Available online at http://www.journalcra.com

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 17, Issue, 05, pp.32717-32726, May, 2025
DOI: https://doi.org/10.24941/ijcr.48936.05.2025

ISSN: 0975-833X

REVIEW ARTICLE

DETERMINING A PLANTATION PLAN FOR OPTIMUM CO2 SEQUESTRATION IN MULTI-STORIED MULTI-TENEMENT BUILDINGS

Sumit Bose[1] and Madhumita Roy[2]

PhD scholar, Jadavpur University, Kolkata, India

ARTICLE INFO

Article History:
Received 18th February, 2025
Received in revised form
20th March, 2025
Accepted 11th April, 2025
Published online 28th May, 2025

Key words:

Householdcarbon footprint,CO^2 emission, urban residential buildings, climate change, carbon sequestration, home garden.

**Corresponding author: Sumit Bose*

ABSTRACT

The increasing concentration of GHG gases in the atmosphere is accelerating climate change and global warming.Urban residential buildings, which are one of the major emitters of Carbon Dioxide(CO2) gases amongst other GHGs must do something to bring about a change in emission scenario. This paper examines scope of sequestration of total operation phase CO2 emission from urban multi-tenement multi-storied residential buildings by plantation grown inside the plot.Quantitative analysis of CO^2 emitted by residential buildings and CO^2 sequestered by plantation grown withing the premises show that plantation in only 4% of the plot area, as per stipulation by local municipal authority, can sequester only close to 3.49% of the CO^2 emitted by the building. However, detailed study ofsite plans of different existing building in Newtown with respect to use groups like driveways, paved areas, services and mandatory open green space, show that there is scope of increasing this mandatory green open space by a considerable amount. Benefits in term of CO2 sequestration from this added green open space is also quite fair.This paper also finds that assuming a scenario with increased plantation, in added green open spaces, potted plants in areas designated for other uses like paving and services, plantation in terraces, vertical gardens at select places, plants in balconies, window ledges, more indoor plants, this proportion of CO2 sequestration can be increased to as high as 40% of what is emitted by the building itself.

Citation: Sumit Bose and Madhumita Roy. 2025. "Dynamics of personal-social counselling practices onadolescents' societal adaptation in Fako division, south west region of Cameroon*". International Journal of Current Research, 17, (05), 32717-32726.*

INTRODUCTION

The 'Paris Agreement' adopted within the United Nations Framework Convention on Climate Change (UNFCC), asks all the participating countries to limit global average temperature rise this century to below 2 Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 Celsius (Nations, United Nations Climate Change, 2015). Carbon Dioxide (CO^2) constitutes an important part of anthropogenic GHG –accounting for approximately 77% of the global total CO^2 equivalent GHG emission (T V Ramachandra, 2015)(Change, 2008). On the other hand, considering building life cycle theory the maximum emission comes from the 'Operation Stage' – ranging from approximately 70 to 85% of the total lifecycle emission.(Yan, 2018)**,** (Adalberth, 2000)(Mei Shang, 2021). (T Ramesh, 2012)(Fei Zheng Y. W., 2023). Hence the need for mitigation ofCO^2emission from building operation phase becomes of utmost importance. The increased carbon dioxide (CO^2) in the atmosphere can be removed from the atmosphere and stored in biological or geological mediums (kumar, 2006).Plants being the only source of carbon sequestration, can be given some importance in the building development so that it can sequester, if not the whole, a part of the CO^2 that the building emits. Home gardens (kumar, 2006) and indoor plants (Torpy, Irga, & Burchett, 2014), beside contributing to the exterior and interior visual aesthetics of residential houses, also play a vital role in purification of the indoor air quality as well as the air quality of the premises. This paper makes comparative study of CO^2 emitted by the building in operation phase and CO^2 sequestered by plants grown within the campus and tries to design an optimum plantation system for building sites for maximum mitigation goal through sequestration. The objective of the study is to propose a system for the urban administrators, town and urban planners, architects and designers and also the urban dwellers to follow, which will contribute, to whatever extent, towards mitigation of emission through plantation grown within the plot of the building. Existing building standards, rules and regulations in terms of open green areas and vegetation and plantation inside the plot need serious overhaul and proper study for the benefit of the future. This paper examinesexisting plantation scenario in multi-storied building plots in Newtown and scope of increasing it to an achievable limit and further quantifies the benefits in terms of sequestration as per the changed scenario.

Background

Research Field and Boundaries: With the intention of doing a study that will be more precise and keeping several limitations in mind, the research boundaries of this paper are set as -1) it studies buildings in urban agglomerates only, 2) it studies only residential buildings, 3) it assesses only the 'operation phase' of the building, 4)the character of the buildings this research focuses on are only multi-storied and multi-tenanted, 5) this paper studies emission of only Carbon Dioxide (CO^2)

Research gap – Existing research papers have mostly tried to reduce the CO^2 emission from buildings by working on alternate materials for building construction, finding more sustainable materials with low embodied energy or materials that effectively reduce energy consumption during operation stage by reducing heat consumption or by intervention at the design planning stage taking climatological factors into consideration for effective control of heat or light or ventilation. But sadly, we have never thanked the plants properly and made serious studies of their capabilities and contribution. Its high time we give some good research effort to do the same. Considering this fact, this research finds itself in the midst of a sea of scope to contribute to our goal of mitigation of emission control.

Study Area -Newtown (Rajarhat-NewTown), the planned satellite city of Kolkata City in the Indian state of West Bengal (Fig 01) is chosen as the site for this study. It is adjacent to Kolkata & Bidhan Nagar (also known as Saltlake) - the other planned satellite city of Kolkata. The Kolkata City, Bidhan Nagar and Newtown all are included in Kolkata Metropolitan Area. Started in 1990, Newtown is administered by NKDA (NewTown Kolkata Development Authority). Geographically the area of Kolkata, Bidhan Nagar and Newtown sits on the lower Gangetic Delta of eastern India. Latitude and longitude of Newtown are precisely 22.64° North and 88.48° East respectively, with an average elevation varying from approximately 3.0 meters to 10.0 meters. This research paper selects Newtown as the site of research study as it has strong scope of development in the urban and housing sector with proper sustainability approach (Table 01).

