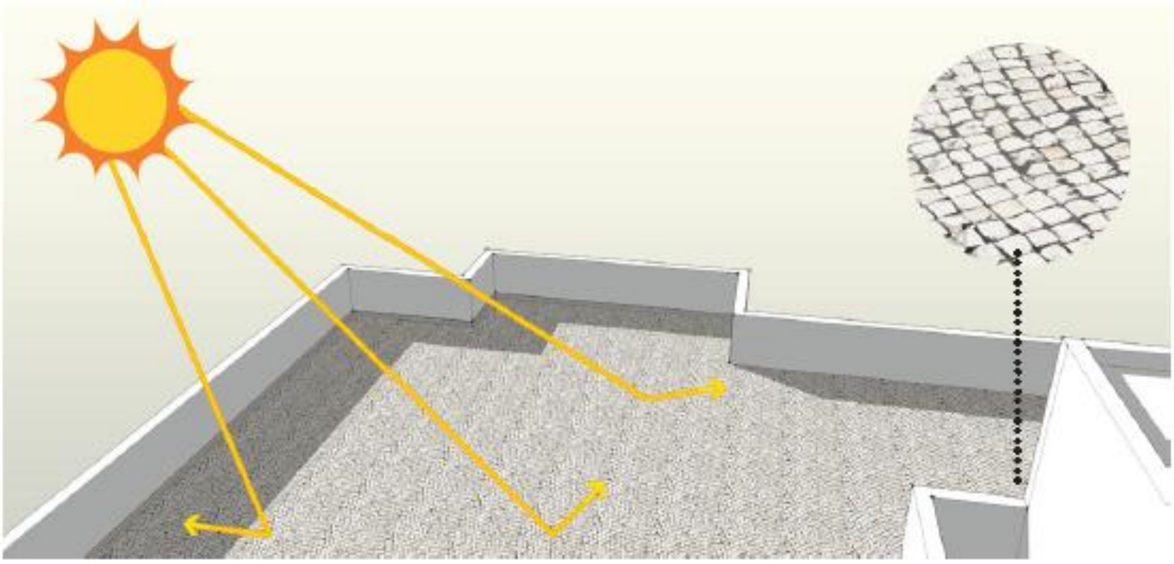


Figure 16 China Mosaic used for roof insulation

➢ ***Dependence on air conditioning can raise electricity demand tenfold! Therefore, optimize passive design for thermal comfort.***

6.1.3 Built form and density

Affordable Housings today, often fall prey to the projected High rise-High density models. However, high rise doesn't necessarily mean high density, it rather implies much less per capita open space. (Refer Annexure C)

The public and private sector response to combat the demand of housing as seen in past 20 yrs shows, a crooked/ profit-based approach to deal with the process of urbanization.

''Slum enclaves in prime localities of the city have turned out to be gold mines for private developers.''[13]

The housing design tries to squeeze in more and more people into a high rise, in as little land as possible. This is often justified with the argument of 'manufactured land scarcity[14]', or to achieve the goal of 'common good'[15].

In July 2006, the Bombay high court had observed that "the SRA scheme has become a profitable business venture attracting persons, who are forcing their decision on the slum dwellers by the posts they are holding...'[16]

The built form of the 9 Affordable Housing of various typologies are analyzed for quality of life in high-density living under the following parameters:

a) Open Space in immediate proximity of the House

The low-income households often have less money and more stomachs to feed. Thus, they are bound to engage in multiple jobs or create several sources of small income to meet their needs. Consequently, the stress component in lower income groups is far greater. Therefore, quality of life within a house is a major concern especially in the affordable housing sector.

---

[13] Maharashtra's slum rehab scheme is a gold mine for builders
Nauzer Bharucha | TNN http://timesofindia.indiatimes.com/india/Maharashtras-slum-rehab-scheme-is-a-gold-mine-for-builders/articleshow/47858054.cms

[14] Time and again restrictions on zoning regulations, land use and density create artificial scarcity of land in the city. Cities often have undeveloped or underdeveloped land parcels that could be better put to use for re-densification and urban regeneration of the city.

[15] Slum Rehabilitation schemes often work on the agenda of creating Public Infrastructure (metro, riverfront, roads etc.) and Services that will provide greater opportunities of growth for the larger good. But, in a number cases these lands just end up serving the rich and wealthy)

[16] Mumbai's slum rehabilitation scheme: Slum dwellers short changed by politician-builder nexus
http://timesofindia.indiatimes.com/city/mumbai/Mumbais-slum-rehabilitation-scheme-Slum-dwellers-short-changed-by-politician-builder-nexus/articleshow/40013463.cms

''About 15 million households suffer from the problem of 'congestion'. Of these, about 6 million need only an extension of one or two rooms, to meet their normative requirement of housing.''[17]

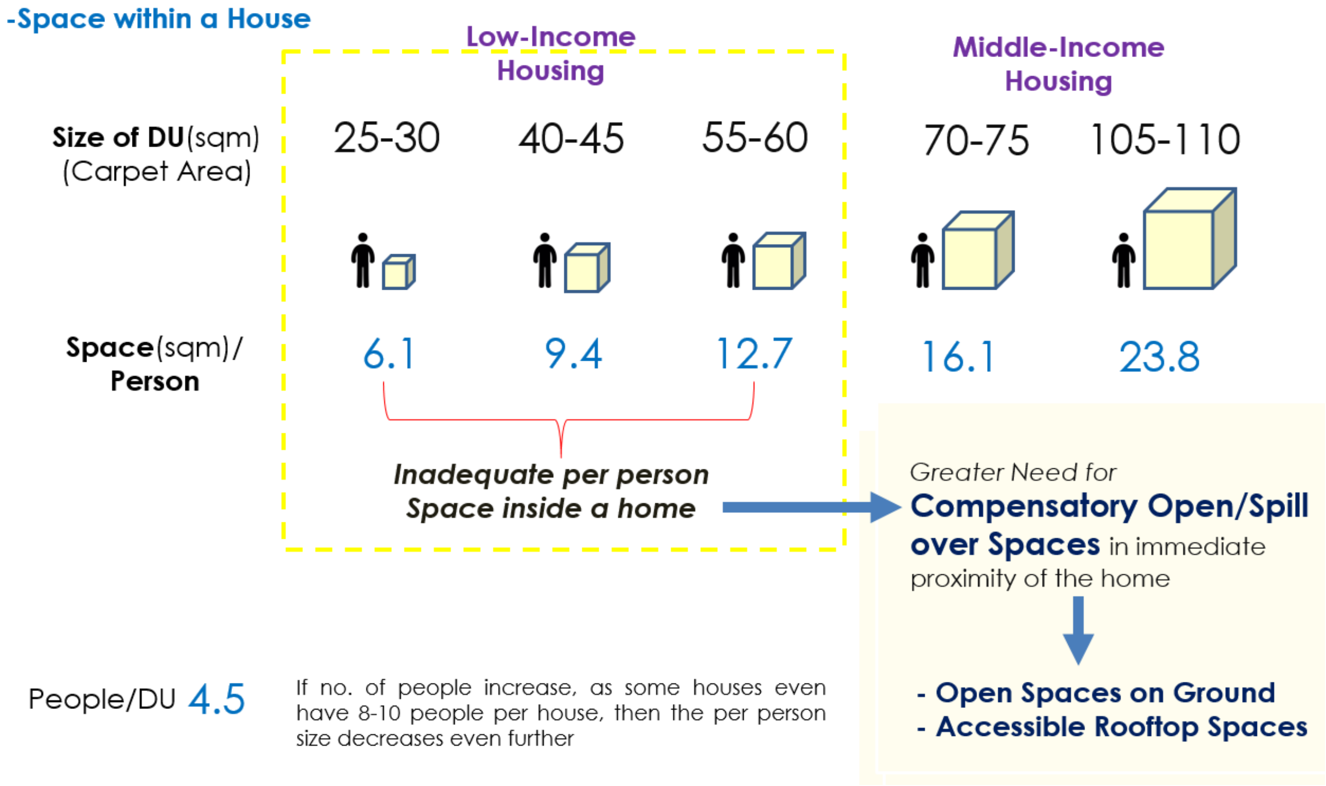


Figure 17 Per Capita Space within a Household

The 'psychological comfort'[18] of an individual within a house often get compromised by living in a small/ restricted space. On an average for a Dwelling Unit size of 25-30 sqm and a family size of 5 people, the per person space is a mere 5-6sqm. Studies show for a decent living and comfort a minimum of 12-15sqm size is required. In India the family sizes go even upto10-12 members per household. This means just a mere 2sqm per person space, which for sure implies a stressed lifestyle.

Thus, to suffice this lack of per capita space within a house, there should be a space/open area within close proximity of the house for spill over of day to day activities. These spaces will not just help release stress among the individuals but also create healthy lifestyles.

[17] Expert View of Prof. (Dr.) Amitabh Kundu on AFFORDABLE HOUSING Challenges for providing shelter to every household, SHELTER, HUDCO

[18] According to environmental psychology to people Psychological Comfort Comprises of Personal Space, Territorial, Crowding and Privacy (Wei Chih-Fen, 1995)

a.1) Open Space on ground within plot

In RUDA-GDCR, the basis of open space/ Common Plot requirement for affordable housing is a percentage of Plot area. In such a situation, as greater densities are housed on the same plot the per person open space reduces substantially. In our case studies, it was found that the Open space per person reaches to about half as we start building low (up to G+4) to high rise (S+11). Also, as we build high the usability of open spaces decreases too, thus restricting the people on upper floors within their homes.

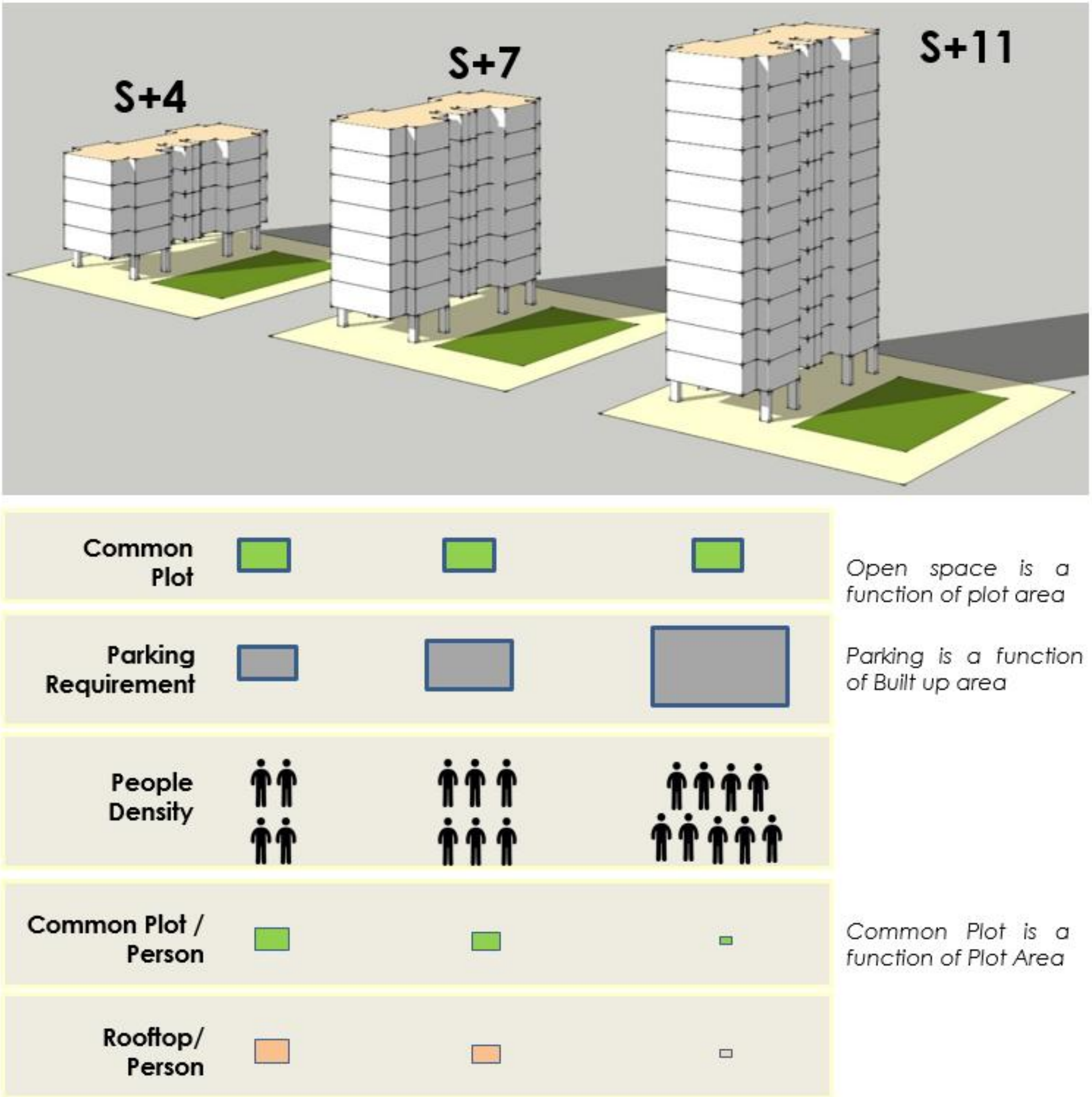


Figure 18 Implications of RUDA-GDCR on various Housing Typologies

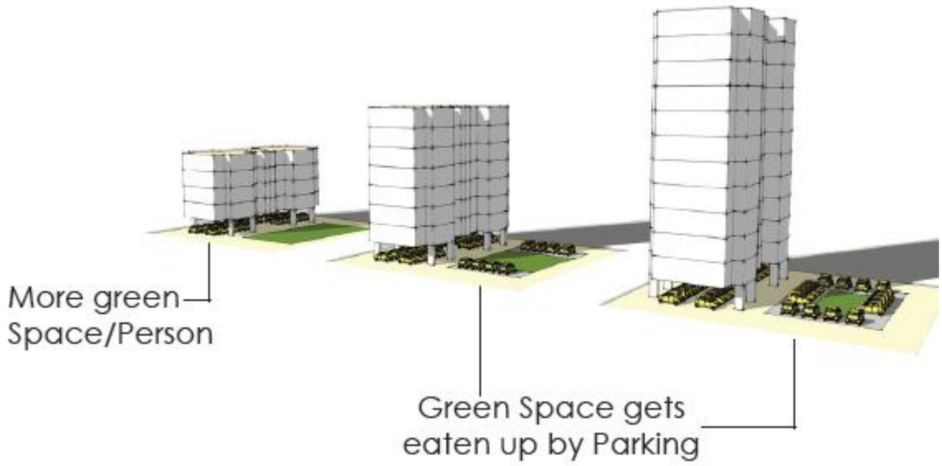
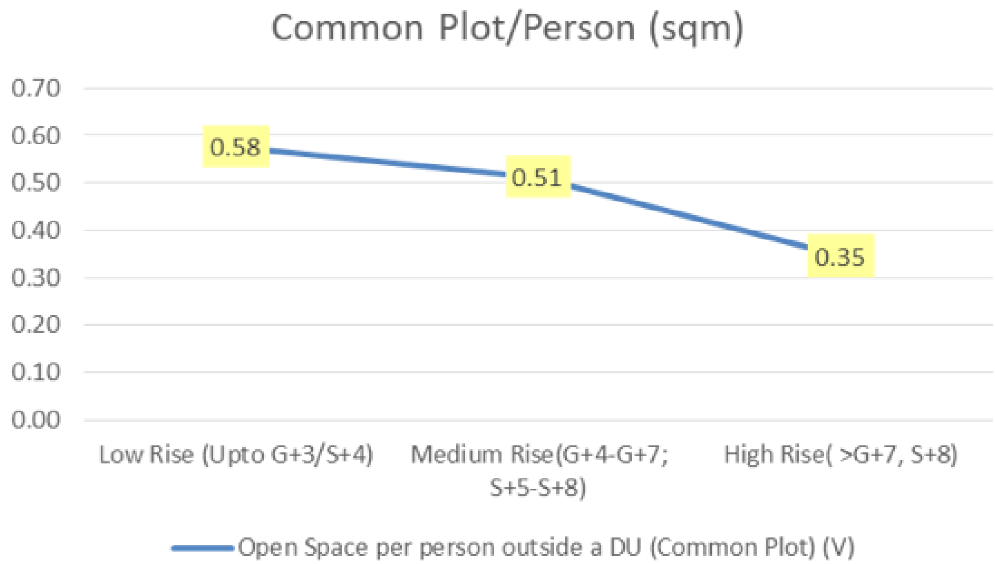


Figure 19 Parking area eats up the Common plot area as the Building height increases