Pollution control guidelinesandrules- The "Ministry of Urban Development (MoUD)" launched the "Atal Mission for Rejuvenation and Transformation (AMRUT)" in 2015. The Department of Municipal Affairs, Government of West Bengal, which administers the Newtown area, launched the AMRUT in 2016. In an effort to lower emissions and other pollutants, the government of West Bengal and India has taken aggressive measures to enhance the amount of green space in urban areas. The authority has laid down various rules and regulations of which the following are quite relevant to our present study

- To reach a green cover of 15% in the urban areas by 5 yrs from its inception
- To make mandatory rules for all new housing schemes to have 15% green cover – this provision is to be considered during the time of sanction from urban local bodies.
- To encourage the involvement of citizens, communities, and private sectors in the creation and maintenance of urban green space
- To carry out tree census periodically
- To make obligatory the role of citizens to support tree preservation and to encourage plantation through incentives.
- To create nurseries to support plantation
- Terrace garden to be permitted to improve green space
- Attempt to be made to cover every building with tree lines around it

The Newtown Kolkata Development Authority (NKDA) building rule suggests building owners of plots less than 1500 sqm. to leave 4% area of the site as open green space as a step to counter carbon footprint.

Sources of Emission & Quantification: This paper identified sources of CO2 emission or activities of a urban multistoried and multi-tenement residential buildings which are responsible for CO^2 emission, based totally on existing literature review. The sources or activities are identified as follows - 1) Electricity consumption, 2) fuel consumption for cooking, 3) fuel consumption for vehicles, 4) respiration, 5) potable water consumption. However, this emission due to electric consumption has been considered in this paper as the building is solely responsible for it. CO^2 emission due to respiration by residents is generally skipped by all researchers. This paper for all CO^2 emission quantification process takes into account this emission from respiration with a view that it needs to be considered when CO^2 sequestration by plants inside the premises is studied.

Quantification results show that total annual CO2 emission from asingle multi-storied multi-tenement building,having six (6) number flats, studied in Newtown comes to 14.308 TonneCO2/ annum. Emission from electricity was 6.080 TonneCO2/annum, 4.525 TonneCO2/annum from respiration, 1.738 TonneCO2/annum from cooking fuel, 1.183 from water consumption and 0.782 TonneCO2/annum from fuel consumption due to automobile idling time. The percentage distribution of emission from different sources were approximately 42.21 % from electricity, 31.42% from respiration, 12.07% from cooking fuel, 8.21% from water consumption and 6.10% from automobile idling time fuel consumption.

LITERATURE REVIEW

It is provoking that not much research and investigation has been conducted on sequestration by plant species in tropical areas (Toochi, 2018). Some research work has been done considering Indian local trees, forestry, and agricultural lands. However, there is almost no literature on sequestration by urban home gardens or indoor gardens. The analysis faces significant challenges due to the absence of reliable inventories and inconsistencies in estimating the carbon sequestration capacity of residential gardens. (kumar, 2006). There is definitely a huge research gap in this field of carbon sequestration by local (West Bengal) urban home-grown small-size plants. Carbon Sequestration, as per all papers, totally depends on number of plants, volume or leaf area, the weight of plants, or physical conditions like water supply and light availability. With almost no relevant information on Carbon sequestration rates of small-size local plants, it becomes prudent enough to fall back on one or two research papers that are more appropriate and applicable considering all parameters. Out of all research papers studied, the papers by Torpi et al. (Torpy, Irga, & Burchett, 2014) studying carbon sequestration by indoor plants is worth mentioning as it is the only paper that, though based on foreign conditions, gives us information about indoor plants and also small plants. The author specifies that is very difficult to assess the rate of sequestration by plants as it depends upon the species type, physical conditions inside the house, and most importantly the lighting conditions. However, keeping aside the foreign conditions of the research study, dealing with mostly different species of trees not appropriate to tropical conditions, this research work still draws the sequestration rate factor for quantification of CO^2 consumed by indoor plants based on this paper (Torpy, Irga, & Burchett, 2014) only. The paper mentions that sequestration rate for indoor plants ranges from 47.9 $mgCO^2$/plant/hr to 168 $mgCO^2$/plant/hr, depending upon varying light conditions and different species. To deal with this huge range, this paper considers an average of this range, i.e. 107.95 $mgCO^2$/plant/hr = 0.001

$TonneCO^2$/plant/year (average of47.9 $mgCO^2$/plant/hr and 168 $mgCO^2$/plant/hr) as the sequestration rate for any indoor plant. The paper specifies some more information -1) highest sequestration rate is 657mgCO2/m2 leaf area/ hr, 2) 5m2 of green wall contains - 57m2 of leaf area, 3) 68mg CO2/m2 leaf area/hr is the sequestration rate for 'areca palm'. The other research paper where from analytical information can be used for this research work is the paper by CRISIL ((CERE), 2021). This research, though not dealing with entirely small home-grown plants, was based on entirely outdoor trees and plants in urban Indian context. There is information on small and mid-size outdoor trees and plants that are of Indian origin and are grown in urban areas with tropical hot and humid climates. A reference guideline for quantification of CO^2 sequestration by plants in Indian urban scenario can be drawn from CRISIL research work. The findings of the research work can be analyzed to deduce the average CO^2 sequestration by plants in Indian urban context as 8646.29 $MTCO^2$ by 33,368 trees over a span of 15 years or 0.019 $TonneCO^2$/plant/annum**.** Information from existing literature studies that is found to be useful for CO^2sequestration quantification in this research work are presented in Table 02–

METHODS AND MATERIALS

Identification of Sequestration rates and factors: The methodology adopted for quantification of total amount ofCO^2that can be sequestered by plants inside the premises of a multi-storied multi-tenement urban residential building has been based completely on inputs from existing research studies. The plants that can be found inside the premises is divided into three(3) groups – 1) out-door plants that can be grown in theopen spaces around the building, considering both, plants grown in unpaved green open spaces and plants grown in pots on paved areas and terraces, 2) Vertical gardens and 3) indoor plants that can be grown inside the building that is inside the flat areas or common areas, including balcony and window ledges. For calculation of CO^2 sequestration by outdoor small and medium ranged plants, data from CRISIL ((CERE)) experiments were adhered to – '33,368 trees and plants will sequester 8646.29 $MTCO^2$ over a span of 15 years', which gives an average rate of 0.017 $MTCO^2$/plant/year = 0.019 $TonneCO^2$/plant/year. For calculation of sequestration rate of indoor plants, data from research work of *Profiling indoor plants for the amelioration of high* CO^2 *concentrations by F.R. Torpy, P. Irga, M.D. Burchett* (F.R., P, & M.D.) were used - CO^2 sequestration level ranged from 47.9 to 168 $mgCO^2$/plant/hr for indoor plants, which means an average rate of 107.95 $mgCO^2$/plant/hr = 945642 $mgCO^2$/plant/year = 0.945 $KgCO^2$/plant/year = 0.001 $TonneCO^2$/plant/year. Green walls becoming popular these days, the scope of sequestration of CO^2 by green walls was also considered. For this quantification, data from *Profiling indoor plants for the amelioration of high* CO^2 *concentrations F.R. Torpy, P. Irga, M.D. Burchett* (F.R., P, & M.D.) was used.This research paper by *F.R. Torpy, P. Irga, M.D. Burchett* (F.R., P, & M.D.)gives two very useful information regarding plant growth and sequestration of CO^2 by green walls – 1) 5m2 of green wall contains - 57m2 of leaf area and 2) highest sequestration rate is 657 $mgCO^2$/m2 leaf area/ hr. This paper considers the first information as it is placed by the authors - 5m2 of green wall contains - 57m2 of leaf area or in other words 1sqm of green wall have 11.4 sqm of leaf area. However, the second information says that this is the highest rate of sequestration by plants. So, for a more reasonable research work, a much lesser value of 460 $mgCO^2$/m2 leaf area/hr (70% of the actual value) = 0.004 $TonneCO^2$/ m2/ year is considered as the average rate of sequestration by green walls