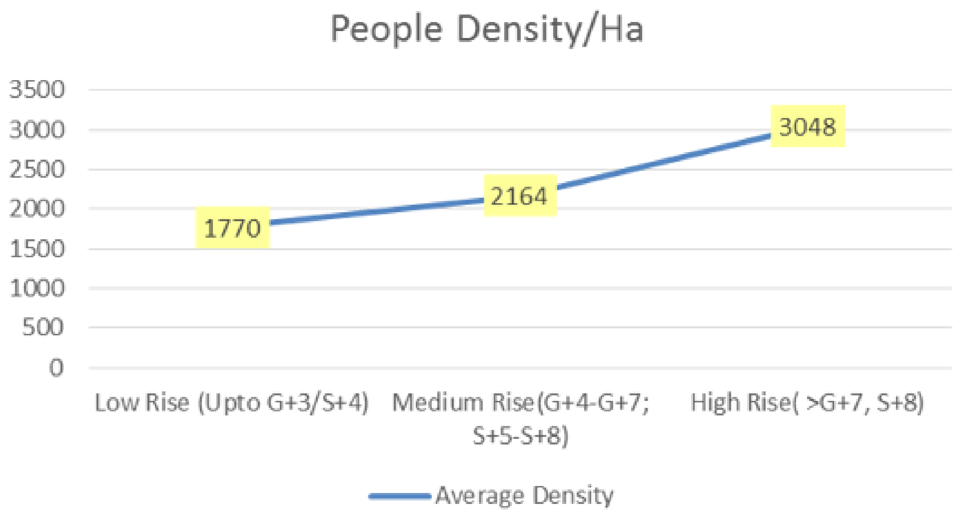
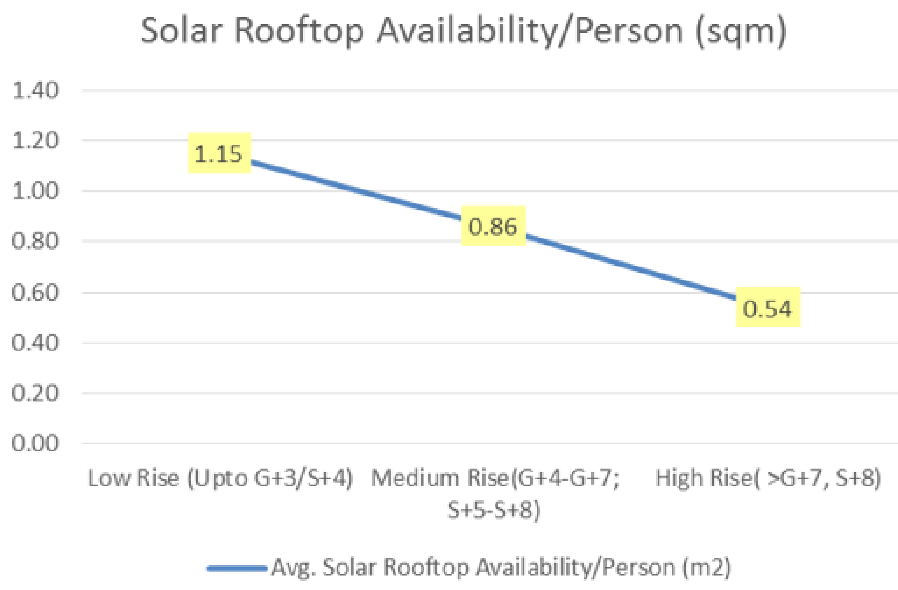


Figure 20 Common Plot and Density in the 3 typologies



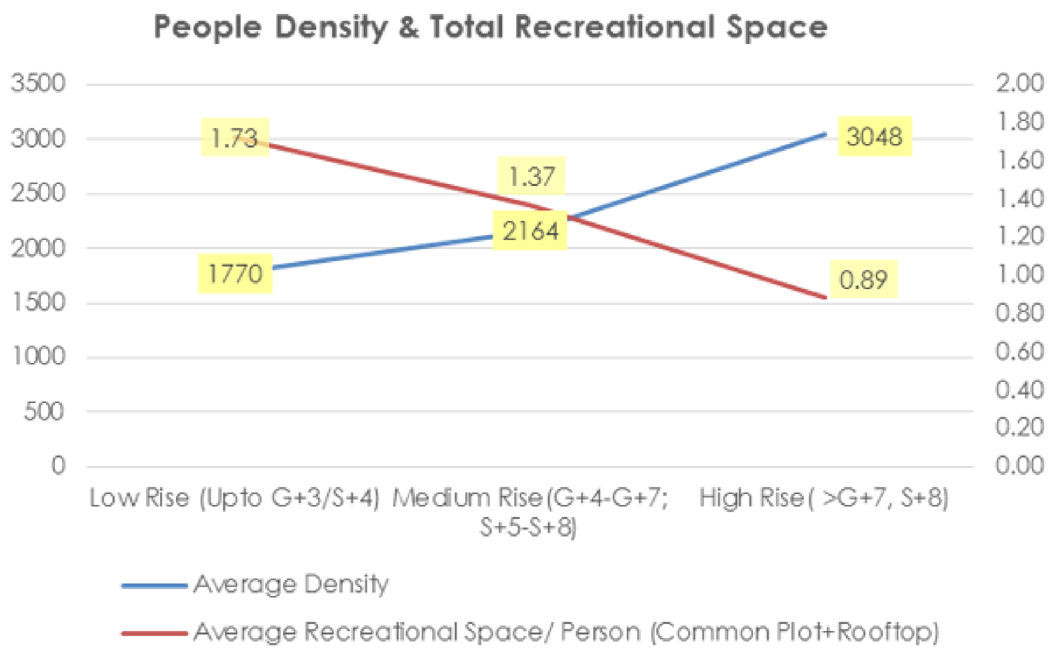


Figure 21 Density and Recreational Space

Therefore, in order to maintain optimum psychological comfort and well-being the open space in a Plot should be a function of the population density of the Plot rather than its area. This will help ensure adequate open space for people to sustain a healthy living. It would promote an optimum gross density of the Neighbourhoods too and check for overcrowding and discomfort.

a.2) Potential of Roofs as a Productive Space

As we seek a low-carbon future, roof-top solar PV potential per unit built up area or per capita becomes a strong criterion to determine a sustainable urban form, which is discussed in the previous section. Additionally the rooftop space in the buildings is also a contributor to the open space in close proximity of the housing for the following activities :

- Space for **recreational activity**

- Installing **Shading structures** to prevent heating of the roof and provide shaded spaces for activities and community gathering

- **Environmentally Productive Space** to cut down heat absorption and have common vegetation space

Figure 22 Useability of Terrace and Roof Top Space

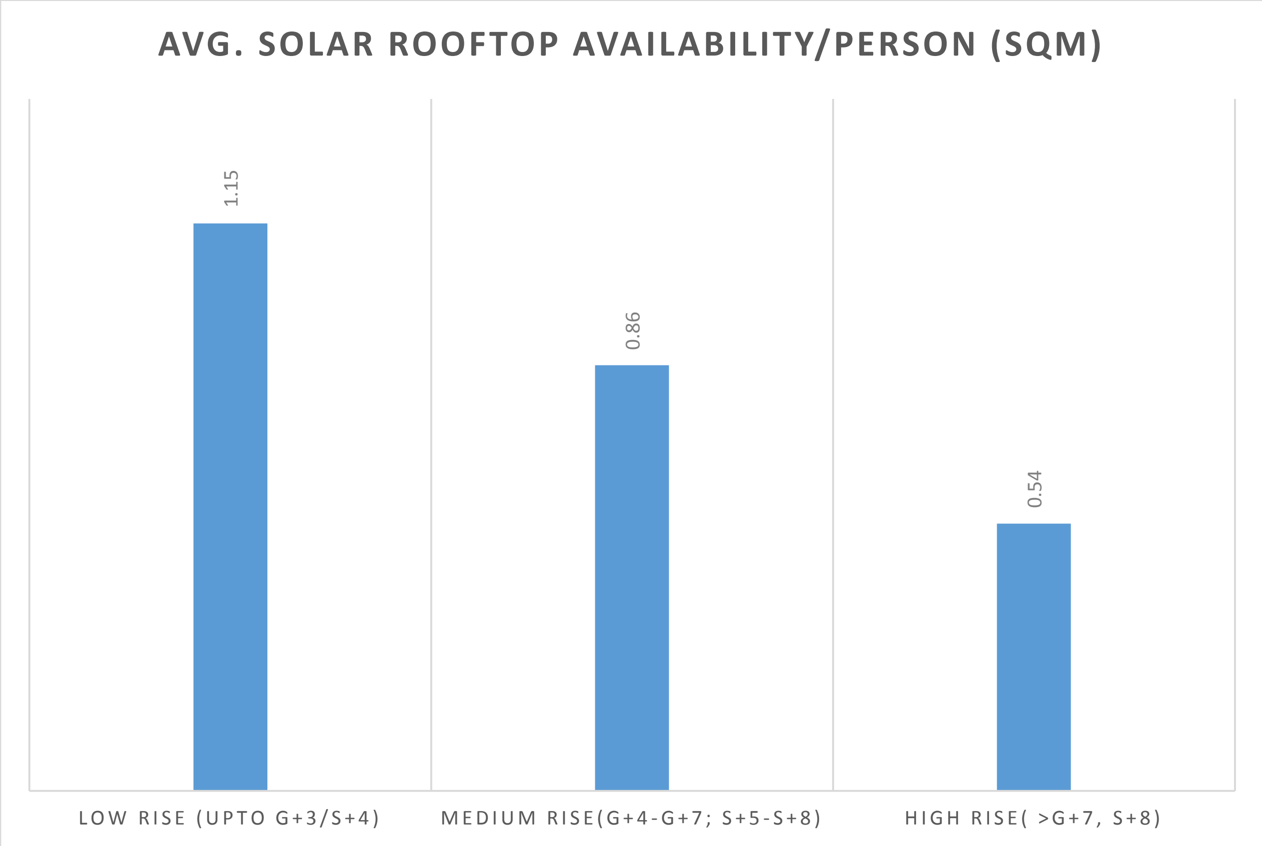


Figure 23 Per Capita Solar PV potential of the 3 typologies

Roof top space contributes to the per capita open space requirement for spill over activities like drying clothes, recreation and space for growing vegetables etc. The use-ability of terraces/ rooftops as a recreational space decreases as we build higher.

In the study, it was discovered that the potential for generating solar energy from roof decreases as we build higher due to lesser rooftop area availability and increased demand in high rises. Also, the per person electrical energy demand increases in high rises thus further reducing their Zero Carbon potential.

b) Ideal Building type from environmental perspective

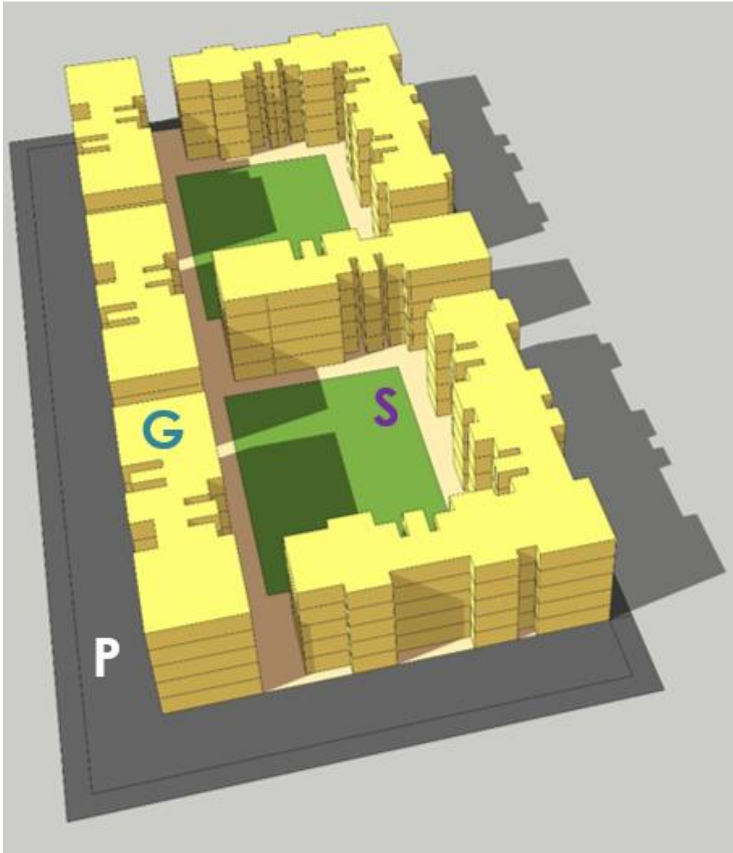


Figure 24 A Typical Housing

Building Unit Area (Plot area)	**=**	**Ground Coverage(G)**	**+**	**Parking Area(P)**	**+**	**Soft Scape (S)**	*Recreational space + Environmentally productive space*
B	**=**	**G**	**+**	**P**	**+**	**S**	

The Plot area or the Building Unit area generally gets consumed in the following :

1. **Building footprint**,
2. **Hard-scape** (parking, pathway, roads etc.), and
3. **Soft-scape** (Open area, lawns, kids play area).

The hardscape does not allow for rain-water percolation and constantly absorbs and radiates more heat. On the other hand, soft scape helps maximize the 'Environmentally productive space' [19] and provides opportunity for recreation.

[19] Environmentally Productive Space(EPS) is essentially a permeable soft ground that could have space for vegetation, planting etc. and that allows for rain water percolation to the ground thereby also recharging the ground water table. It further helps reduce Urban Heat Island Effect .

On analysis of the present RUDA- GDCR Bye laws, Stilt+4 typology optimizes density, soft ground and parking. (Refer Annexure-'E') In this model all the parking requirement as per RUDA-GDCR bye laws can be accommodated within the stilt space, thus releasing more space in the plot area for optimising Ground Coverage and increasing EPS.

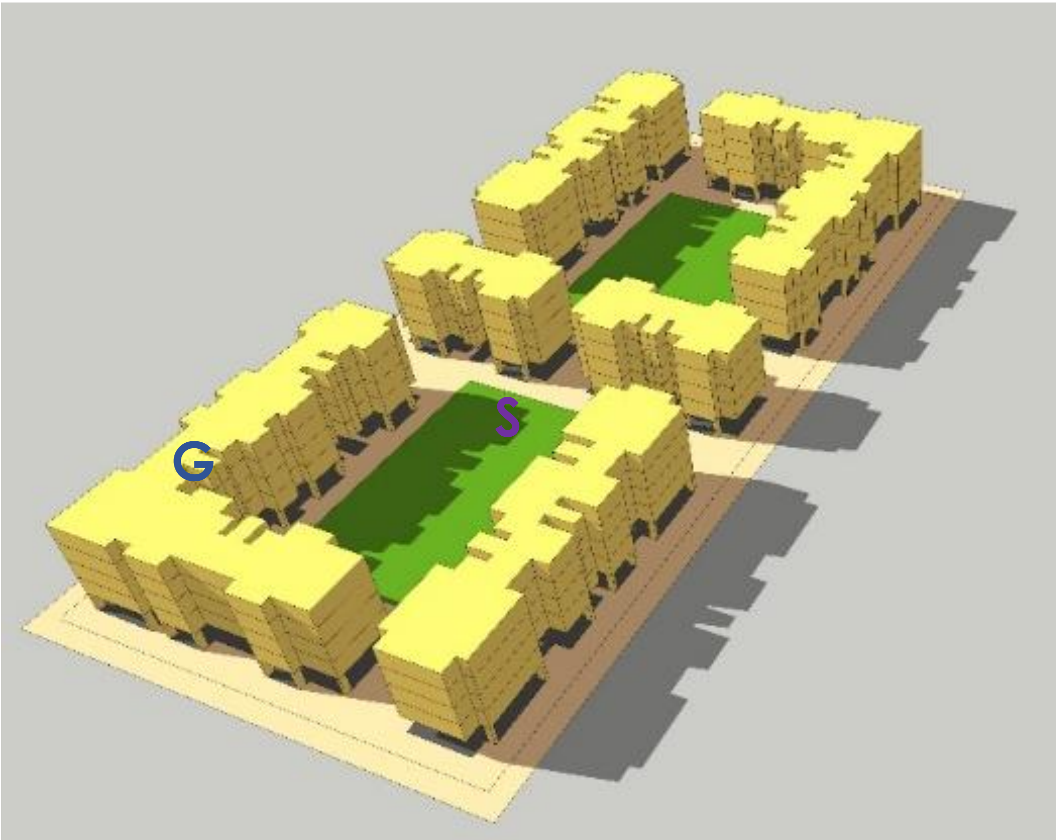


Figure 25 S+4 typology, Maximum EPS

Maximizing ground coverage automatically implies a higher built up area within the same plot. Thus, for optimisation of environmentally productive space and density S+4 typology makes the best case in the low rise format.

EPS can also be increased by utilizing the available rooftop area optimally for plantation, kitchen gardening etc. These activities could also serve the dual purpose of sunshade at roof level, further reducing heat gain in roofs.

c) Carpet Area to built-Up area ratio

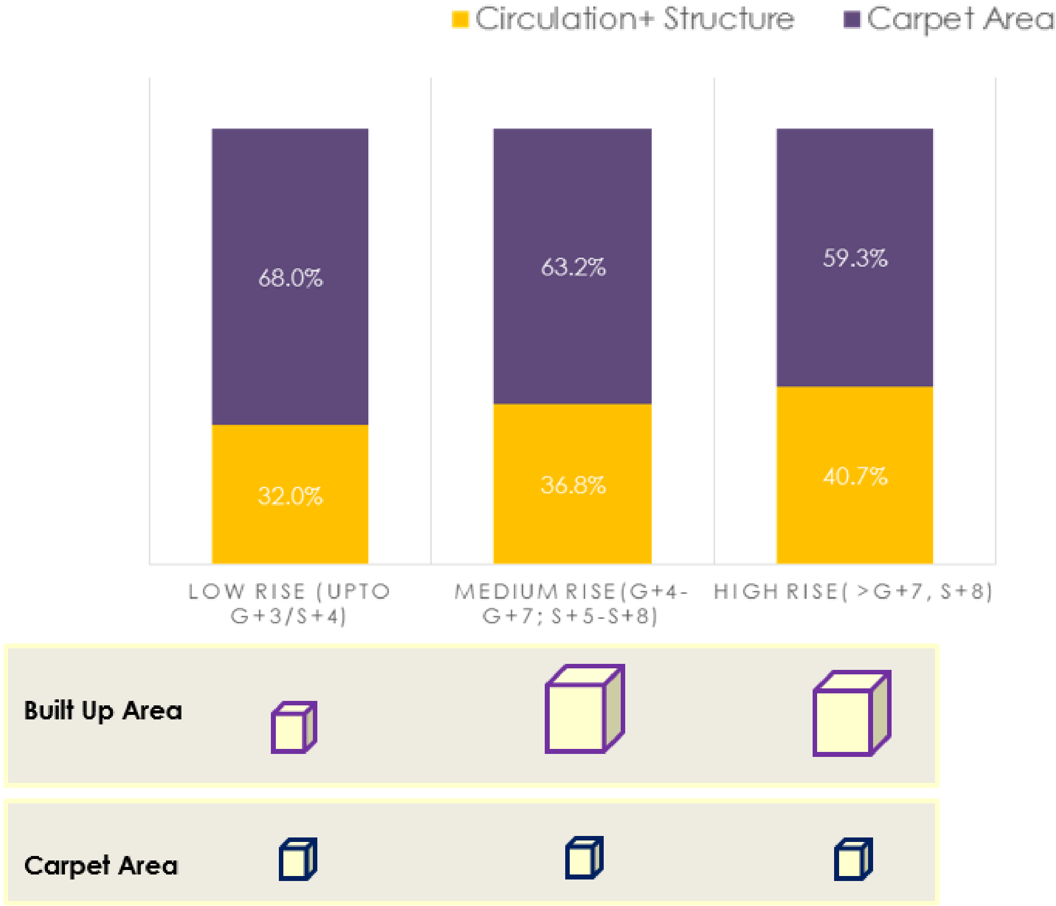


Figure 26 Ratio of Carpet area to Built-Up area

In the study, it was learned that for delivering the same amount of Carpet Area or Habitable Space, one had to build about 9% more Built Up area in high-rise as compared to Low rise. This happens majorly due to the increase in the space consumed by Structure and the increased requirement of Staircase and Corridor widths. This essentially highlights the space efficiency of low rises in delivering more habitable built up area. In addition, since one has to build less to get the same habitable space, the overall cost reduces further.

Furthermore, the low rise housing is cheaper and easier to build and thus the time-taken from the start of construction to the occupancy by the resident is much less. On the developer front, the 'sell-ability of these flats is much high as compared to High rises'. [20]

[20] In conversations with Builders and Marketing from Ahmedabad and Rajkot.

d) Efficient Use of Plot Area

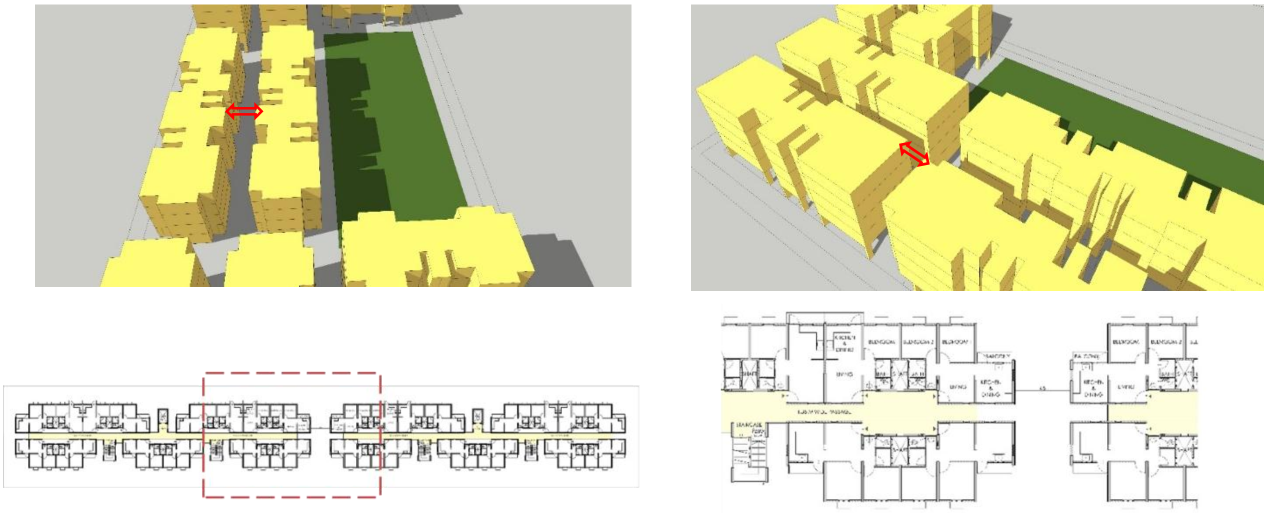


Figure 27 Building to building Margin and various configurations

The present RUDA-GDCR prescribes a minimum of 4.5m margin for Buildings with height less than 15m. This reduces the space efficiency of the Plot and limits the configuration options.

The building-to-building margin space between two adjacent buildings should be reduced where there are no major openings on the walls facing each other.

e) Per Capita Plot Area requirement

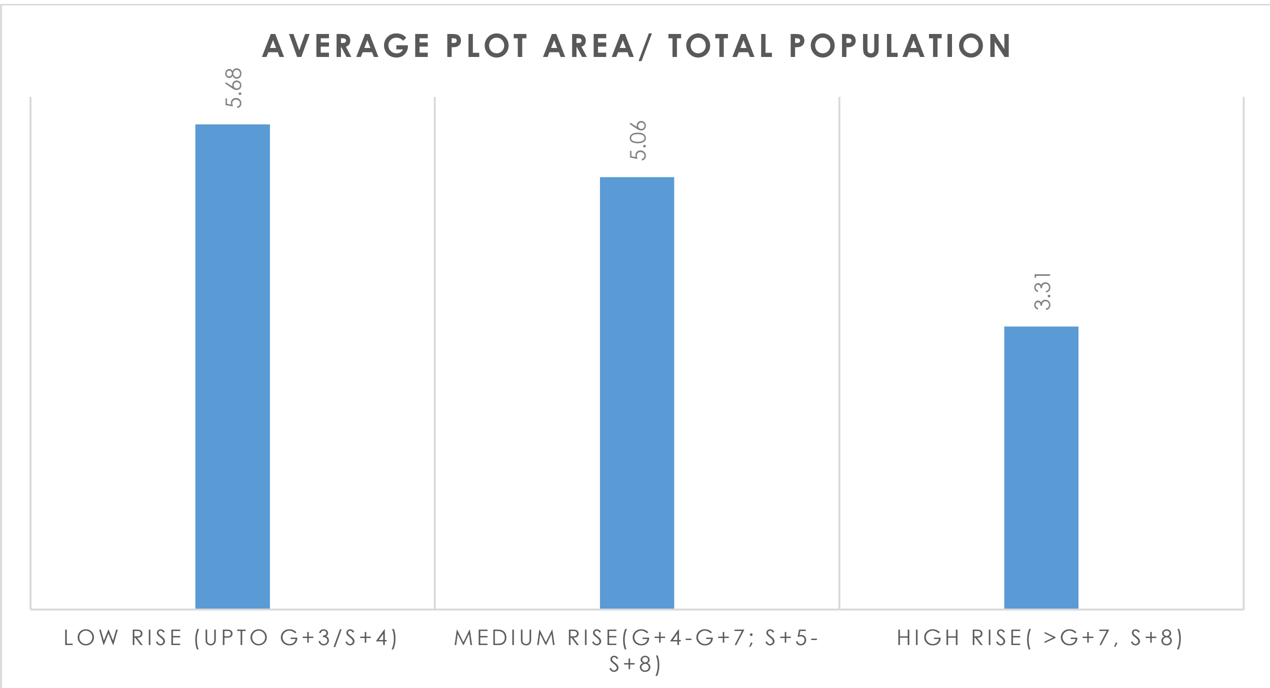


Figure 28 Per Capita Plot Requirement in various Typologies

If we divide the total plot-area by the average population of the housing it is discovered that with just *12% increase in plot area same density can be achieved with low rise as compared to medium rise*. This essentially means that by releasing 12 % more land at neighbourhood level, one is able to achieve the same density as that in medium rise with low rise buildings.

In order to move towards a low carbon future and reduce the embodied and operational energy consumption, Low rise typology makes a perfect case. It further, also brings down the overall cost incurred for per square unit of Habitable Space.

6.1.4 Conclusion

- **Smaller homes need compensatory open space in immediate proximity. Common Plot bye laws in RUDA GDCR should be based on density instead of Plot area.**
- **Low rise buildings offer double the rooftop space as compared to high rises.**
- **S+4 typology offers maximum environmentally productive space, and would have minimum Urban Heat Island Effect.**
- **Low-rise buildings are more efficient than high-rise buildings, in Carpet area to Built-Up Area ratio.**
- **With about 12% increase in Plot area efficiency, same density can be achieved in a Low rise as in a Medium rise.**

6.1.5 Recommendation

- **Common Plot Area requirement should be based on people density instead of Plot area.**
- **Minimum Building to building distance can be reduced where there are no major openings on the walls facing each other.**

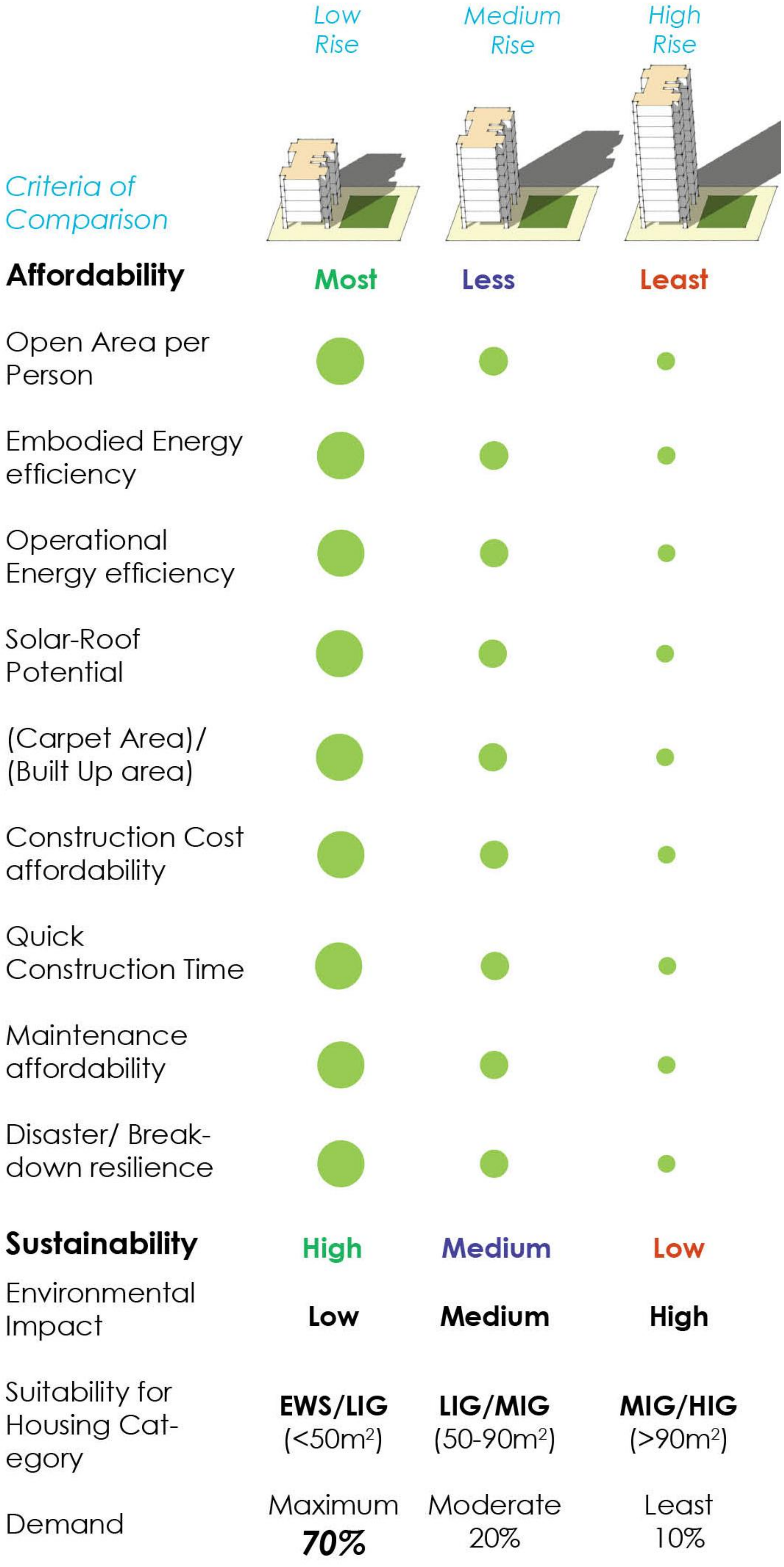


Figure 29 Comparison of Low,Medium and High Rises

6.2 Neighbourhood

The energy analysis of different housing forms – low rise, mid rise and high rise show that high rise is the least energy efficient in terms of embodied energy due to high steel consumption in the structure, operational energy due to requirement of lifts and pumps and require a high maintenance budget for the upkeep of these systems. Hence, it does not seem to be the solution for affordable housing, leaving low rise and mid-rise as potential low carbon affordable housing typologies.

The study of various other parameters like energy efficiency, parking requirement, built up area efficiency, solar roof top availability per unit area and open space per capita reveals that stilt plus four storeys is the ideal form to be adopted for delivering quick energy efficient mass housing in the affordable segment without compromising the living environment.

The argument in favour of building mid rise housing comes from the idea of high land cost or land scarcity within urban limits which encourages the builder to add more floors to maximise plot utilisation.

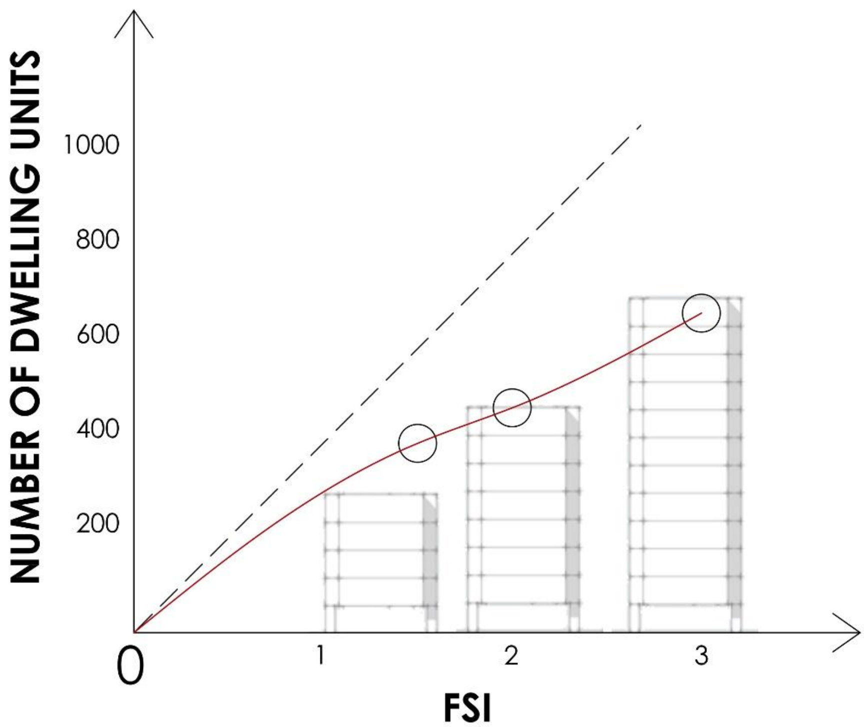


Figure 30 Relationship between FSI and Density

The myth of Land scarcity promotes the idea of high density high rise housing. But, in reality land can be freed for development through change in landuse regulations, land pooling, land readjustment and Transit oriented development strategies. This manufactured scarcity creates a false shortage of supply, thereby increasing land costs. Following are the general causes for higher **Land Cost**:[21]

- Flow of **black money** into real estate market
- **High stamp duty**
- **Large pieces** of land within the city remain tied up in **litigation** due to various acts
- **Land hoarding** by wealthy people
- **Encroachment** of Public land
- **Stringency of land conversion** rules make conversion of agriculture land on the periphery tedious.
- **Lack of flexibility in converting urban land** from one use to another hinders efficient allocation of urban space.

However, increase in FSI does not certainly imply a proportionate increase in density. The data from case studies of affordable housing projects in and around Rajkot shows that with increasing FSI the built up area required to deliver same carpet area increases due to increase in :

a) Circulation area (Corridor& Lifts etc.)
b) Built Mass (Structure footprint & Walls etc.)
c) Increased requirement for Space between buildings, reducing plot area efficiency and limiting configuration options.

[21] Summarizing from 'DRAFT *Three Year Action Agenda, 2017-18 to 2019-20', circulated to the Governing Council of the NITI Aayog on 23rd April, 2017.*

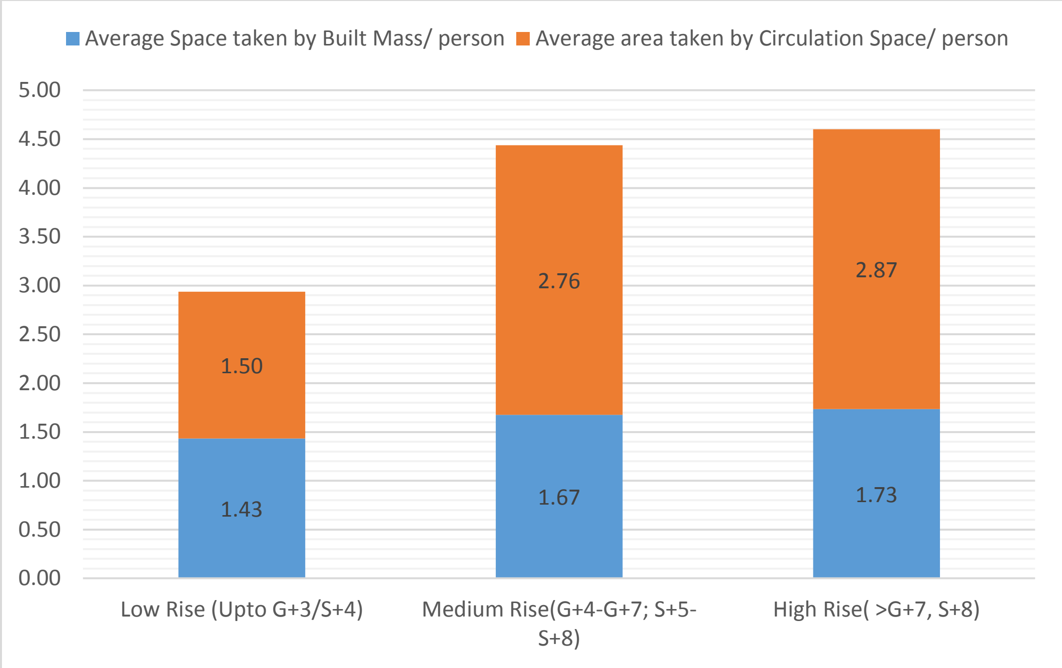


Figure 31 Comparison of per person Circulation Space & area taken by Built Mass

This demonstrates that increase in height reduces the Space Efficiency of the built up area to deliver the same habitable space or Carpet area. In addition, this entails that more amount of Building Materials are used to deliver the same Carpet area, thus increasing the per capita Embodied Energy and therefore greater Carbon Emissions. As the amount of Building material increases, the cost/sqft to deliver the same Carpet Area also increases, thus decreasing the Affordability.