Quantification of Sequestration: The annual sequestration volume of CO2 by mid-size plants in green open spaces is quantified by multiplication of number of plants with the sequestration rate of a mid-size plant i.e. 0.019 $TonneCO^2$/plant/year. The number of plants that can be grown in the specific green open area is calculated by dividing the area by 0.36 sqm – assuming each home-grown mid-size plant to cover 0.6 m by 0.6 m area. The same procedure is applied to find sequestration volume of CO2 for mid-size plants grown in other areas like paved areas in ground floor and spaces in the terrace. Terrace plantation is calculated by assuming an area approximately 1.0m to 1.5m wide, all along the parapet wall, as per availability, dedicated to terrace garden. All areas are exactly plotted in terrace plans of all sample plots, checking feasibility and areas found out. Number of mid-size plants are quantified by dividing this area by 0.36 sqm as has been done for open green spaces in the ground floor. Sequestration rate of a mid-size potted plants in the terrace is taken as 0.019 $TonneCO^2$/plant/yeari.e. same as plants in green open space in ground floor. For vertical gardens, leaf area (sqm.) is first found out by multiplying the wall area value in sqm. with11.4 sqm assuming 1sqm of green wall have 11.4 sqm of leaf area. This value (area of leaf in sqm.) is multiplied by 0.004 $TonneCO^2$/ m2/ yearto find the sequestration volume of CO2 by vertical gardens.CO2 sequestration volume by indoor plants is obtained by multiplication of number of indoor plants with sequestration factor of indoor plants i.e. 0.001 $TonneCO^2$/plant/year. Total volume of CO2 sequestration is obtained by summation of all these CO2 sequestration volumes i.e. sequestration volume of CO2 by mid-size plants in green open spaces, by potted mid-size plants in areas in ground floor other that green open spaces, by mid-size plants in the terrace, by vertical gardens inside the plot and by indoor plants in the window ledges, balconies and inside the flats and common spaces.

Identification of optimal plantation scope: The number of plants that can be grown in a residential premises, inside the building or outside, is very difficult to ascertain. General reconnaissance survey and literature study showed that there is a general apathy towards growing trees and plants inside the premises in urban India and in Kolkata. Reasons are numerous - like building maintenance problems, damp and leakage problems in roof slabs when plants are grown in the terrace, mosquito and pest problems, lack of enthusiasm and support to take the responsibility of maintenance of plants, etc. With this scenario prevailing, this research paper considers two (2) scenarios to study the optimal and convenient plantation plan for different plots

Scenario 1 - It is assumed that the residential building restricts plantation area to only what is mandatory as per the NKDA municipal rules. The plantation area is only 4% of the plot area or as per sanction plan, which is open to sky and not paved, termed as 'green area' requirement as per existing municipal rule.

Scenario 2 – In scenario2, it is assumed that the plot has an enhanced plantation area, which comprises of the same 4% of the plot area as green space (open to sky and not paved) as per municipal rules and some more plantation in the paved or unpaved covered areas in the plot around the building and also some terrace garden. There is also some green vertical walls which can be accommodated in the open areas around the building and in the terrace along stair-head room or overhead reservoir. Added to these, there are indoor plants in individual flats or common areas like stairs or lift lobby.

To find the optimal plantation scope in the building site, it was found logical, to first find the existing land-use of the site i.e. how the surface of the site is being used for different uses. To do this sanction plan was considered as most reliable. Land use was categorized into 1) Covered building area 2) driveways, 3) paved areas other than driveways, 4) services areas and 5) green open space as per stipulated 4% of the plot area. All these areas were plotted in drawings and percentage distribution of land use was obtained. The CO2 sequestration scope of existing set-up was also quantified. In the next process, all areas, where there is further scope of plantation were identified – places in the site not used for any particular function, places with scope of green open space, places which are paved but can be used for potted plantation, places for potted planation in the terrace areas, places where vertical green walls can be accommodated. Further the cope of indoor plants are also investigated. With no logical way to quantify number of indoor plants in flats and indoor areas, it was decided to assume that each flat accommodated on an average 15 indoor plants – distributed inside the flats, window ledges, balconies and common spaces. CO^2 sequestration scope is calculated for both scenarios 1 & 2 and compared to the total CO^2 emission by the building during its operation stage.

Sample Survey

Sample survey design Considering 'Sample Survey' of a whole building complete, searching for energy use data, necessary information could be received from only one multi-storied, multi-tenement residential building in Newtown. Most flats in Newtown lying vacant or unoccupied, it was difficult to gather complete information from one whole building. Whereas, architectural plans of several buildings in Newtown could be gathered. With this situation there, this research paper analyses the information from one single building in Newtown, finds the mean annual CO2 emission/sqm. of built-up area and utilizes that mean value to predict total annual CO2 emission from other buildings. For sample survey a whole building, in Newtown, was chosen. The plot area 271.73 sqm. The ground covered area is 149.446 sqm. which is approximately 55% of the plot area, which is as per NKDA building rules the maximum ground coverage for residential plots less than 1500 sqm. The ground open space is 122.284 sq, which is about 45% of the plot area. Green open spaces (not paved) was introduced by NKDA to improve environmental aspects of urban areas like storm water management, heat-island, greeneries, etc. It is fixed at minimum 4% of the plot area. The green open space in this plot is 10.88 sqm, which is exactly the minimum area required (4%). The plot area, ground coverage, open spaces and other dimensions of open spaces of the plot like front open space, rear open space and side open spaces are mentioned in the Table 03. The front open space is 2.0 m, rear open space is 2.10 m, the side open spaces are 2.470 m and 1.3 m. (Table 03 & Fig 02).