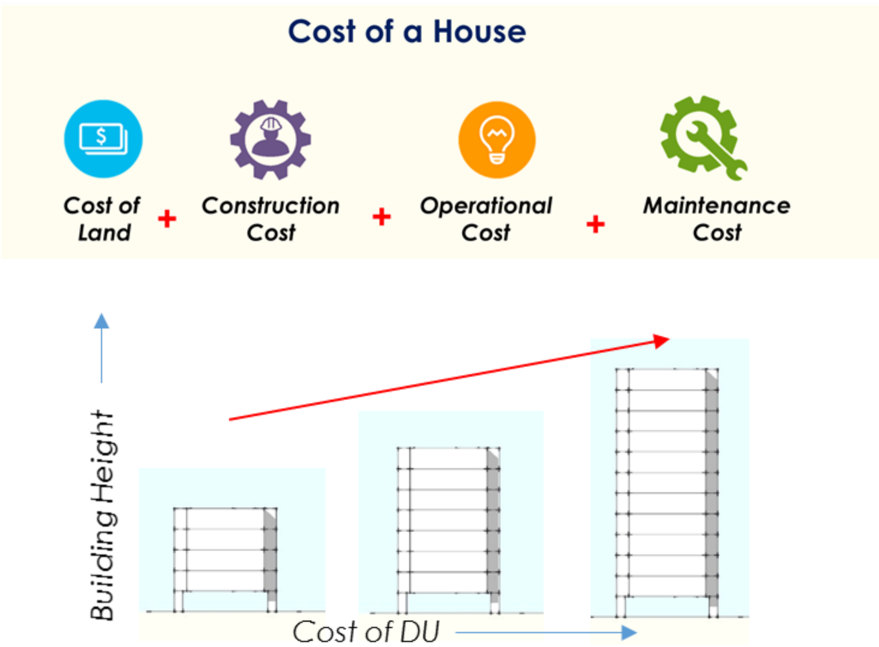


Figure 32 Relationship between Building Height and Cost of a Dwelling Unit

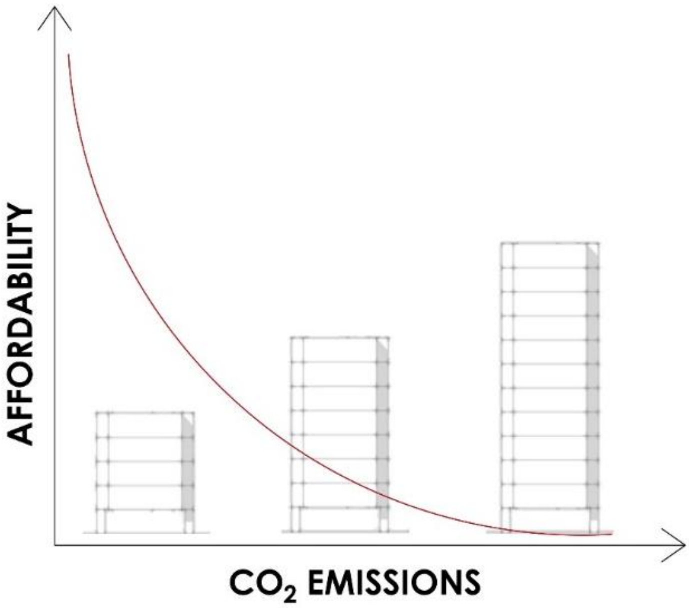


Figure 33 Affordability decreases with increase in Embodied Energy/ Carbon Emissions

In addition, the data analysis concludes that low-rise housing typology requires only 12% more land area per capita. This implies that with 12% increase in plot area efficiency, same density can be achieved with low-rise housing as in mid-rise. The paper looks at the potential of intensive land utilisation with the low-rise typology at the scale of a neighbourhood. The strategies proposed while increasing land efficiency also derive 3D spatial forms recognising and emphasising the value of shared amenities and pedestrian friendly streets through mixed-use typologies.

6.2.1 Optimising land by reducing set back

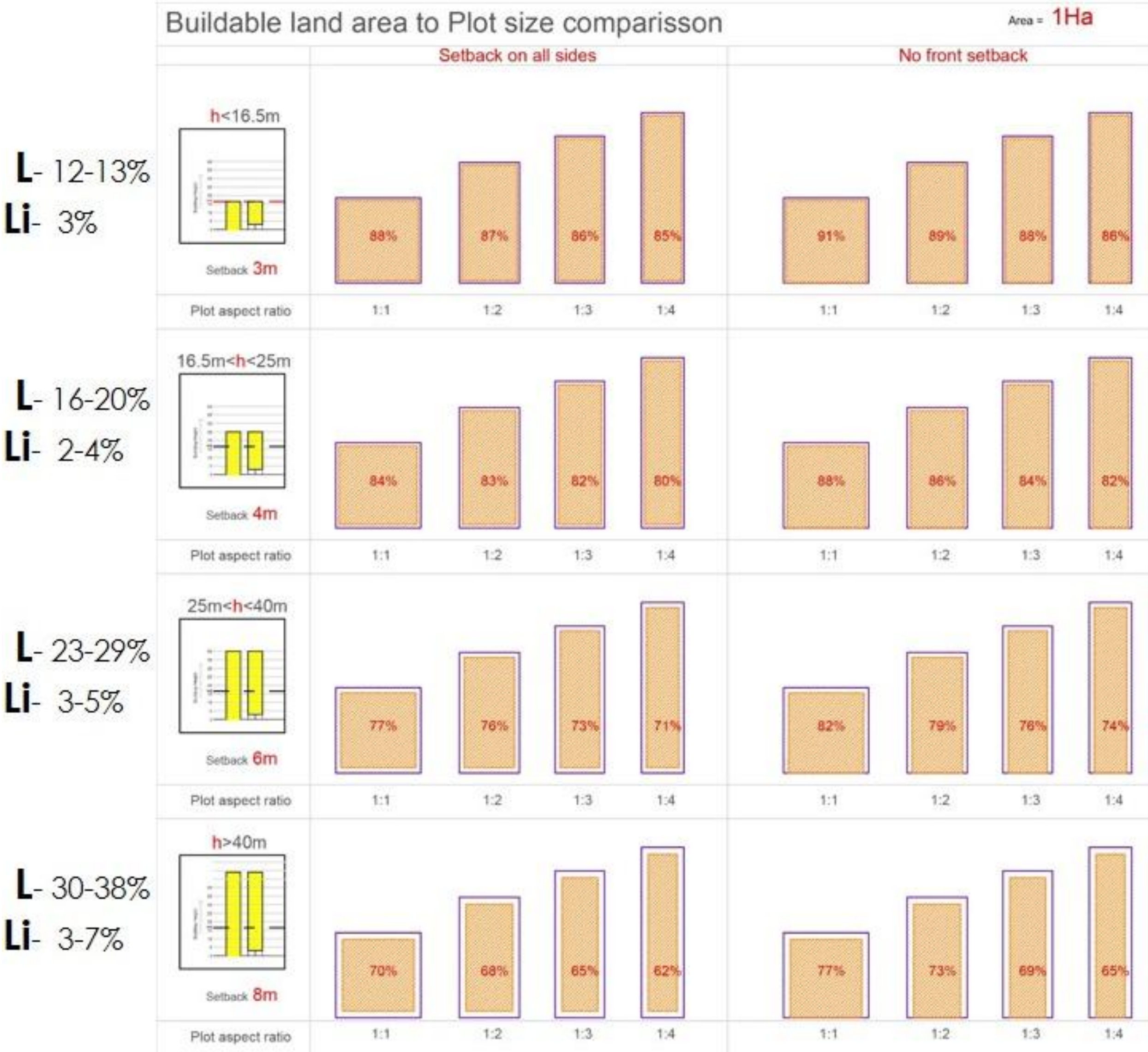


Figure 34 Buildable area to Plot size Comparison

L- Buildable Land area lost to setback
Li- Buildable Land area increased on removing front setback

Area of Plot:
1.0 Hectare

As per current RUDA byelaws 12-38% plot area is lost in setback depending on the location, size and shape of the plot. Since the open space for circulation, ventilation and safety in the front of the plot is already met by the access road in front, it is recommended that the front setback is reduced to 1.5 meters. This adds 3-7% more land to buildable area on the plot. At the same time this brings the built edge close to the street encouraging active frontage and eliminating boundary walls and blank edges.

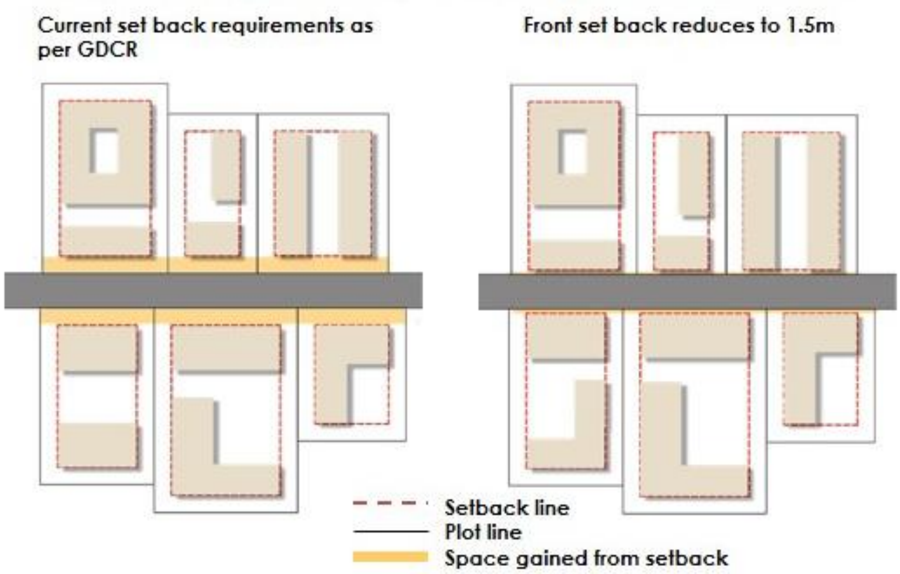


Figure 35 Reduction in Front Margin

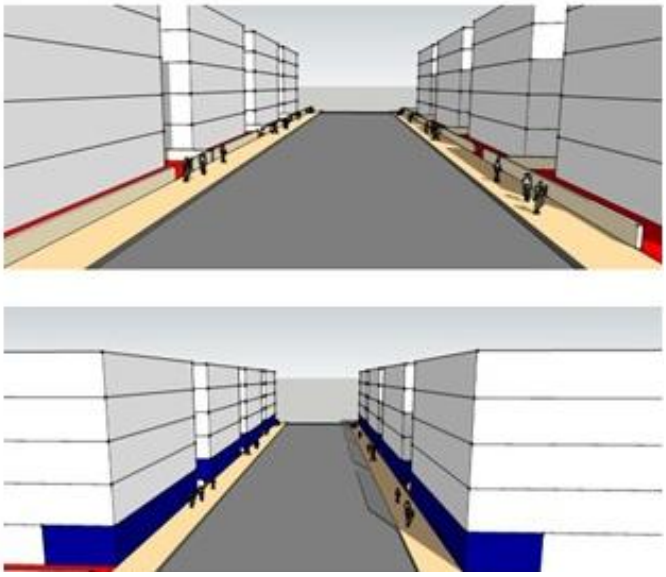


Figure 36 Comparission of layouts with and without Front Setback

With Front Setback

Less Buildable area, lesser configuration options

The buildings are disconnected with the street.

No Front Setback

Greater Buildable area, more configuration options

Safer neighbourhoods with Eyes on the street

A well defined street edge character, increasing legibility and imageability of the

6.2.2 Optimising land by Adopting Mixed use typologies

Segregating land use decreases the efficiency of the plot and increases the need to travel larger distances, hence more dependency on vehicles. Daily needs, retail and small office commercial needs should be incorporated in the lower floors of residential development built to the street edge. This allows for more efficient use of land, ensures walkable distances to amenities and creates opportunities for livelihood in the vicinity of affordable homes, which in turn makes the roads safe, and helps develop pedestrian friendly streets with active edges.

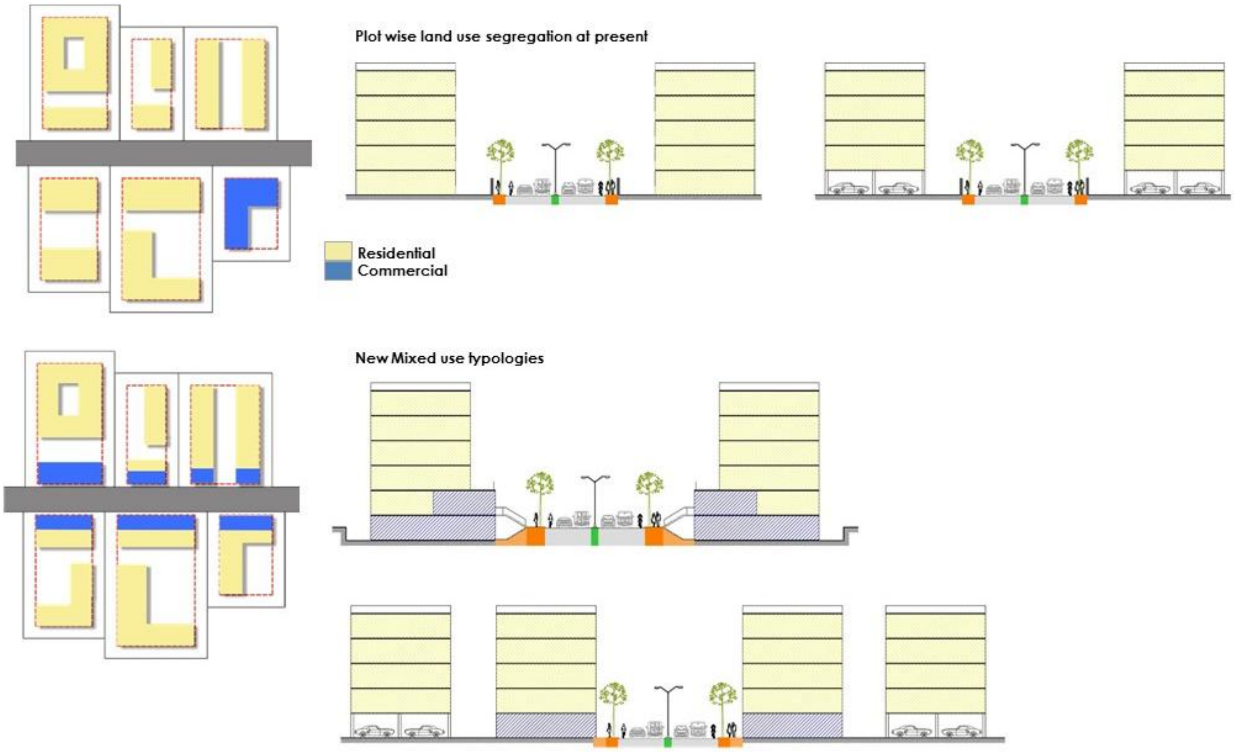


Figure 37 Mixed Use Typology at Neighbourhood Level

Mixed-use typologies with ground plus four storey (Walk-up Buildings[22]) can be adopted with commercial activities at the ground floor. Alternately, a half basement can also be planned along major streets to get two levels of commercial activity below four storeys of residential. Parking requirements can be met in stilts of the blocks, which do not sit on the main road.

6.2.3 Conclusion

Strategies at neighbourhood planning level can help optimize the land use to achieve higher densities in the same land area.

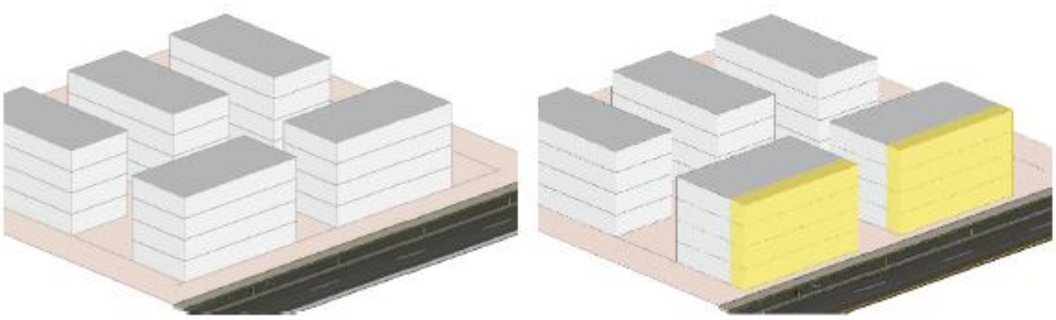
- **Front Margin for buildings abutting roads with R.O.W. greater than 9m should be reduced to 1.5m, to free more buildable land at plot level.**
- **Mixed Use Development can also help release some additional land, by accommodating for neighbourhood level commercial and institutional at the**

[22] Walk up Buildings are essentially 3-5 storey high buildings that are not solely dependent on lifts to serve the upper floors. These are much more affordable than medium and high rise buildings as the dependency and hence cost of installation and maintenance of lifts is nullified.

ground floor of Affordable Housing. Thus creating more opportunities and reducing travel needs.

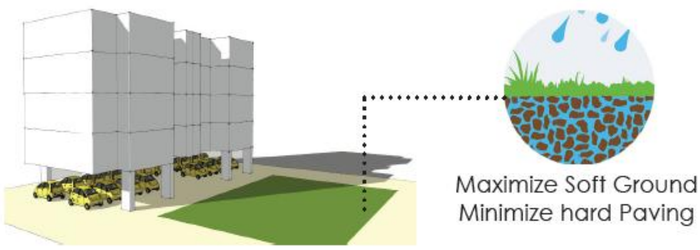
6.2.4 Recommendations

- **Reduce front Margin** *from 4.5m to 1.5m. Promote Build to Line typology. This helps in:*
  a) ***Increasing Buildable area*** *and thus ground coverage.*
  b) Creating safer neighbourhood, with 'eyes on the street'



- *Promote* **Mixed-use***,*
  a)Reduces need for motorised travel - basic amenities & livelihoods integrated with housing
  b) Ensures Pedestrian friendly streets and vibrant streetscape.

- '**Maximize Soft ground**'* *in order to :*
  a) Have Maximum Water percolation
  b) Provide space for plants and vegetation.
  c) Minimize Urban Heat Island Effect



(*Best achieved by taking all the parking requirement under the building, in Stilt+4 format)

6.3 City level

Approximately 60% of the city's population will live in affordable home settlements. Location of homes close to economical Public Transport systems, to places of employment and within reach of educational and health/ social infrastructure becomes an essential aspect of affordability. This also has impact on the carbon footprint of mobility in the city[23].

With this in mind the spatial distribution of affordable housing viz-a-viz transportation network and social infrastructure across the city is looked at a conceptual level.

6.3.1 Transit & Location

Locating maximum affordable housing within 500m of the mass transit routes like the proposed BRT route and 200m from the major roads will allow easy access to affordable public transport. This locational advantage helps ensure:

1. Spatial equity [24] in the city
2. Quick economic Integration of the affordable segment into the city by providing easy access to livelihood options across the city
3. Reduced need and dependence on private transport, therefore reduction in the mobility carbon footprint

[23] If affordable housings are placed far off in peripheral areas, the number of trips for work-home commute will increase. This would lead to urban sprawl and thus increasing transportation carbon footprint.
As the distance to the urban centre decreases, experts expect that the vehicle kilometres travelled or daily trips per person would decrease, and walk, cycle and transit trips would increase.(LOW-CARBON COMPREHENSIVE MOBILITY PLAN: RAJKOT)

[24] Equitable development of Land use, such that people from all socio-economic bagrounds can afford to live in all parts of the city

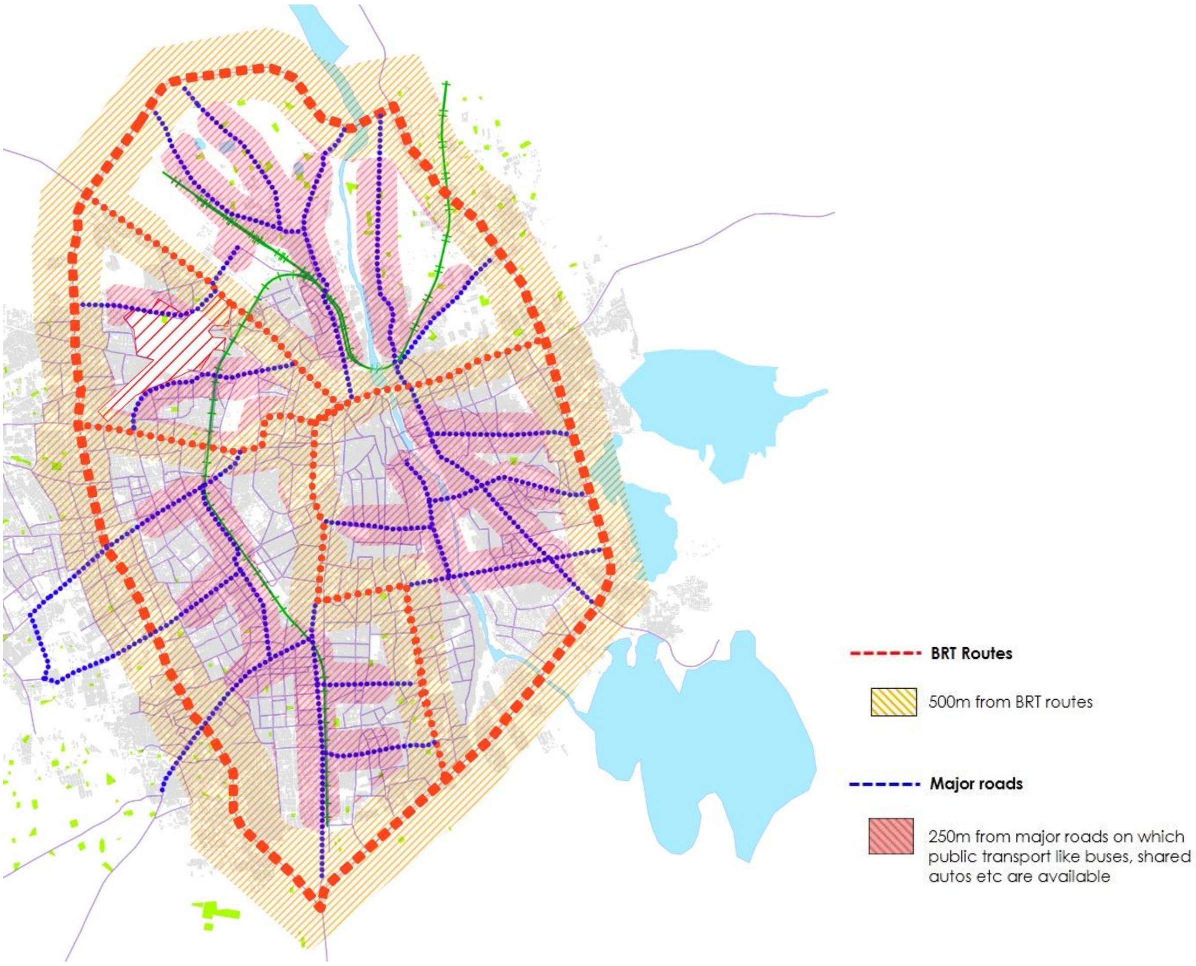


Figure 38 Locating maximum Affordable Housing with easy access to Public Transport

Looking at this zone proposed for affordable housing in conjunction with the existing city development shows that about two third of the area in this zone which is the core city area is already developed. Policies and guidelines should ensure reservation of land in developed areas for affordable housing through Redevelopment or densification of low density/ under-utilised land parcels. New affordable housing should be given incentives in the areas yet to be developed. Since, these areas are generally towards the city periphery, the urbanisation pressure is much less and thus land is comparatively cheaper. Hence, it is viable for the government and private builders to invest in these areas and deliver the houses at a buyable price for the lower income groups.

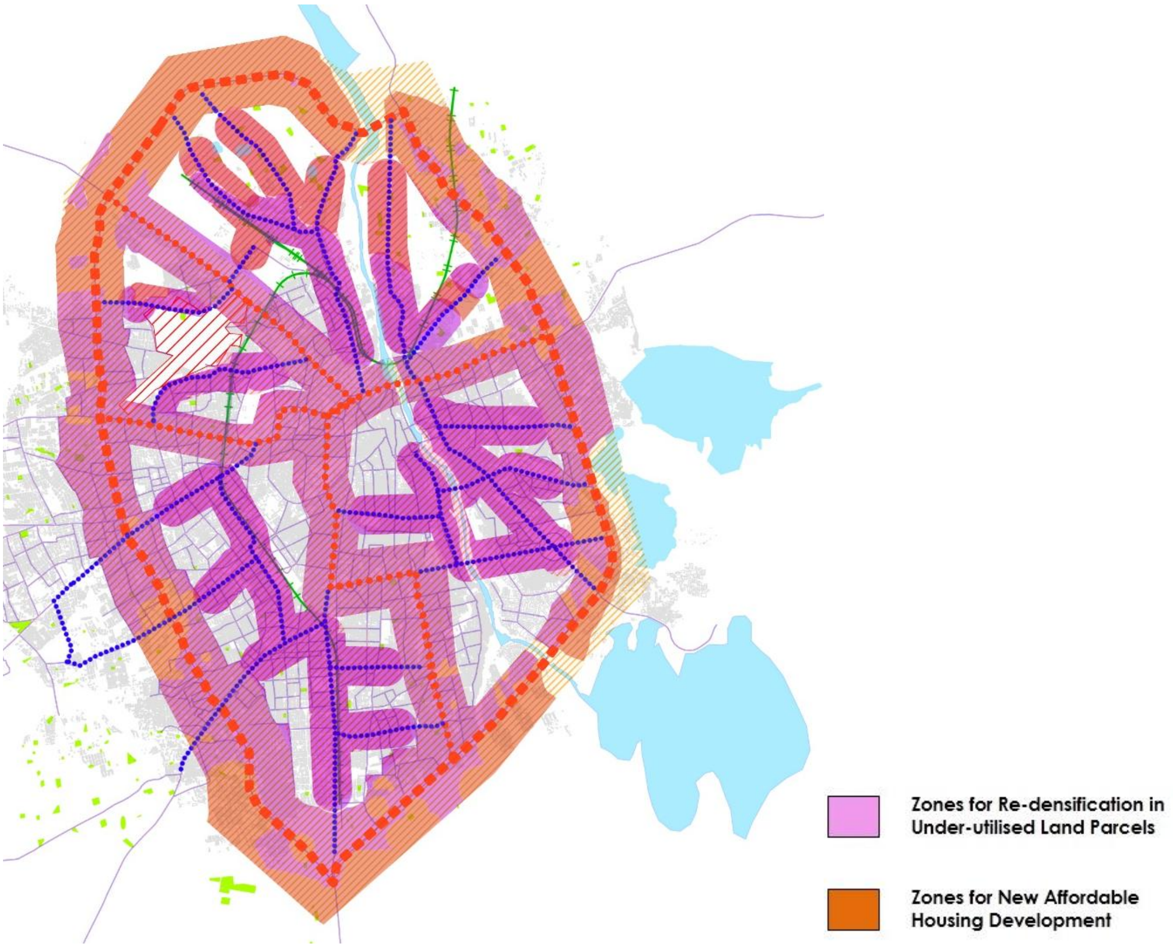


Figure 39 New and existing development

6.3.2 Accessibility and transit efficiency

A comfortable pedestrian grid needs to be maintained through the city especially in the zones identified above to ensure easy access to public transport. Large city blocks or cul-de-sacs limit connectivity and the advantage of locating within walkable distance of mass transit is lost.

Figure 40 Maintain the Pedestrian grid

A finer grid at neighborhood level also allows direct and short connections to nearby daily needs and other common facilities reducing the need to travel long distances and private vehicle ownership. Large developments should have pedestrian thorough fares every **50m.**[25]

6.3.3 Dwelling size and density

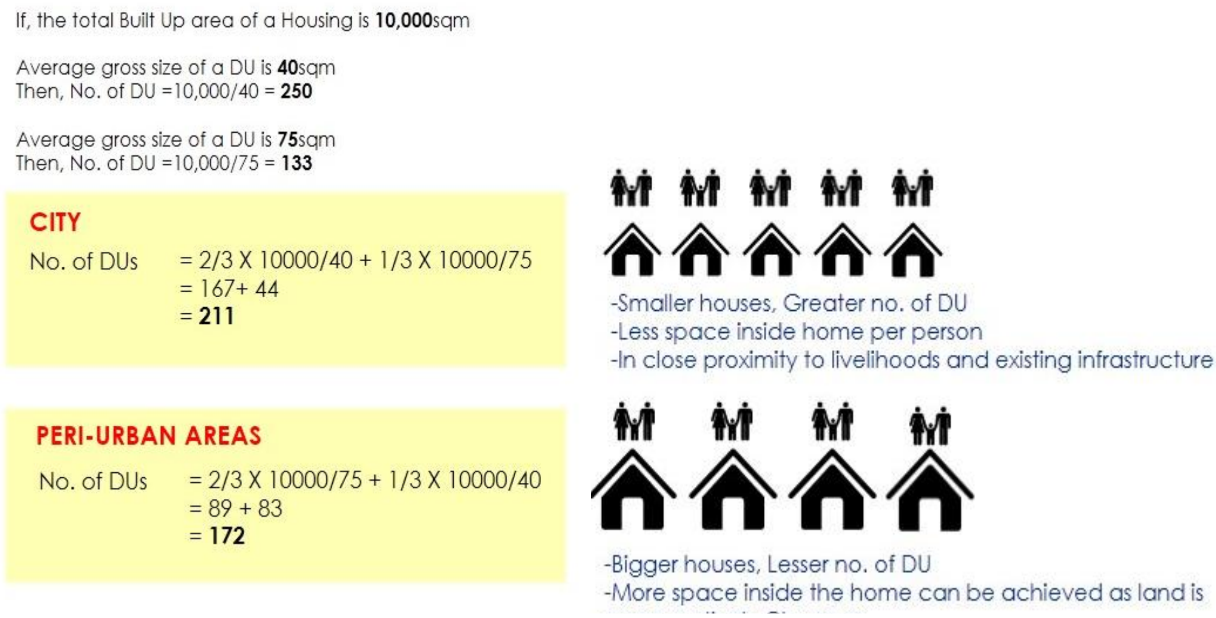


Figure 41 Dwelling Size and Density

To create low-carbon, resource-efficient and compact cities, people density needs to increase. This can also be done without increasing the FSI. Home sizes can be modulated to achieve higher densities in core city areas where land values are high and available land is less. More shared spaces and resources can be planned here. Here two-third of the units can be smaller and remaining can be larger, so that maximum people can get the benefit of being located in the city core. Towards the city periphery more land is available for the same cost therefore more of larger units can be accommodated here.

[25] This helps maintain a walking distance to Public Transport (Bus, Metro etc.) points within 10minutes.

6.3.4 Conclusion

Mobility through Low carbon affordable transit options governs the Location of affordable housing at city scale.

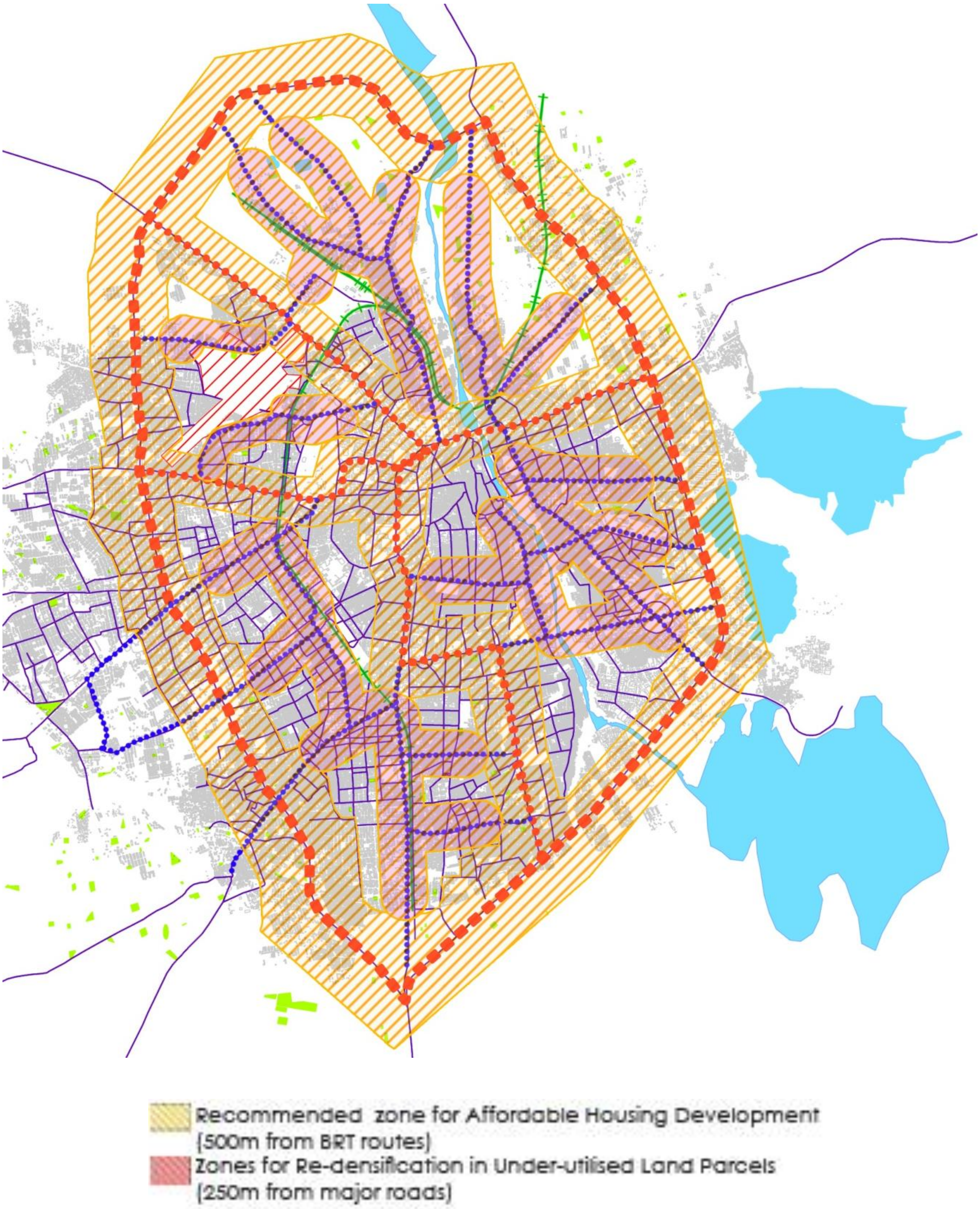
- **To ensure spatial equity within the city it is recommended to have land reservation for affordable housing in the new development around the city and promote densification of under-utilised pockets within the developed parts of the city close to mass transit routes.**
- **In addition, a fine pedestrian movement network needs to be incorporated in neighbourhood plans, irrespective the size of landholding or buildable plot, at intervals not exceeding 50m to enable quick and easy walking access to neighbourhood facilities and to public transit lines.**
- **High density affordable housing within the city can be achieved if the dwelling sizes are reduced and more common facilities and open spaces are planned as shared resources to compensate the high land cost in the core city areas.**

6.3.5 Recommendation

Ensure walkability (<500m) to the Public Transit Routes. *Frequent pedestrian connections at every 50m in the city blocks encourages walkability and enhances liveability.*

Frequent Pedestrian (Non-motorised) Connection to main streets with Public Transport

- *Locate* **maximum affordable housing within 500m of the mass transit routes** *like the proposed BRT route and* **200m from the major roads**, *allowing easy access to affordable public transport.*



This locational advantage for affordable housing helps ensure:

a) Reduced need and dependence on private transport, therefore **reduction in the carbon footprint of mobility in the city.**

b) **Spatial equity** *for all citizens.*

c) Quick economic integration and progress for the new migrant and the young aspirant.