For finding the scope of further plantation in building sites (**Scenario 2**), more plots (7 numbers) areexamined in detail and analyzed. Following the process as mentioned in methods section, existing ground space utilization, in all these plots are examined as per sanction plans, plotted in drawings and percentage coverage calculated. Ground floor space utilization is categorized into 1) built-up area, 2) drive ways, 3) other paved areas, 4) areas utilized for services mainly plumbing and sanitary and 5) mandatory green open spaces as per municipality stipulations. To investigate scope of further plantation in ground open space, areas which are not being utilized for any specific purpose but which have scope of green open space arefound out and plotted. Areas which are being used for different purposes but has scope of having potted plants are also plotted. The terrace areas are examined for plantations with potted plants in all samples. Vertical gardens are marked in ground floor areas and terrace searching for suitable ideal locations with proper sunlight. Number of indoor plants are assumed as 15 per flat.

The quantification process of CO^2 sequestration is as follows:

1)CO^2 sequestration from mid-size outdoor plants in green open space
= Number of plants x 0.019 TonneCO^2/plant/year
2)CO^2 sequestration from mid-size outdoor plants – potted and on paved areas
= Number of plants x 0.019 TonneCO^2/plant/year
3)CO^2 sequestration by potted plants at terrace
= Number of plants x 0.019 TonneCO^2/plant/year
4)1 sqm of green wall = 11.4 sqm of leaf area
CO^2 sequestration by green wall
= Green wall area(sqm) x 11.4 x 0.004 TonneC02/annum
5)CO^2 sequestration by indoor plants
= No. of plants x 0.001 TonneCO^2/year

RESULTS

Results of* CO^2*emissionQuantification

6.1.1 CO2 Emission in Sample 03: The quantification process was based on Sample Survey and application of most relevant consumption coefficients and emission factors. Survey data fromthe multi-storied, multi-tenement whole building (sample No. P-03), mentioned previously, were tabulated the total emission from building came to 14.404 TonneCO^2/annum. This paper considered all flats (6 nos.) and all common areas of the building. The total emission from electricity was 6.080 TonneCO^2/annum, 4.525 TonneCO^2/annum from respiration, 1.738 TonneCO^2/annum from cooking fuel, 1.183 from water consumption and 0.879 TonneCO^2/annum from fuel

Source Google Maps / New Town Development Authority, West Bengal

Figure 1. Map of Kolkata, Bidhan Nagar and Newtown

Table 1. Status of development in different sectors of New Town

Location	Action area-I	Action area-II	Action area-III	CBD
Area in hectares	677	1310	783	183
Progress of infrastructure development	All most complete	More than 50% work completed	Work in progress	Work in progress

Source - (Amar Biswas, May 2017)

Table 2. Sequestration Information obtained from Literature Review

Plant Category	Source	CO2 Sequestration rate	Rate/ coefficient/factor
Indoor Plants	(Torpy, Irga, & Burchett, 2014)	CO2 Sequestration rate by indoor plants	0.001 TonneCO2/plant/annum
Vertical Garden	(Torpy, Irga, & Burchett, 2014)	CO2 Sequestration rate by plants (as per leaf area)	657mg CO2/m2 leaf area/ hr,
	(Torpy, Irga, & Burchett, 2014)	5 sqm. of green wall contains	57 sqm. of leaf area
outdoor plants (mid-size)	CRISIL ((CERE), 2021)	CO2 sequestered by outdoor plants and small trees	0.019 Tonn CO2/plant/annum

Table 03. Particulars of Whole Building studied in New Town

	Areas & Dimensions			As per stipulated NKDA Building Rules
	Measurements as per site		% coverage as per Site	
	Quantity	Units		
Plot Area	271.73	sqm		
Covered Area	149.446	sqm	55.00 %	Maximum Ground Coverage for Residential Plots below 1500 sqm= 55%
Open Area	122.284	sqm	45.00 %	45%
Green Area	10.88	sqm	4.00 %	4 %
Open Paved Area	111.404	sqm	41.00 %	No Rules
Front Open Space	2.000	meters		1.2 M for residential buildings up to 15.1 m height
Rear Open Space	2.100	meters		2.0 M for Residential Plots upto 300 sqm and building height 15.1 M
Side Open Space (1)	2.470	meters		0.8 meters for plot area less that 300 sqm and building height less that 15.1 meters
Side Open Space (2)	1.300	meters		2.4 meters building height less that 15.1 meters

Table 5. Comparative contribution of 4% green open space in sequestration of emitted CO2 in sample plots

	Total Annual Emission	Plot area	Open green Space			CO2 emission reduction	
	(projected value based on emission results of sample 03)		(as per sanction plan - following stipulation of minimum 4% of plot area)			(through sequestration by plantation in green space of 4% provided as per sanction plan)	
	TonneCO2/annum	(sqm.)	(sqm.)	% of plot area	No. of plants (projected)	TonneCO2/annum	% of total emission
P-01	13.25	200.53	9.50	4.73	26	0.50	3.78
P-02	17.82	266.64	11.83	4.44	33	0.62	3.50
P-03	14.45	271.73	10.88	4.00	30	0.57	3.98
P-04	20.05	299.65	12.63	4.22	35	0.67	3.32
P-05	21.96	335.84	14.50	4.32	40	0.77	3.48
P-06	23.85	361.37	14.70	4.07	41	0.78	3.25
P-07	26.44	400.96	16.20	4.04	45	0.86	3.23
P-08	26.33	399.50	16.70	4.18	46	0.88	3.35
Mean Value of CO2 emission reduction by plants grown in open green space of stipulated 4% of plot area =							**3.49**

Mean value of sequestration by mid-size plants (covering 0.6m x 0.6 m = 0.36 sqm.) is 0.019 TonneCO2/annum (((CERE)); Assumption - Each plant takes an area of 0.6 m x 0.6 m.

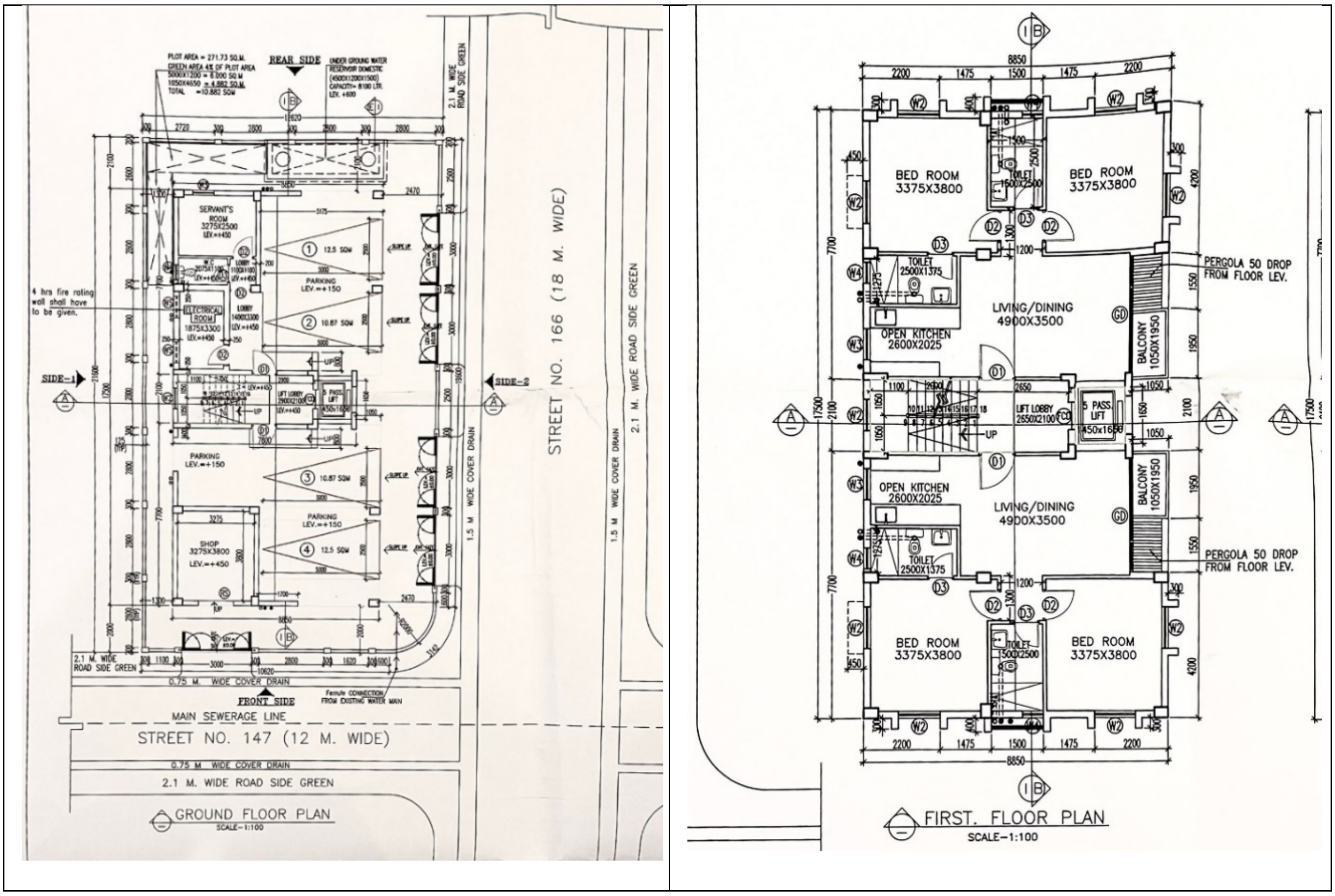

Figure 2. Ground Floor Plan & Typical Plan for 1st, 2nd and 3rd Floors

Table 06 - AREA DISTRIBUTION AS PER SANCTION PLAN IN SITES OF SAMPLE SURVEY

SL.No	Plot Area	Covered area		Open Area		Boundary wall		Driveway		Paved		Serives				Green Open Space		Further scope of open green		Total Green open space	Space remaining	
	Area (sqm.)	Area (sqm.)	%	Area (sqm.)	%	Area (sqm.)	%	Area (sqm.)	%	Area (sqm.)	%	Hard Surface / Area (sqm.)	%	Underground Area (sqm.)	%	Area (sqm.)	% (A)	Area (sqm.)	% (B)	% (A+B)	Area (sqm.)	%
P - 01	200.53	110.44	55.07	90.09	44.93	7.30	3.64	33.75	16.83	5.79	2.89	6.29	3.14	23.33	11.63	9.50	4.73	2.56	1.28	**6.01**	1.58	0.79
P - 02	266.64	148.50	55.69	118.14	44.31	8.00	3.00	41.92	15.72	11.41	4.28	8.50	3.19	23.69	8.88	11.83	4.44	11.20	4.20	**8.64**	1.60	0.60
P - 03	271.73	150.49	55.38	121.24	44.62	7.94	2.92	39.96	14.71	7.55	2.78	8.33	3.07	16.04	5.90	10.88	4.00	19.40	7.14	**11.14**	11.14	4.10
P - 04	299.65	167.12	55.77	132.53	44.23	8.76	2.92	19.81	6.61	23.21	7.75	7.60	2.54	27.55	9.19	12.63	4.22	20.26	6.76	**10.98**	12.71	4.24
P - 05	335.84	183.00	54.49	152.84	45.51	9.13	2.72	40.06	11.93	0.00	0.00	5.50	1.64	19.34	5.76	14.50	4.32	38.86	11.57	**15.89**	25.45	7.58
P - 06	361.37	198.72	54.99	162.65	45.01	9.81	2.71	11.61	3.21	0.00	0.00	8.00	2.21	34.53	9.56	14.70	4.07	40.60	11.24	**15.30**	43.40	12.01
P - 07	400.96	220.30	54.94	180.66	45.06	10.40	2.59	87.89	21.92	0.00	0.00	5.50	1.37	17.07	4.26	16.20	4.04	21.77	5.43	**9.47**	21.84	5.45
P - 08	399.50	219.41	54.92	180.09	45.08	9.91	2.48	63.60	15.92	5.57	1.39	7.59	1.90	26.86	6.72	16.70	4.18	44.39	11.11	**15.29**	5.48	1.37

Table 07 - Scope of emission reduction through sequestration by enhanced plantation in sample plots