7 Conclusion

This Position Paper to understand the Potential of Low-Carbon Resource Efficient Affordable Housing has been developed from an empirical study of affordable housing projects in Rajkot with reference to the development controls and regulations (DCR) of Rajkot City and its Masterplan. The findings of this study for resource and energy efficiency through strategic interventions at the building design and construction level, at the level of neighbourhood planning, and at the scale of city planning, can be generalised for Gujarat and for similar Tier 1 and Tier 2 cities elsewhere. By projecting the potential of efficiencies for affordable housing program for Gujarat under the Housing for All Mission we are able to estimate the cumulative energy efficiency gains and cumulative reduction GHG emissions. *(Figure 6)*

Importantly, the study also seeks synergies between the imperative of affordability, the qualitative needs of housing environments and low-carbon construction and operation of buildings. It is the convergence of these three dimensions pointing to a housing morphology of low-rise four to five storey high buildings as the optimal form for affordable housing that is the most significant finding of this study. The low-rise high-density model is found to be the most efficient. *(Figure 29)*

At the building design and construction level, the analysis of nine affordable housing projects of the Rajkot Municipal Corporation shows that buildings that are low rise - four stories high or have stilts on the ground floor with four stories above - are more energy efficient compared to taller buildings. This is so for embodied energy (Figure 6), operational energy *(Figure 10)* as well as for the potential of rooftop solar PV to meet energy demand *(Figure 12)*. In the design and construction of buildings, it is seen that inclusion of simple passive design standards – roof and wall insulation, external shading of windows, limiting window size and cross ventilation optimise the thermal comfort of homes. This optimisation translates into lower energy demand for cooling with air conditioning in the future. Embodied energy in the building construction can be minimised with appropriate selection of materials and steel-efficient structural design. Low rise buildings using fly ash block masonry or light weight AAC block masonry combined with steel-efficient design have the least embodied energy and, therefore, minimum carbon emissions. *(Figure 7)*

Given the desirability of low rise residential buildings from the point of view of energy efficiency, strategies for neighbourhood planning of residential schemes to optimise the utilisation of land were investigated *(E.2 Optimizing Land by Adopting Mixed Use Typologies)*. Some modifications in the DCR – reduction of set-backs and permitting mixed use along vehicular roads, reviewing the basis of standards for distances between buildings open space and vehicular access and parking - yield efficiencies in the utilisation of land. With these amendments, similar densities of housing to those of with seven storey high developments can be achieved. *(Figure 28)*

An important finding of the analysis of mid-rise (seven storey) and high rise (ten to twelve storey) shows that at high densities with small, affordable dwelling units, the availability of open space and soft ground diminishes and vehicular parking competes with recreational soft ground. The requirement of greater distances between buildings, as building height increases, limits the densities that can be achieved with mid-rise buildings. The high rise buildings, on many counts – construction and operational cost, high carbon footprint, social and cultural inappropriateness for small dwellings with high occupancy – are not a path to resource and energy efficiency and are not an "affordable" type of housing. *(*Figure 29*)*

The necessity of compensating the tight dwelling unit sizes and their constrained indoor dwelling area per capita is answered by the low-rise model where roof terraces and the ground are close by and quickly accessible to homes. This is achieved at no additional cost. Accessible and proximate open space needs a standard of provision per capita.

The typology of four storeys of flats above stilts (S+4) is found to be optimal. In this system vehicular parking and other common services are accommodated under the building footprint at the stilts level, leaving more soft ground available for recreation and plantation. Urban heat island effect is reduced. *(E.1 Optimizing Plot Area for maximizing Environmentally Productive Space)*

In the light of the findings of this study that the low-rise high density morphology for urban housing, especially for the Affordable Housing category, is optimal, the common assumptions about the necessity of increase permissible FSI beyond 1.5 need to be critically reviewed. It is seen that in an open speculative market of urban land raising permissible FSI does not bring down the cost of land per dwelling unit – the land value climbs proportionately with the increase in permissible FSI. The increase in FSI does not result in proportionate increase in density (dwelling units per hectare) (Figure 30). Seven storey high buildings cost 10 to 15% more to build compared with four storey buildings and, similarly cost more to operate and maintain (Table 1). Seven storey high buildings incur 10 to 15 % greater CO_2 emissions in their construction compared with carefully designed four storey buildings; they incur 15% more CO_2 emissions in their operation; they significantly compromise the quality of life of residents by restricting recreational and proximate "habitable space" necessary for small homes.

It is strongly recommended that an FSI of 1.5 be adopted as the norm for Affordable Housing in urban areas. Exceptions may be made in core areas of metros only, but limiting the permissible FSI to 2.0.

At City level, the inclusion and distribution of affordable housing across the city's fabric and close to public/mass transport routes would be strategic toward meeting the SDG of reducing income disparities and also to promote low carbon mobility for the majority of citizens. In neighbourhood planning for city extensions and for redevelopment within the city, convenient pedestrian access for affordable housing residents to public transport routes needs to be ensured. The city Master Plan and local area plans may accommodate these principles.

The DNA for **Low Carbon Affordable City**

LOW RISE -HIGH DENSITY

DU/Ha – ***400***

Open Space/DU- **15m²**

Construction Cost- Rs.**900-1100**/sqm

80% Solar Potential *for renewable energy from rooftops*

3 million tonnes less of CO_2 emissions, if Low rise format is used instead of High Rise

Quick construction time *with rationalized simple building technologies*

Best opportunity for wealth distribution through construction process

- **GDCR** that promotes walkability and maximizes car free green and recreational space.

- **Integrated into building codes:** *Shading, Insulation, Natural Ventilation* and low carbon building materials.

- **Promote Low Rise** (Upto 5 storey), **Restricted Medium Rise** (Stilt+7), since it has higher environmental impact as well as higher costs, to inner city areas in Tier 1 & 2 towns.

-**Public Transport** combined with Walkability as primary mode of Mobility Systems.

"Gujarat will build an estimated 9,78,000 ....building these in the **low rise-high density** form (instead of high-rise apartments) maximises the potential of electricity from rooftop solar PV, a building stock that approaches net zero energy demand and which **will save 3 million tonnes of CO_2 emissions.**"

7.1 Next steps

The findings and recommendations discussed above need to be deliberated upon by key stakeholders in the facilitation of Affordable Housing – The Municipality, the City Town Planning Department, the State Town Planning Department and the State Ministry for Housing. At the level of the Municipality amendments to the building byelaws can be considered. The City Town Planning Department would require to evolve the DCR to facilitate low-rise high-density with efficient utilisation of land. The State Town Planning Department would examine the distribution of Affordable Housing in the regeneration of the existing city as well as in the plans for city extensions, especially in relation to public transport networks. The State Ministry for Housing would establish energy and resource efficiency guidelines to institute appropriate building materials and construction systems.

It is the finding of this paper that significant improvements in the qualitative performance and reductions in the carbon emissions can be achieved with greater economy thereby enhancing affordability. Synthesising the potentials of design, construction and planning at the building, neighbourhood and city levels would lead toward low-carbon, affordable and liveable city systems. This strategy would be powerful instrument for meeting Sustainable Development Goals and also for achieving a significant reduction in carbon emissions with economic growth and quality of life in our cities.

Figure 42 Low Carbon Resource Efficient Affordable Housing

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Government Documents

- *Rajkot Urban Development Authority, General Development Control Regulations (RUDA GDCR),* Dated 27th October2016.
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Annexures

Annexure A Urbanisation in Gujarat state

The trends of urbanization and the demand for affordable housing at the State level and development in the cities

A.1Gujarat urban statistics:

No	City	Population	No	Name of city	Population
1	Ahmedabad	55,77,940	16	Nadiad	2,18,095
2	Surat	44,67,797	17	Bhuj	1,48,834
3	Vadodara	17,52,371	19	Gandhidham	2,47,992
4	Rajkot	13,23,363	19	Mahesana	1,84,991
5	Bhavnagar	6,05,882	20	Morvi	1,94,947
6	Jamnagar	6,00,943	21	Navsari	1,60,941
7	Junagadh	3,19,462	22	Godhara	1,43,644
8	Gandhinagar	2,92,797	23	Patan	1,25,497
9	Amreli	1,05,573	24	Porbandar	1,51,770
10	Anand	1,98,282	25	Gondal	1,12,197
11	Deesa	1,11,160	26	Jetpur	1,18,302
12	Palanpur	1,22,344	27	Surendranagar	1,77,851
13	Bharuch	1,69,007	28	Valsad	1,14,634
14	Botad	1,30,327	29	Vapi	1,63,630
15	Kalol	1,13,153	30	Veraval	1,54,634
			31	Dwarka	38,873

Figure 43 City wise Population data of Gujarat, Source: MoUD&Census 2011

Total population **6.27 crores**

42.60% urban population

2001-2011, Gujarat has witnessed a **growth rate of 36%** in urbanization

Projected to have **66% urbanization** by the year **2030**

Annexure B List of RMC Projects

List of Projects in Rajkot for analysing Building Efficiency:

Sr. No.	Project Name	Name Of Scheme/Programme	Nature of Project 1. Slum Relocation 2. In-situ Slum Rehabilitation 3. Public Private Partnership Slum Rehabilitation 4. Reconstruction of dilapidated Government Buildings 5. Any Other	Status(Completed /Ongoing)	Date of Start of Construction	Date of Project Completion
1	Kittipara, NR. Refyuji Colony	Rajiv Awas Yojana	2	Complete	2014-15	NA
2	MMGY 22A,Popatpara Rajkot	MMGY	5 (AHP)	Complete	2014	2016
3	MMGY 30B	MMGY	5	Complete	2014	2016
4	MMGY 3B	MMGY	5	Complete	2014	2016
5	Nr. Bishop House FP 95B	PMAY PPP	3	Ongoing	2015-16	NA
6	Bharat Nagar, 7A	PMAY PPP	3	Ongoing	2015-16	NA
7	Nr. Bharat Nagar, TP 28 Mavdi, FP 49/A (Smart GHAR I)	Smart Ghar I (PMAY)	5	Ongoing	2015-16	NA
8	Nr. Bharat Nagar, TP 28 Mavdi, FP	Smart Ghar III (PMAY)	1	Ongoing	2015-16	NA
9	Raiya Dhar 17A	BSUP-III		Complete	2011-12	NA
	Raiya Dhar 17B	BSUP-III		Complete	2011-12	NA
	Raiya Dhar 34A	BSUP-III		Complete	2011-12	NA

Figure 44 List of Projects in Rajkot for analysing Building Efficiency, Source: Rajkot Municipal Corporation

Identifying the different types of designs, in terms of height of building and materials used, used in affordable housing

Given the information collected in the site visits to Ahmedabad and Rajkot, affordable housing design in Gujarat has the following variations.

Parameter	Variations	Remarks
Number of storeys	Ground floor +3	Lift and firefighting system not required
	Stilt floor + 4	
	Stilt floor + 7	Lift and firefighting system required
	Stilt floor + 10 or 11	
Type of walling materials / construction	RCC framed structure + Traditional red clay fired bricks	
	RCC framed structure + AAC blocks	
	MIVAN / MASCON	

These 2 parameters will influence the materials demand and the embodied energy. 9 projects executed by the Rajkot Municipal Corporation (RMC) with various combinations of height (no. of storeys) and materials were identified.

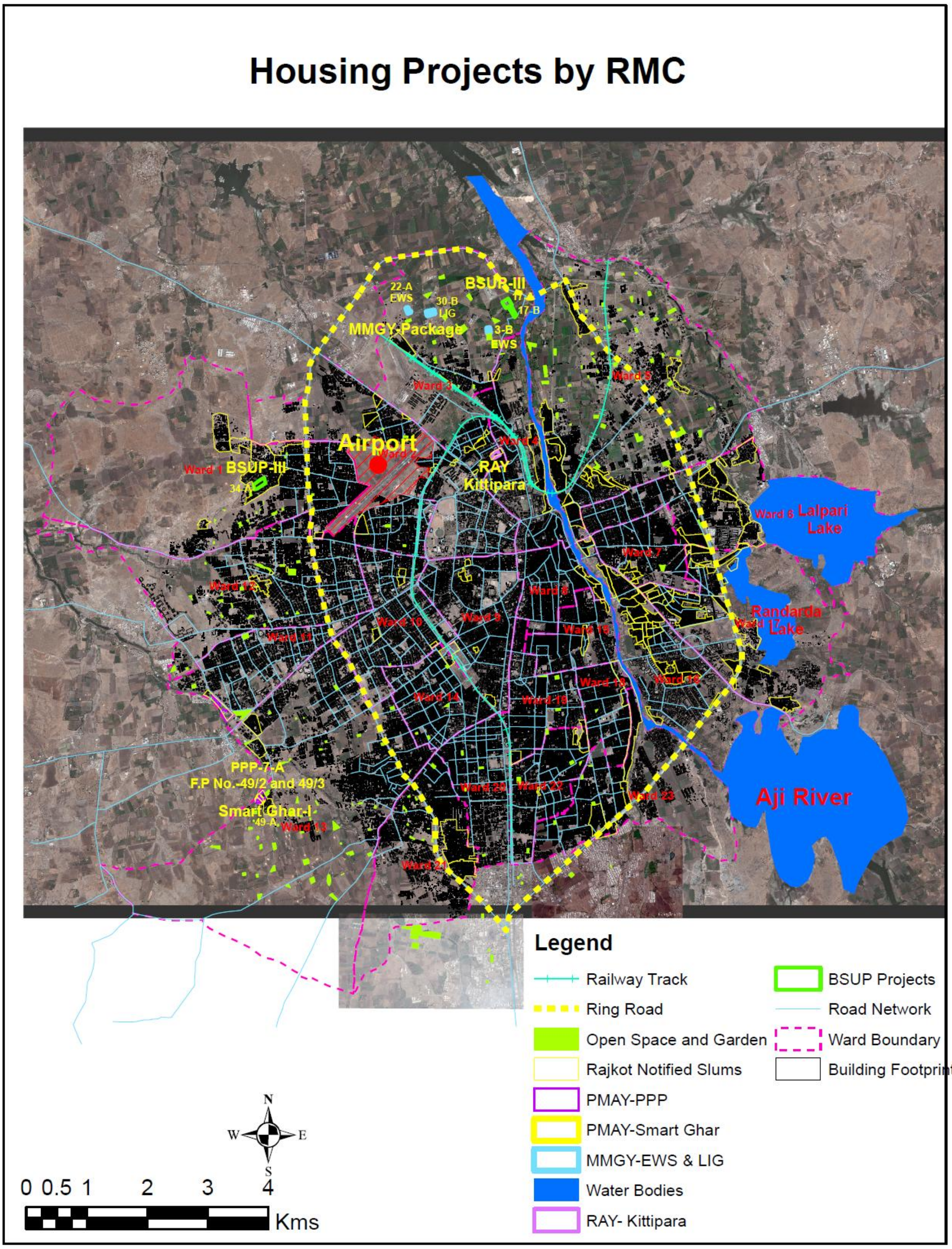
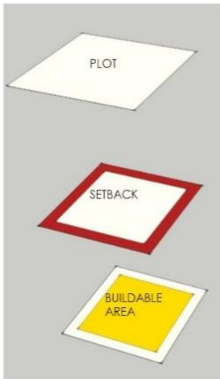


Figure 45 Location Map of Various Projects done by RMC

Annexure C Preliminary Analysis of Building Bye laws

C.1 Buildable land area to Plot Size Comparison Analysis

The current building bye laws of setbacks in RUDA GDCR, are tested on plots of area 1Ha, 0.5Ha,0.25Ha with plot aspect ratios 1:1, 1:2, 1:3 and 1:4. This analysis is done to understand how much buildable area of the plot is left after removing setbacks.



L- Buildable Land area lost to setback

Li- Buildable Land area increased on removing front setback

15.5.1.2 Minimum side and Rear Margins for Building unit up to 500 sq.mts for Residential – Dwelling 1, 2, & 3 (Except High-rise) and Non- Residential Uses

No	Area of the Building unit	Required Rear or Side Margin
1	Up to 80 sq.mts	1.5 any one side
2	Above 80 sq.mts and up to 150 sq.mts.	2.0 any one side
3	Above 150 sq.mts and up to 250 sq.mts.	2.5 any one side
4	Above 250 sq.mt and up to 400 sq.mts.	2.25any two side
5	Above 400	4.0 all sides

15.5.1.3 Minimum side and Rear Margins for Building unit above 500 sq.mts for Residential – Dwelling 1, 2, & 3 and Non- Residential Uses

No	Building Height	Required Rear and all other side Margin
1	Up to 16.5	3.0
2	Above 16.5mts and up to 25mts	4.0
3	Above 25 and up to 40mts	6.0
4	Above 40mts	8.0

Note: Minimum margin at the corner or curvature at all points shall be measured tangential or perpendicular distance from the building to plot boundary.

15.5.2 Minimum Margin between Buildings

No	Building Height	Required Margins(in meters)
1	Up to 16.5mts	4.5
2	Above 16.5mts and up to 25mts	6.0
3	Above 25 mts and up to 40 mts	9.0
4	Above 40mts	12.0

Figure 46 Building Bye Laws for Setback, Pg-132 RUDA GDCR 2031

Area of Plot: **1.0** Hectare

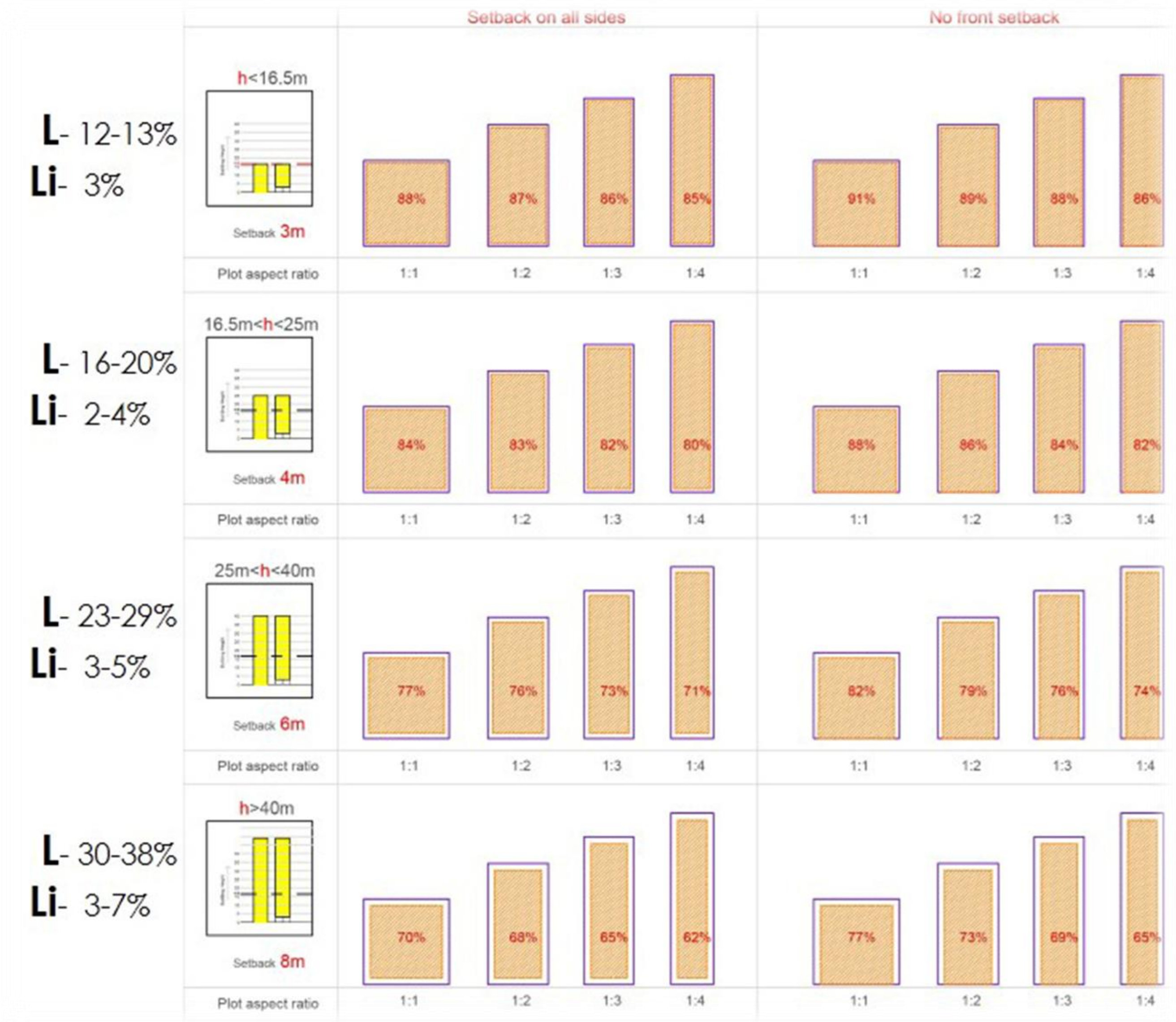
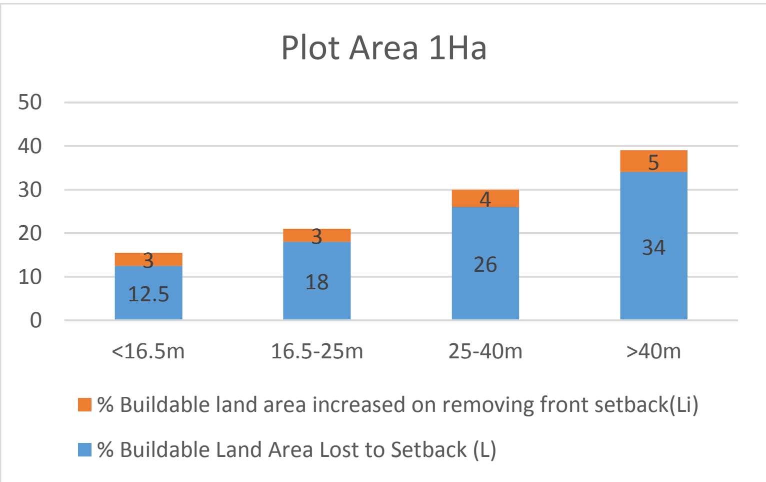


Figure 47, Buildable Area to Plot Size Comparison, Area 1Ha



Area of Plot: **0.5** Hectare

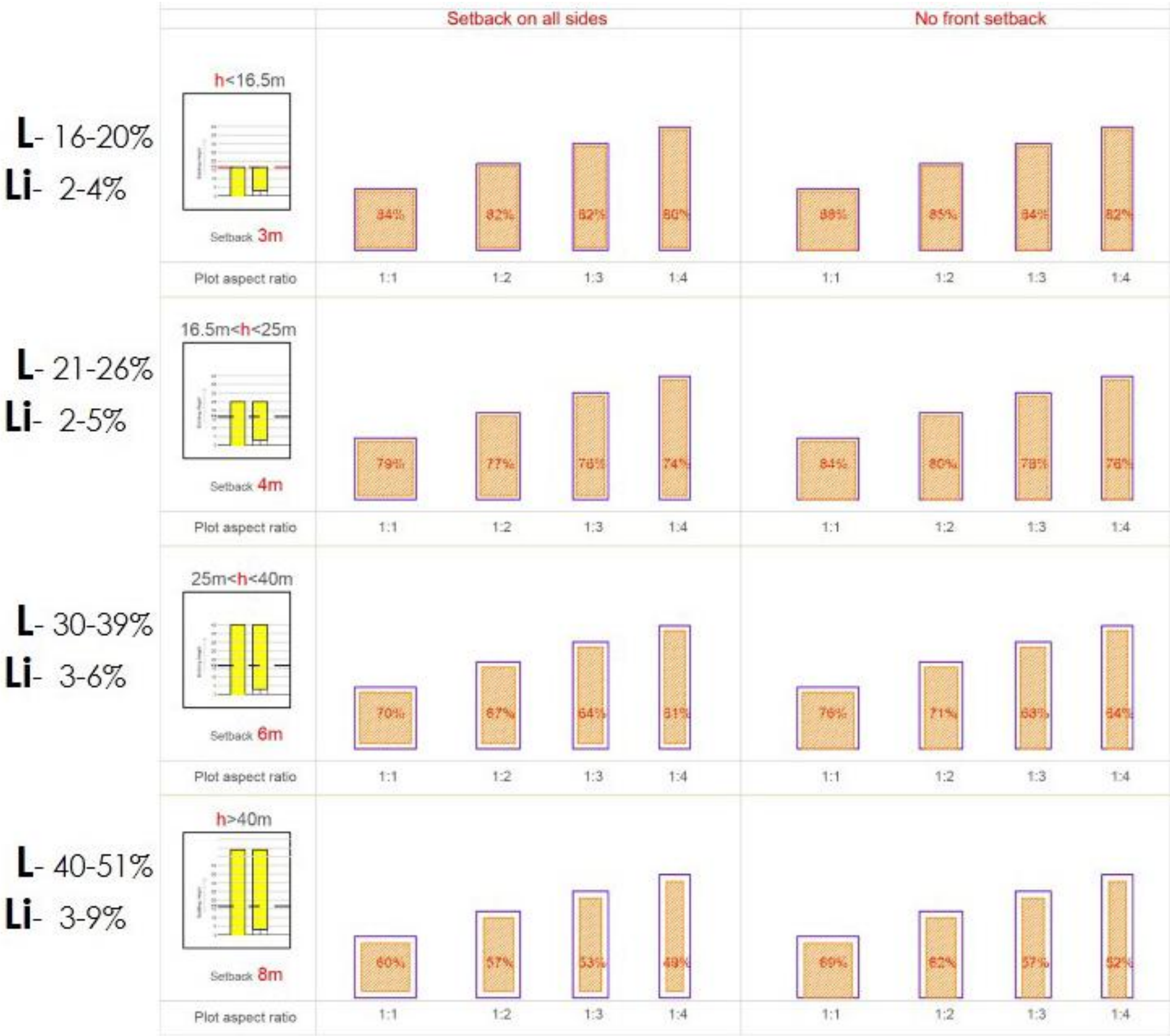
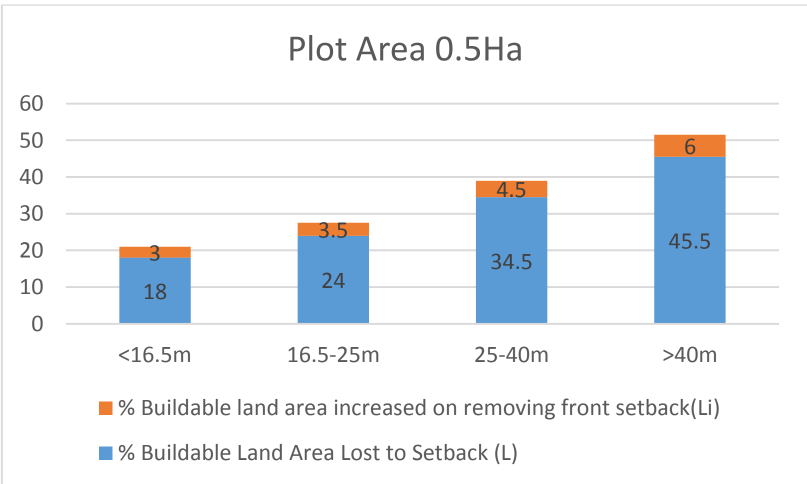


Figure 48 Buildable Area to Plot Size Comparison, Area 0.5Ha



Area of Plot: **0.25** Hectare

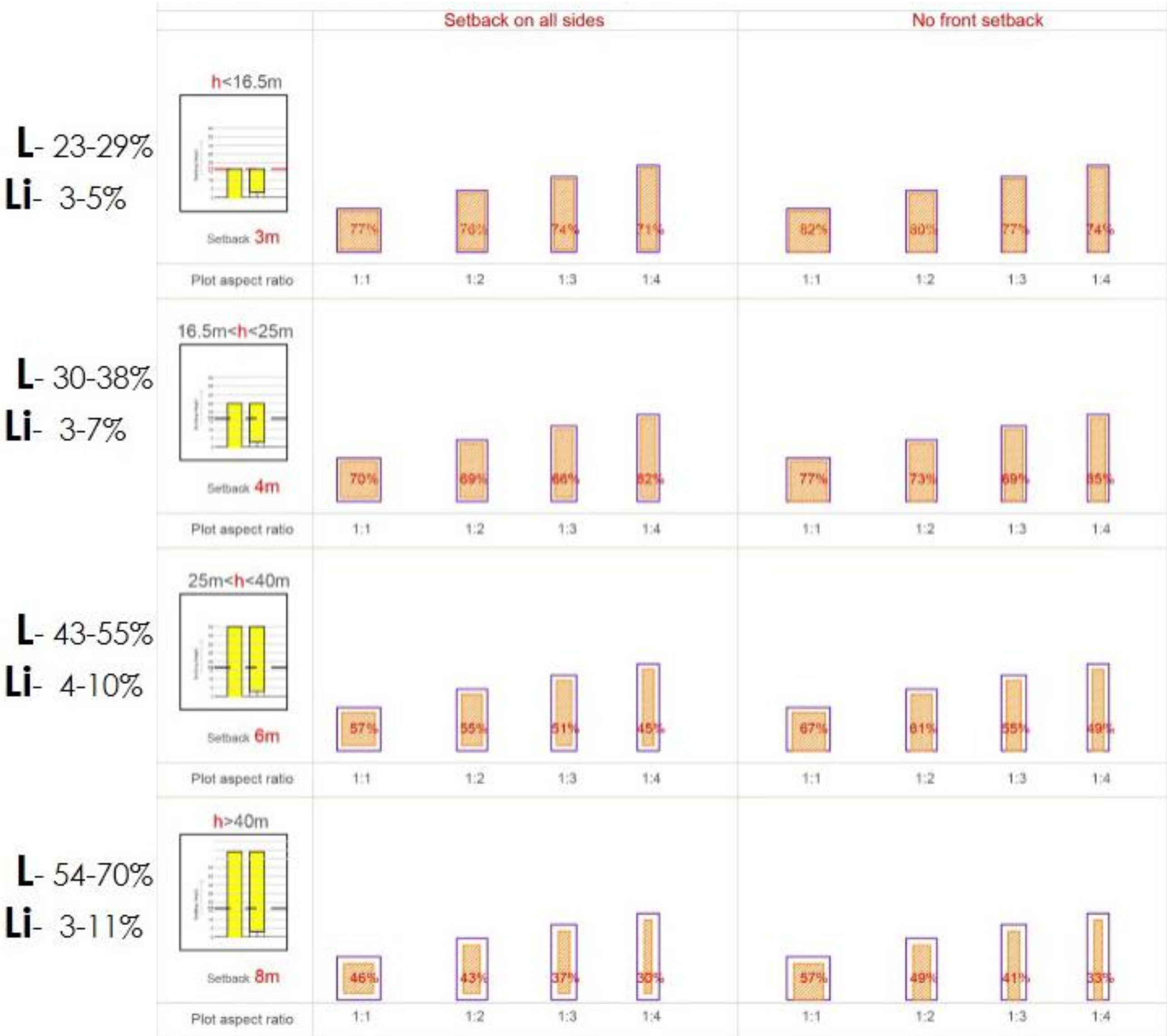
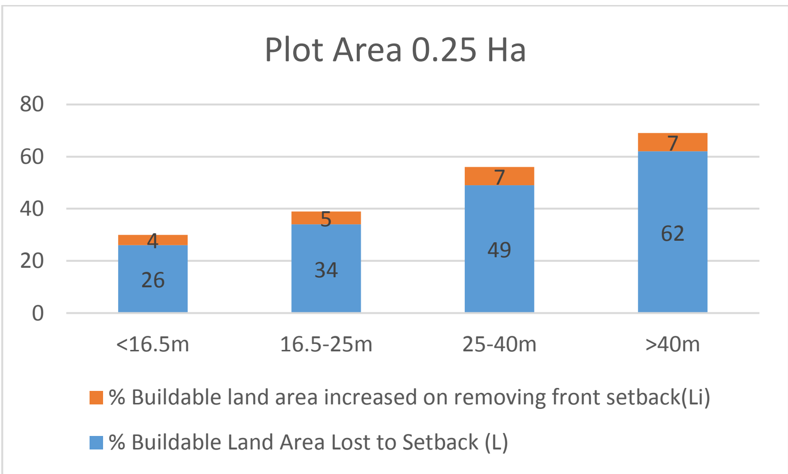


Figure 49 Buildable Area to Plot Size Comparison, Area 0.25 Ha



C.2 Spatial Configuration Analysis for general Low Rise-High Density Housing

Plots of area 1 hectare, and plot aspect ratio 1:1 and 1:2 are considered. These plots are then evaluated on the potential of various spatial configuration options. These spatial configuration have been derived from the type of parking:

Case A: Surface Parking only

1. Peripheral Parking
2. Island Parking

Case B: Stilt Parking only

1. Single Big open space
2. Several small open spaces

Following considerations have also been undertaken for this study:

- 90% of the total built-up area is considered to be of residential use only, rest 10% is assumed to have been of mixed-use/common use like commercial, club house etc.
- A building block is 12m wide at max, and length of one block in general is not more than 50m
- Area of Dwelling unit = 50sqm (Unit area-35-40sqm, 10-15sqm given to circulation)
- 70% of rooftop area is considered as a useable roof space, rest 30% is assumed to have been consumed by staircase, structure, water tank etc.
- 80% of building footprint is considered as parking space, rest 20% is assumed to have been consumed in structure, staircase etc.
- Number of people in one house 4.5.

Figure 50 Spatial Configuration options for 1:1 type plot

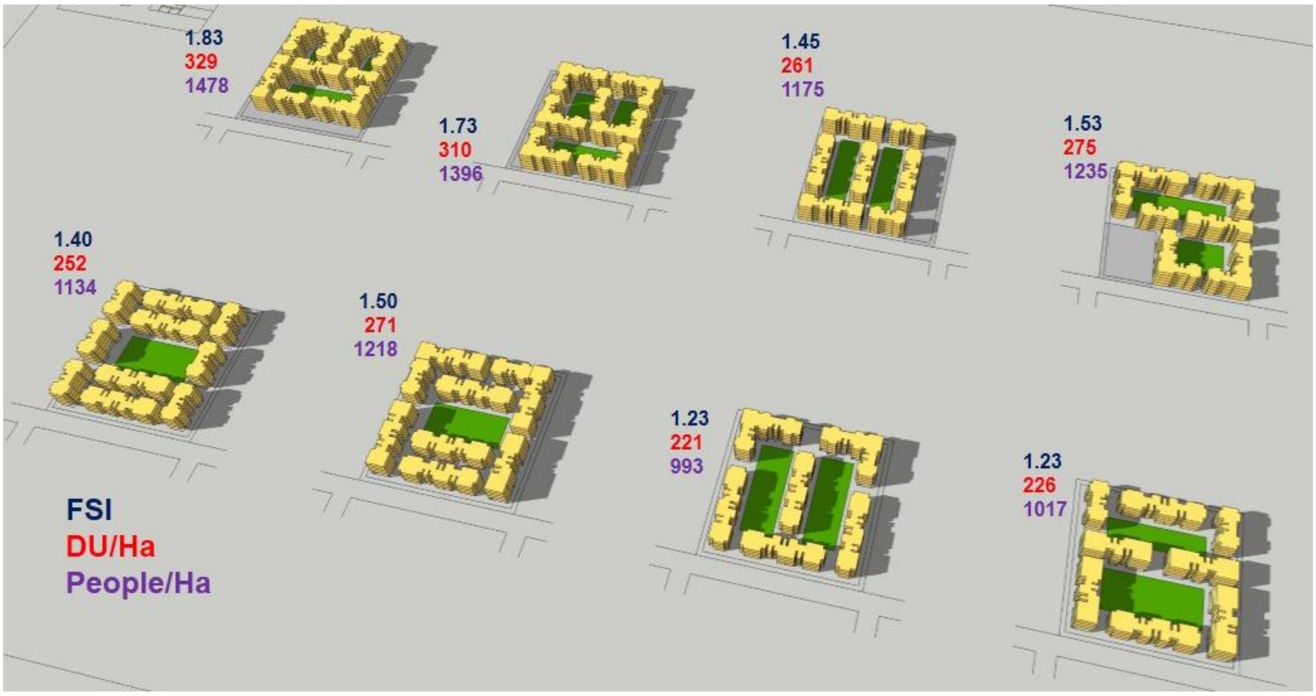


Figure 51 Comparison of various Spatial Configuration options for 1:1 type plot

Figure 52 Spatial Configuration options for 1:2 type plot

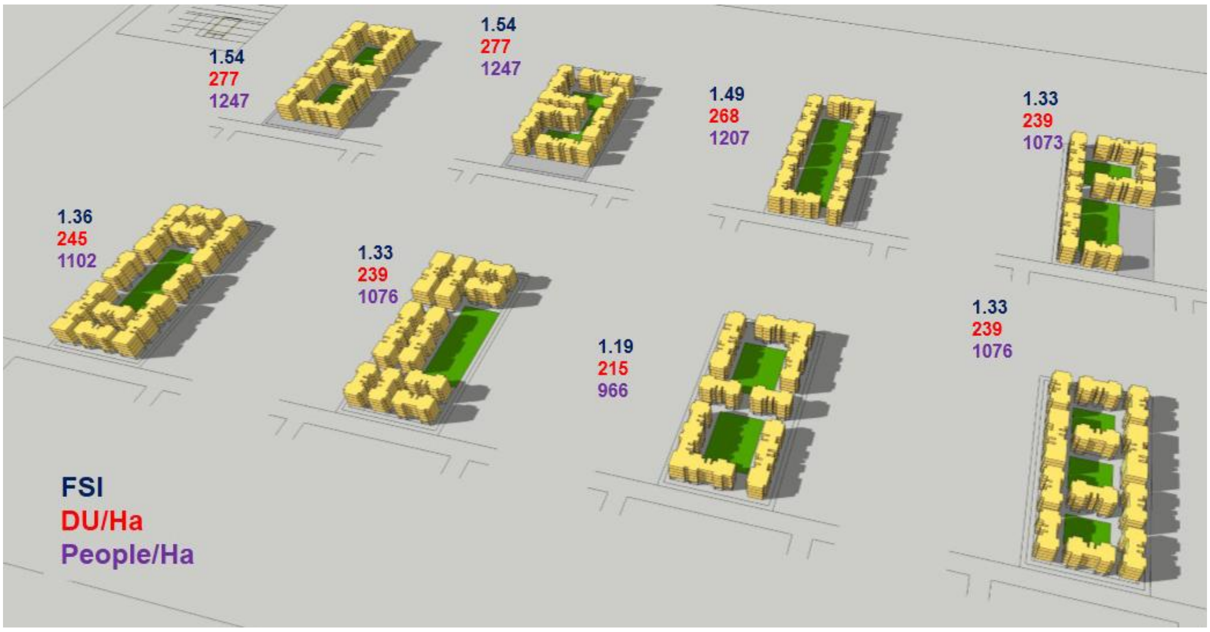


Figure 53 Comparison of various Spatial Configuration options for 1:2 type plot

Annexure D Methodology for calculation of material demand, embodied energy and operational energy