	Total Annual Emission	Plot area	Open green Space						Potted Plants in areas other than green open space in ground floor			Potted Plants in terrace			Green vertical wall			Indoor Plants		TOTAL EMISSION REDUCTION	
	(projected value based on emission results of sample 03)		existing - as per 4% Rule	Further scope of green open space	Total Green Open Space (as per 4% + proposed additional space)			emission reduction	Potted mid-size plants in areas other than green open space		emission reduction	Potted mid-size plants in terrace		emission reduction	Area for vertical wall	leaf area	emission reduction	No. of plants assumed	emission reduction		
	TonneCO2/annum	(sqm.)	(sqm.)	(sqm.)	(sqm.)	% of plot area	Total number of mid-size plants	Tonne CO2/ annum	(sqm.)	Total number of mid-size plants	Tonne CO2/ annum	(sqm.)	Total number of mid-size plants	Tonne CO2/ annum	(sqm.)	(sqm.)	Tonne CO2/ annum	Numbers	Tonne CO2/ annum	Tonne CO2/ annum	% of total emission
P-01	13.25	200.53	9.50	2.56	12.06	6.01	33	0.64	8.33	23	0.44	44	122	2.32	30.2	344.28	1.38	120	0.12	4.90	36.94
P-02	17.82	266.64	11.83	11.20	23.03	8.64	64	1.22	24.86	69	1.31	45.5	126	2.40	81.1	924.54	3.70	120	0.12	8.75	49.09
P-03	14.45	271.73	10.88	19.40	30.28	11.14	84	1.60	14.90	41	0.79		0	0.00	60.2	686.28	2.75	120	0.12	5.25	36.34
P-04	20.05	299.65	12.63	20.26	32.89	10.98	91	1.74	16.00	44	0.84	49	136	2.59	59.19	674.77	2.70	120	0.12	7.99	39.82
P-05	21.96	335.84	14.50	38.86	53.36	15.89	148	2.82	19.50	54	1.03	69.8	194	3.68	58.7	669.18	2.68	120	0.12	10.32	47.01
P-06	23.85	361.37	14.70	40.60	55.30	15.30	154	2.92	23.80	66	1.26	53.4	148	2.82	73.86	842	3.37	120	0.12	10.48	43.95
P-07	26.44	400.96	16.20	21.77	37.97	9.47	105	2.00	13.20	37	0.70	52	144	2.74	70.64	805.3	3.22	120	0.12	8.79	33.24
P-08	26.33	399.50	16.70	44.39	61.09	15.29	170	3.22	19.75	55	1.04	27.8	77	1.47	38.4	437.76	1.75	120	0.12	7.60	28.88
Mean Value of CO2 emission reduction by plants grown in open green space of stipulated 4% of plot area =																					39.41
Mean value of sequestration by mid-size plants (covering 0.6m x 0.6 m = 0.36 sqm.) is 0.019 TonneCO2/annum (((CERE))																					
Assumption - Each plant takes an area of 0.6 m x 0.6 m.																					

consumption due to automobile idling time. The percentage distribution of emission from different sources were approximately 42.21 % from electricity, 31.42% from respiration, 12.07% from cooking fuel, 8.21% from water consumption and 6.10% from automobile idling time fuel consumption.

CO2 Emission in other Samples (01,02,04,05,06,07,08): As has been said earlier, due to lack of complete information from all buildings, the quantification of CO2 emission process was restricted to only one single building in Newtown, where from all information could be gathered, and this information was analysed to find the mean annual CO2 emission/sqm. of built-up area. This mean value is utilized to predict total annual CO2 emission for other buildings. The results of quantification of total annual emissionof all 8 buildings are presented in Table 04.

Analysis forCO^2 Emission – Sequestration Balance

Scenario 01 –4% green open space - Sample 03: Primary objective of this research paper being quantification of CO^2emission during operation stage of a multi-storied multi-tenement urban residential building and the sequestration potential of plants grown inside the premises, there arises the need to compare the CO^2 emitted by such buildings and theCO^2 that can be sequestered by plants inside the premises. For this study the multi-storied multi-tenement urban residential building surveyed and analysed in this paper is taken for consideration. The total CO^2 emission from this residential building (considering the whole building with six number flats and common areas), as quantified previously, is 14.182 $TonneCO^2$/annum. This plot has an area of 271.182 sqm. Out of this, the covered area (covered by building) is 149.446 sqm. (55% of plot area) and the open area (open to sky) is 122.284 sqm. (45%). Terrace area is 149.446 sqm. Green open area not paved is 10.88 sqm. (4% of plot area as per building rules). The side open spaces are 2.47 m and 1.3 m and the front open space and rear open spaces are 2.0 m and 2.1 m respectively. Quantification of sequestration considering plants in only 4% green space for plants as per existing building rules - Considering there is only 10.88 sqm. green area (minimum 4% of plot area as per NKDA building rules), and there are only mid-size plants, each on an average covering 0.6m x 0.6 m = 0.36 sqm approximately, there can be approximately 30 number such plants in the site. Considering them as outdoor plants with CO^2 sequestration rate as 0.019 $TonneCO^2$/plant/year, the annual total CO^2 sequestration from the building comes to 0.57 $TonneCO^2$/annum. Considering that there are no other plants in the site, this quantity of CO^2 sequestered when compared to the total annual CO^2 emitted by the building (14.182 $TonneCO^2$/annum) becomes too negligible. The amount of CO^2 sequestered by plants grown inside the site comes to only 4.0% of the total annual CO^2 emission.

Scenario 01 - 4% green open space - Samples (01,02,04,05,06,07,08): Applying the same quantification method and same assumption that there is no plantation other than what is there in the stipulated open green space (4%) the sequestration potential of all 8 samples are found out. The sequestration scope of mandatory green open space of all 8 samples are shown in Table 06.It is evident from analysis of data in Table 07that mean value of annual emission reduction by the process of sequestration of CO2 carried out by plantation in 4% area of the respective plots is 3.49% or in other terms the plantation in 4% stipulated open green space can annually sequester approximately 3.49% of the total annual CO2 emission by the building itself (Table 05).

Scenario 02 – enhanced plantation - all Samples - 01,02,03,04,05,06,07,08: Reconnaissance survey in Kolkata and Newtown showed that there are many multi-storied multi-tenement urban residential buildings where there are, other than love for plants, a higher degree of awareness and appreciation for benefits of keeping plants inside the site. There are many premises which grow plants and trees more than what is typically prescribed by the law. As a hypothetical case this paper considers the same plot, being studied in Newtown, with increased number of plants than what can be accommodated in the minimum 4%. The detailed examination of use of land area of different plots studied in sample survey showed that there is much scope of increasing the green open space from the stipulated 4% (Table 06). This can be raised by further 2-12% of the plot area. This finding certainly raises hope of better emission reduction scope through sequestration by plantation in green open spaces in samples studied and other plots as well.

Tabulation, quantification and analysis CO2 emission through added plantation in extra green open space (raised from stipulated 4%), potted plants in suitable places in the ground floor and terrace, vertical gardens in appropriate places and indoor plants, show that CO2 emission reduction through sequestration by plants can be increased to a great extent. The annual mean value of reduction of CO2 emission comes to about 39.41% of the total CO2 annual emission, which is quite encouraging. The analysis (Table 07) also shows that the roles played by the enhanced green open space, potted plants in the ground floor and terrace, vertical gardens, and indoor plants are encouraging and emission reduction by them, though small, adds up to make a creditable amount.

CONCLUSION

With respect to emissions and Climate Change scenario at present in the world, the future is generally depicted as a matter of concern and calls for responsible response from everyone in this society. Urban buildings, taken collectively,being one of the biggest contributors of this emission, the urban residents, along with planners, architects, designers, policy makers and also researchers need to whole-heartedly contribute to this process of mitigation. The building must do something to bring about a change in emission scenario – it must show some responsibility. The urban residential building must reduce CO^2mission to the maximum extent and plantation within the premises should be encouraged to the maximum. There should be an all-out effort to maintain balance betweenCO^2emitted by the building and CO^2 absorbed by plants grown inside the premises. As per findings of this paper, the mandatory green open space of 4%, as stipulated by the municipal authority (NKDA) of Newtown, is being able to sequester only about 3.49% of the CO^2 being emitted by the building in the same plot. A detailed study of ground coverage distribution of multi-storied and multi-tenement residential building plots, in Newtown, shows that there is quite a fair scope of increasing area designated for green open space, from the stipulated 4%, in all building sites, leaving aside all spaces for boundary walls, driveways, paved areas or walkways, areas designated for services, etc. For small residential plots, whose areas range from 200 sqm. to 300 sqm. the mandatory 4% green open space can be increased to 6-10%. For small residential plots, whose areas range from 300 sqm. to 400 sqm. the mandatory 4% green open space can be increased to 10-16% approximately. With this increase in green open space, CO2 sequestration level can also be increased by 2-6% in small plots of 200 sqm. - 300 sqm. and 5-10%. CO2 sequestration level achieved will by 6-8% small plot sizes and 10-15% for bigger plots. This CO2 sequestration by home grown plantation in open green space, though small and almost nothing compared to the amount of CO2 emitted by the building, will, for sure, add a very important value to the mitigation of CO2 and any increase in open green space area in residential plots will more than welcome. Apart from the increased CO2 sequestration this will also add to better storm water management, heat-island, greeneries, aesthetics. Findings of this paper definitely call for a better look at the stipulated minimum green open space of 4% by the municipal authority.

This paper also suggests that in case of an increased plantation scenario, added to the plantation in 4% green open spaces, i.e. plants grown in pots on some paved areas or service areas of the site, over under-ground water reservoir, in the terrace, some vertical gardens and indoor plants inside flats, the CO2 sequestration level can be increased to as high as 40%. Analysis has showed that for buildings on plot size (300sqm- 400sqm) – approximately 30-80 sqm of vertical gardens, 8-24 sqm of potted plantationin ground space, sqm as roof garden, … sqm of ledge gardens attached to verandahs and windows, apart from some indoor plants can be arranged. For …..buildingson plot size (300sqm- 400sqm) – approximately … sqm of vertical gardens, … sqm of plantation in pots in ground space, 27-69 sqm as roof garden, apart from some indoor plants can be arranged. In this situation and increased number of plantations involving green open space not paved or paved, terrace garden, indoor plants and vertical gardens are to be encouraged.

With a reduction of approximately 40% of the total CO2 emission from a residential building through sequestration by plantation grown inside the premises, there arises the responsibility of finding mitigation scope through other means so that a net-zero emission building can be achieved. This paper finds from literature review that better designs based on climatology and sustainability reduces the Operational Energy (OPE) to a great extent. Use of alternate materials with low thermal conductivity and proper insulation of roof and walls reduces the OPE to the extent of 20-30%. The maximum emission of CO2 being from use of electricity and use of fuel for automobiles, there comes the need to reduce use of energies like electricity and fuel for automobiles. replace conventional energy with Renewable Energy (RE) and Electric vehicles. The need of the hour is to cut down on all kinds of fossil fuel use for running automobiles, cooking and heating purpose. There is huge scope of reduction of CO2 emission in the field of Potable Water Production (PWP) by reducing energy consumption during production, distribution and end-use phases. Building household activities like use of solar energy for water heating, optimal use of water, reduction of leakage, reuse of reclaimed water, efficient water harvesting, etc. can reduce emission immensely. To save the world, a very conscious and scientific effort consisting of various mitigation approaches are required – and the building can play a very important part in it.

REFERENCES

(CERE), C. f. (2021). *CRISIL FOUNDATION - CARBON SEQUESTRATION STUDY REPORT 2021.* Centre for Environmental Research and Education (CERE).

(CERE), C. F. (2021, November). *CRISIL Foundation- Carbon Sequestration Study Report 2021.* CRISIL Foundation.

Adalberth, K. (2000). *Energy Use and Environmental Impact of New Residential Buildings.* Lund: Lund University of Technology.

Administration, U. D. (1998). *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings.* U.S. Department of Energy Energy Information Administration.

Amar Biswas, D. O. (May 2017). Rajarhat New Town an Urban Perspective : A Case Study of Urbanization, West Bengal, India. *International Journal of New Technology and Research (IJNTR)*, 39 to 44.

Biswajit, M. D. (Jan-Feb 2020). Effective Sewerage and Drainage for Smart City. *IOSR Journal for Mechanical and Civil Engineering (IOSR-JMCE)*, 50-54.

CENSUS, O. o. (2011). *CENSUS, INDIA.* Office of the Registrar General & Census Commissioner, India, Ministry of Home Affairs, Government of India. Retrieved 2011, from https://censusindia.gov.in/census.website/data/population-finder

Central Electricity Authority, M. o. (2023). *CDM – CO2 Baseline Database for the Indian Power Sector, User Guide - Version 19.0.* Central Electricity Authority, Ministry of Power, Government of India.

Champions, U. C.-l., IRENA, & IEA. (2023). *The Breakthrough Agenda Report 2023 - Accelerating Sector Transitions Through Stronger International Collaboration.*

Change, I. P. (2008). *Climate Change Report 2007, Synthesis Report.* Intergovernmental Panel on Climate Change.

Cho, S.-H., & Chae, C.-U. (2016). A Study on Life Cycle CO2 Emissions of Low-Carbon Building in South Korea. *Sustainibility*, Volume 8 , Issue 6.

Duarte, Y. T. (2007). Direct and indirect metabolic CO2 release by humanity. *Biogeosciences*, Volume 4, Pages 215-217.

F.R., T., P, I., & M.D., B. (December 2014). Profiling indoor plants for the amelioration of high CO2 concentrations . *Urban Forestry and Urban Greening*, Volume 13 Issue 2 Pages 227 - 233.