D.1 Calculation of embodied energy

Given the information collected in the site visits to Ahmedabad and Rajkot, affordable housing design in Gujarat has the following variations.

Parameter	Variations	Remarks
Number of storeys	Ground floor +3	Lift and firefighting system not required
	Stilt floor + 4	
	Stilt floor + 7	Lift and firefighting system required
	Stilt floor + 10 or 11	
Type of walling materials / construction	RCC framed structure + Traditional red clay fired bricks	
	RCC framed structure + AAC blocks	
	MIVAN / MASCON	

These 2 parameters will influence the materials demand and the embodied energy. 9 projects executed by the Rajkot Municipal Corporation (RMC) with various combinations of height (no. of storeys) and materials were identified.

The following methodology is used for evaluating initial embodied energy of the affordable housing projects studied:

- Collection of "Bill of Quantities (BOQ)" of all projects
- Calculation of quantities of cement, aggregates, steel, walling material (burnt brick / AAC) from the quantities of major building items from the BOQs
- Calculation of embodied energy of cement, aggregates, steel, walling material (burnt brick / AAC) in each project
- Divided by the project built-up area to get Embodied Energy per sq.m. of built-up area

D.2 Calculation of number of uncomfortable hours

The methodology followed for calculation of uncomfortable hours is as follows:

- Simulation is done for a west facing bedroom on an intermediate floor (Design Builder is the tool used for hourly simulation)
- The project with the following envelope design (MMGY 22A) is considered as the conventional or base case:
    - Burnt brick walls
    - Sliding window i.e. openable window area is 50%
    - Overhang on window
    - Window to Wall ratio of 10 – 15%
- Number of uncomfortable hours for the base case is estimated through simulation
- Thereafter, number of uncomfortable hours is estimated for the changes in building envelope in the other projects, which are:
    - AAC walls or monolithic concrete walls instead of burnt brick walls
    - Casement window (openable area 90%) instead of sliding windows

D.3 Calculation of solar fraction

The methodology used for calculation of solar fraction:

- Energy requirement of all project is estimated. This includes:
    - Estimated energy requirement in all dwelling units, assuming 2 (1 in each room) fans, 2 tube lights (1 in each room) are operated for 8 hours a day; one CFL in the kitchen is operated for 2 hours a day; one T.V. for 5 hours a day and one refrigerator. This results in an Energy Performance Index (EPI) of 30 – 40 kWh / m2 / year. (not including the common services like water pumping and lift energy). A typical dwelling unit is assumed to have 1 bedroom, 1 drawing room and 1 kitchen. The bathroom lights have not been considered.
    - Water pumping energy (refer section 6.1.1.2)
    - Lift energy (refer section 6.1.1.2)[26]

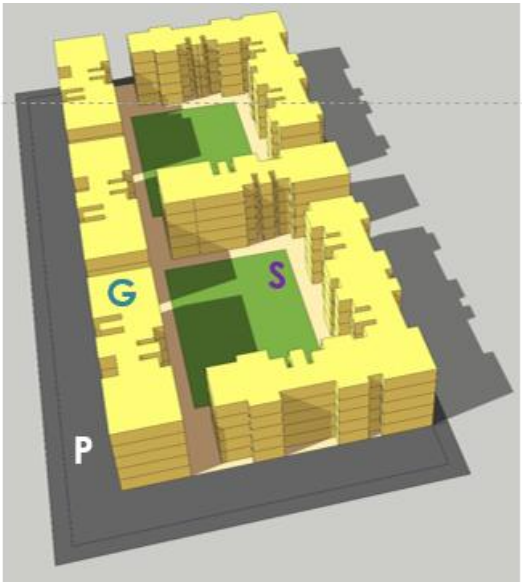
[26] The Energy Performance Index (EPI) of a dwelling unit, including water pumping energy and lift energy (where applicable), in this analysis is estimated to be in the range of 35 – 50 kWh/ m^2 / year.

- Rooftop solar energy generated in all projects is estimated using "RETScreen". The following assumptions are taken:
    - 70% roof area is available for solar installations
    - Poly-crystalline panels with 15% efficiency
    - Inverter and other loses taken as 10%
- Solar fraction is calculated.

Annexure E Efficient use of Plot Area

E.1 Optimizing Plot Area for maximizing Environmentally Productive Space

Building Unit Area (Plot area)	=	Ground Coverage(G)	+	Parking Area(P)	+	Soft Scape (S)	Recreational space + Environmentally productive space
B	=	G	+	P	+	S	



Environmentally Productive Space(E)

- Allows for Water Percolation
- Provides space for Vegetation

Reduction of Urban Heat Island Effect

As per RUDA GDCR:

Sr.No	Type of use	Minimum Parking Requirement	Visitors Parking
1	Affordable Residential Apartments with dwelling units of carpet area up to 50 sqmts	10% of utilized FSI	An additional 10% of the required parking space shall be provided as visitors parking
2	Affordable Residential Apartments with dwelling units of carpet area from 51 to 66 sqmts	15% of utilized FSI	An additional 10% of the required parking space shall be provided as visitors parking
3	Affordable Residential Apartments with dwelling units of carpet area more than 66 sqmts	20% of utilized FSI	An additional 10% of the required parking space shall be provided as visitors parking
4	Commercial use	50% of respective utilized FSI	20% of the required parking space shall be provided as visitors parking

Pg 213 RUDA DP 2031

B = G + P + S

-For achieving maximum density, **G** should be maximized

-For reducing UHI, we should *minimize hard paved(***P***)* surfaces and try to *maximize soft ground(***S***)* .

-For maximum **G**, **P** and **S** should be minimum.

-**S**, helps reduce UHI, P increases UHI

Assuming all residential, parking in only stilt

P = 0.11(n X G)

n- No. of floors in the Building

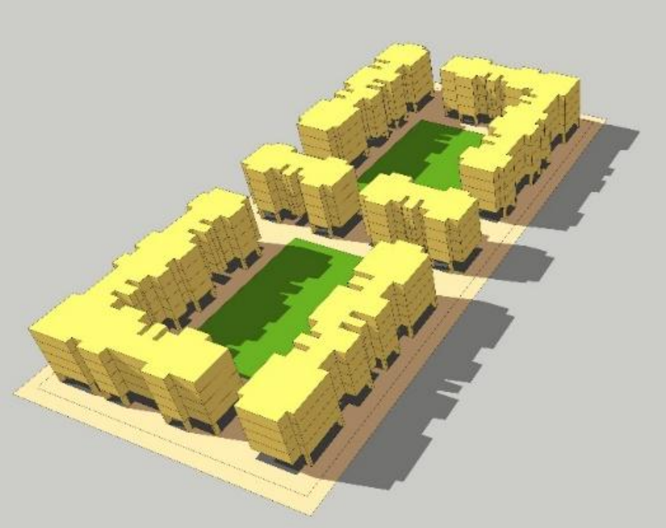
Assuming 2/3 of Stilt is available for parking, rest 1/3 is taken by staircase and services

Assuming, that of the available parking 70% is useable and 30% in used up by structure and circulation

$$0.66 \times (0.70 \times G) = 0.11(n \times G)$$

$$n = 0.66 \times 0.70/0.11$$

$$= 4.2$$



- For minimum Urban Heat Island Effect, all parking should be done under the building, in stilts
- S+4 typology optimizes density, Soft ground and Parking

E.2 Optimizing Land by Adopting Mixed Use Typologies

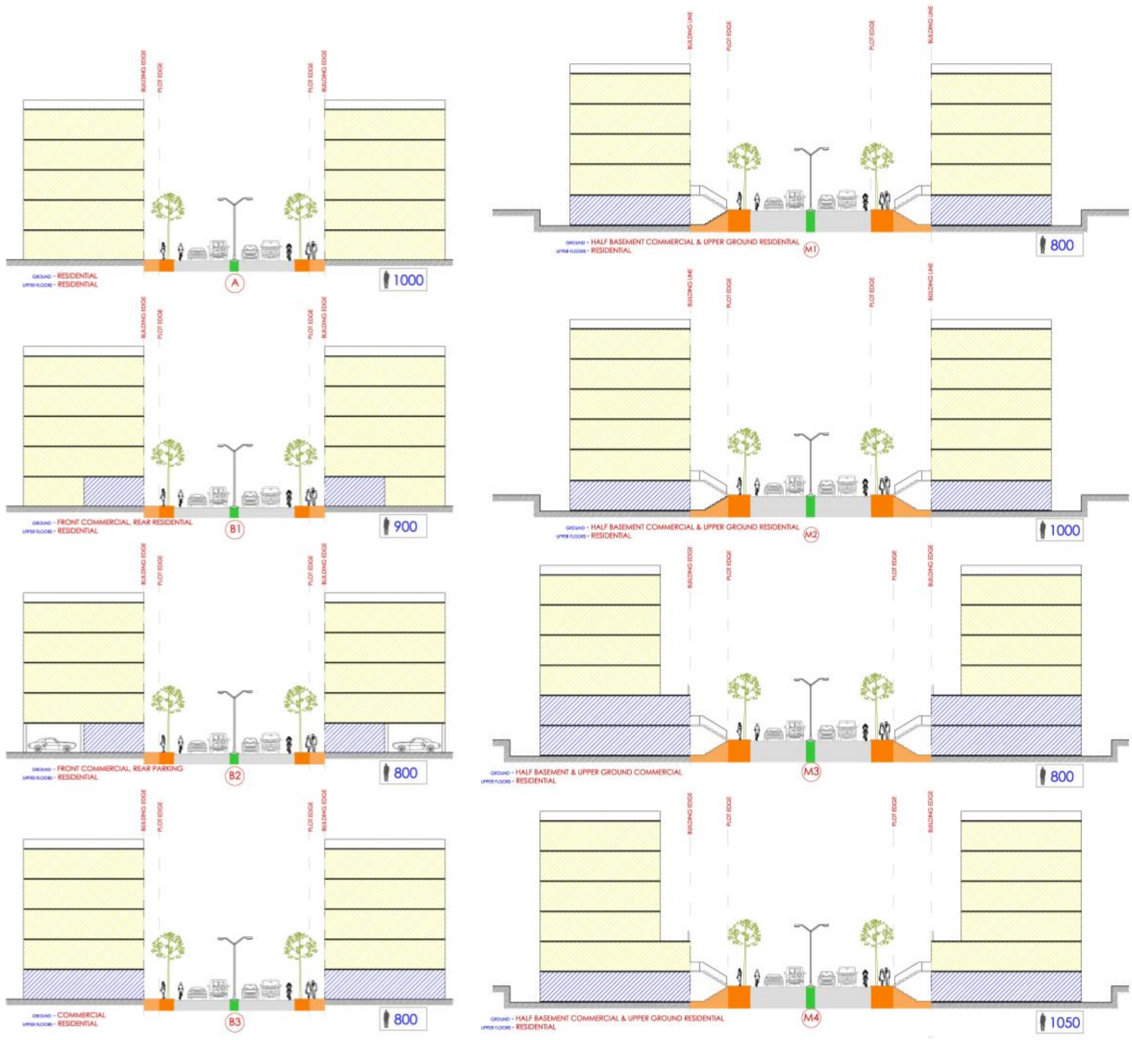


Figure 54 Configuration Options for Mixed Landuse Typology

Table 2 Mixed Use Typology and Density

S.No.	**Case G+4** (H<16.5m)	**Building Height** (Floor to floor 3m)	**Population**
1.	All Residential	15m	**1000**
2.	Half floor Comm., rest Resi.	15m	900
3.	Ground Floor Comm., rest Resi.	15m	800
4.	Half Basement Comm., rest Resi.	16.5m	**1000**
5.	Extended Half Basement and Ground Floor Comm., rest Resi.	16.5m	**1050**
6.	Extended Half Basement Comm., rest Resi.	16.5m	800

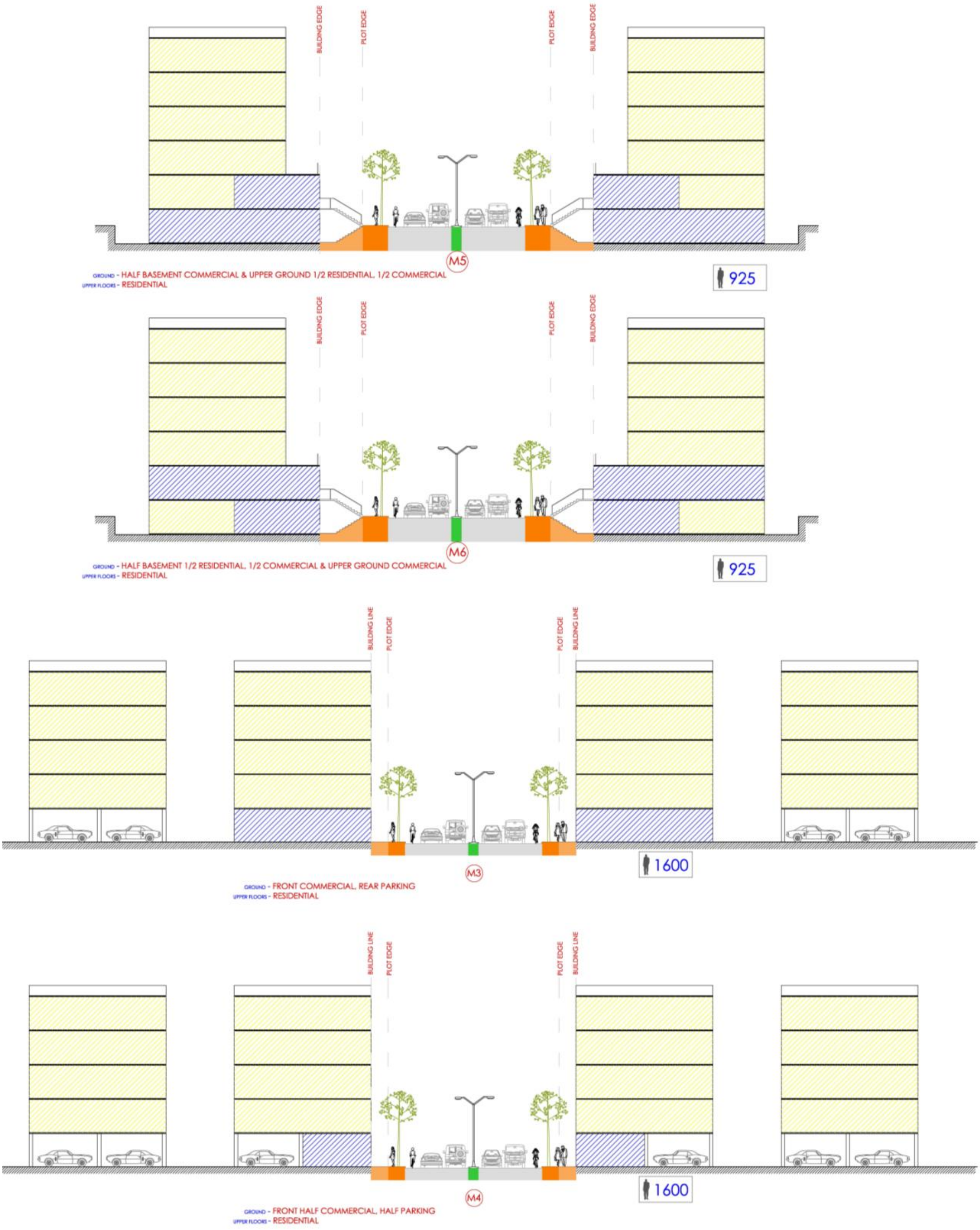


Figure 55 Mixed Landuse Typology and Optimum Density