Fei Zheng, Y. W. (2023). Correlations between Spatial Morphological Indices and Carbon Emission during Operation Stage of Built Environment for Old Community in Cold Regions. *MDPI*, 2.

Fei Zheng, Y. W. (2023). Research on the Correlations between Spatial Morphological Indices and Carbon Emission during the Operational Stage of Built Environments for Old Communities in Cold Regions. *MDPI*, 13092222.

Feng, K. H. (2016). Carbon implications of China's urbanization. *Energy, Ecology and Environment* , Volume 1, pages 39–44. Retrieved from https://doi.org/10.1007/s40974-016-0015-

Gielena, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (April 2019). The role of renewable energy in the global energy transformation. *Science Direct -Energy Strategy Reviews*, Volume 24, Pages 38-50.

Gould, C. F., & Urpelainen, J. (2018, November). LPG as a Clean Cooking Fuel: Adoption, Use, and Impact in Rural India. *Energy Policy*, 122 : 395-408.

Group), P. (. (2016). *Residential Electricity Consumption in India : What do we know ?* Prayas (Energy Group).

Gui, Z., Qi, H., & Wang, S. (2024). Study on Carbon Emissions from an Urban Water System Based on a Life Cycle Assessment: A Case Study of a Typical Multi-Water County in China's River Network Plain. *Sustainability* , Vol 16 Issue 5.

Gui, Z., Qi, H., & Wang, S. (2024). Study on Carbon Emissions from an Urban Water System Based on a Life Cycle Assessment: A Case Study of a Typical Multi-Water County in China's River Network Plain. *Sustainability* .

kumar, B. M. (2006). CARBON SEQUESTRATION POTENTIAL OF TROPICAL HOMEGARDENS. *Springer Nature Link*, 185 - 204.

Li, M., Bekö, G., Zannoni, N., Pugliese, G., Carrito, M., Cera, N., . . . Nobre, P. (August 2022). Human metabolic emissions of carbon dioxide and methane and their implications for carbon emissions . *Science of The Total Environment ScienceDirect*, Volume 833.

Lief Gustavsson, A. J. (February 2010). Life cycle primary energy analysis of residential buildings. *ELSEVIER-Energy and Buildings*, Volume 42, Issue 2, Pages 210-220.

Lim SS, V. T.-R.-C. (2012 , December 15). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*, 2224-60.

Lin, B., & Liu, H. (2015). CO2 emissions of China's commercial and residential buildings: Evidence and reduction policy. *Building & Environment*, Pages 418 - 431 ; volume 92.

Mei Shang, H. G. (2021). A study of carbon emission calculation of residential buildings based on whole life cycle evaluation. *E3S Web of Conferences*, 7.

Ministry of Health and Family Welfare, G. o. (2021). *National Family Health Survey (NFHS-5) 2019-21.* Ministry of Health and Family Welfare, Government of India.

Mithraratne, N., & Vale, B. (April 2004). Life cycle analysis model for New Zealand houses. *ELSEVIER - Building and Environment*, Volume 39, Issue 4, Pages 483-492.

MohammadT.Alresheedi, Haider, H., Shafiquzzaman, M., & AlSaleem, S. S. (2022). Water–Energy–Carbon Nexus Analysis for Water Supply Systems with Brackish Groundwater Sources in Arid Regions. *Sustainability* , Volume 14 Issue 9 10.3390/su14095106.

Nair, S., Hashim, H., Hannon, L., & Clifford, E. (2018). EndUseLevel Water andEnergy Interactions: A Large Non-Residential Building Case Study. *Water*, Volume 10, Issue 6, 10.3390/w10060810.

Nations, U. (2015). *United Nations Climate Change*. Retrieved from https://unfccc.int/most-requested/key-aspects-of-the-paris-agreement

Nations, U. (2018). *World Urbanization Prospects.* United Nations.

Nowak, R. A. (1991). Quantifying the Role of Urban Forests in Removing Atmospheric Carbon Dioxide. *International Society of Arboriculture (ISA)*.

Pritom Bhowmik Akash, P. C. (2024 september). Assessment of carbon footprint of potable water production: A case from Bangladesh. *Science Direct - Green Carbon*, Volume 2, Issue 3, Pages 339-349.

Ramesh, T., Prakash, R., & Shukla, K. K. (January 2012). Life cycle energy analysis of a residential building with different envelopes and climates in Indian context. *ELSEVIER -Applied Energy*, Volume 89, Issue 1, Pages 193-202.

Rui Huang, S. Z. (2018). Comparing Urban and Rural Household CO2. *MDPI Energies*.

T Ramesh, R. P. (2012). LIfe cycle analysis of residential building with different envelopes and climates in Indian context. *ELSEVIR*, 193-202.

T Sadashivam, S. T. (2016). Trends of urbanization in India : Issues and challenges in the 21st century . *IJIRR*, 2375.

T V Ramachandra, B. H. (2015). GHG footprint of major cities in India. *Science Direct*, 473 - 495.

Tan, H., Hao, X., & Hu, J. (September 2019). Building envelope integrated green plants for energy saving. *Sage journals*, Volume 38, Issue 1, Pages 222 - 234.

Tenhunen, S. (September 2021). *Energy Performance of Buildings Directive 2010/ 31/EU: Fit for 55 revision.* EPRS | European Parliamentary Research Service.

Toochi, E. C. (2018). Carbon sequestration: how much can forestry sequester CO2? *MedCrave*.

Torpy, F., Irga, P., & Burchett, M. (2014). Profiling indoor plants for the amelioration of high CO2 concentrations . *Urban Forestry & Urban Greening*, Vol- 13, Issue- 2.

United Nations Environmental Programme, &. G. (2024). *Global Status Report for Building and Construction-Beyond Foundations : Mainstreaming sustainable solutions to cut emissions from building sector.* United Nations.

Utama, A., & Gheewala, S. h. (November 2009). Indonesian residential high rise buildings: A life cycle energy assessment. *ELSEVIER - Energy and buildings*, Volume 41, Issue 11, Pages 1263-1268.

VanGeem, M. L. (2008). *Comparison of the Life Cycle Assessments of an Insulating Concrete Form House and a Wood Frame House.* Illinois, USA: Portland Cement Association .

Xiaomei Yan, S. C. (2018). Carbon Footprints of Urban Residential Buildings: A Household Survey-Based Approach. *MDPI*, article number 1131.

Yan, X. C. (2018). Carbon footprints of urban residential buildings: a household survey-based approach. *MDPI*.

Zimmerman, H. J. (2005). Benchmars for sustainable construction A contribution to develop a standard. *Elsevier*, 1147-1157.

****