

Integration of Solar from Buildings to Cities

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Integration of Solar and Green roof Potentials in Delhi



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Green Roofs??

A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and growing medium, planted over a water proofing membrane.

Source: [The why and how of home horticulture](#) by D.R. Beinz

KEY RESEARCH QUESTIONS

- How green roofs can help to boost the photovoltaic performance?
- How can Rooftop gardens address urban environmental issues?
- Potentials of solar roofs in Delhi?

CONCEPTS OF ROOFTOP GARDENS

Rooftop gardens concept is not the new concept, since the **Mesopotamia region** Green roofs are in practice.

Civilizations built landings of

Ziggurats

Stepped Pyramids.

Hanging Gardens

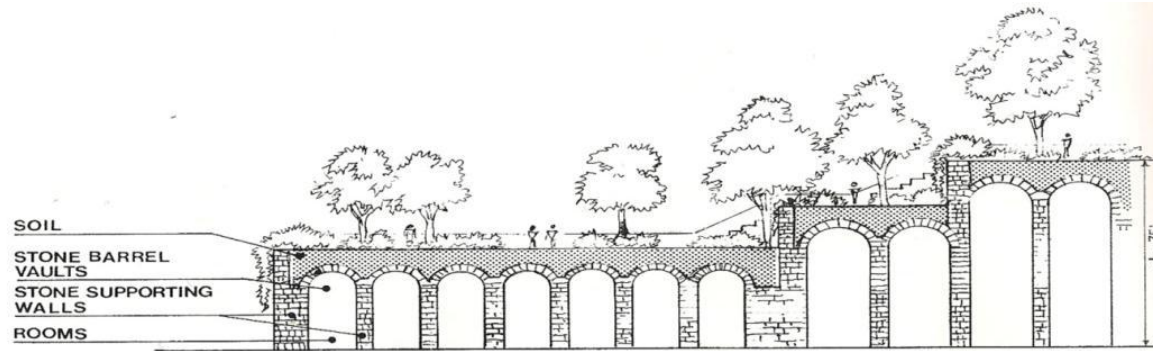


Figure 1 The section drawing of the Hanging Garden of Babylon

Typology of Green Roofs

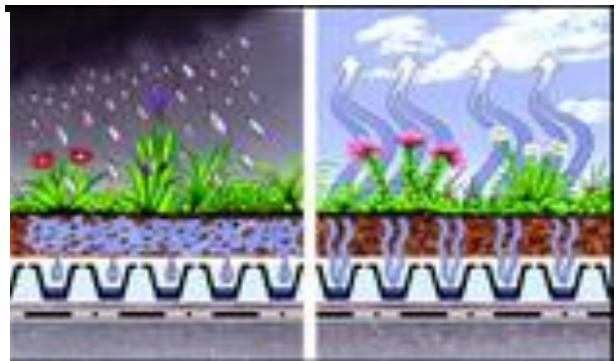
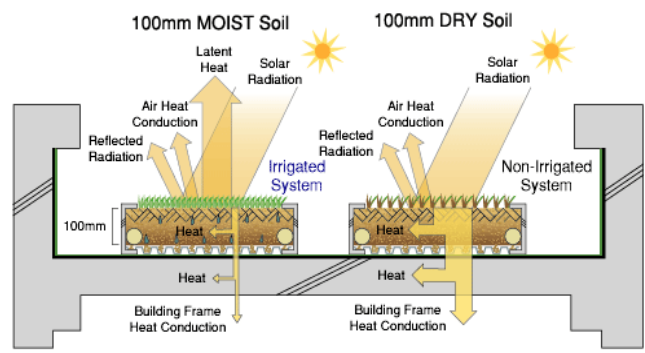
CHARACTERISTICS	EXTENSIVE	INTENSIVE	SEMI-INTENSIVE
Depth of material	6" (15.2 cm or less)	More than 6"	4"-6"
Accessibility	Often accessible	Usually accessible	Partially accessible
saturated weight	Low (48.4-170 kg/sq m)	High (244.1-1,464 kg/sq m)	Varies (170.9-244.1 kg/sq m)
Plant diversity	Low	Greatest	Greater
Cost	Low	High	Varies
Maintenance	Minimal	High	Varies

Source: 1 Green roofs in sustainable Landscape Design
Steven L. Cantor

Performance boost by combining a solar roof-garden with solar photovoltaic panels

1. Evapo-transpiration

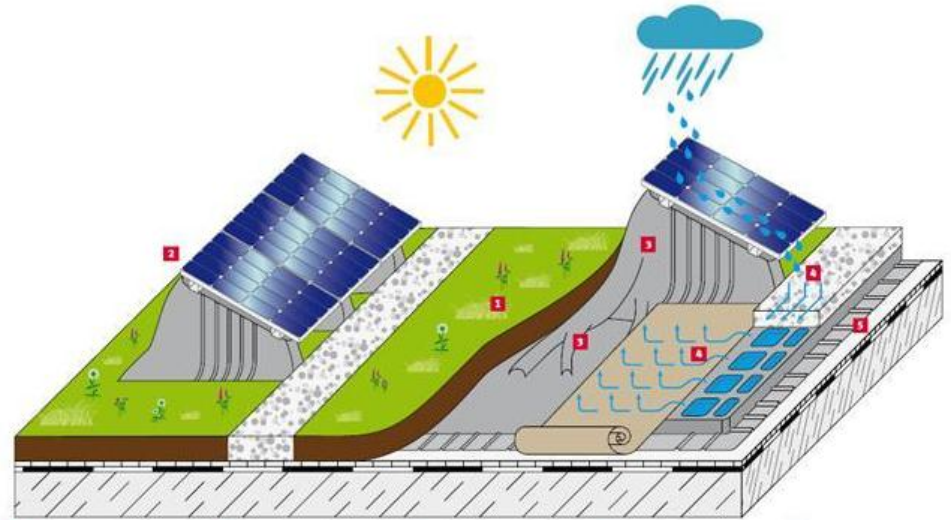
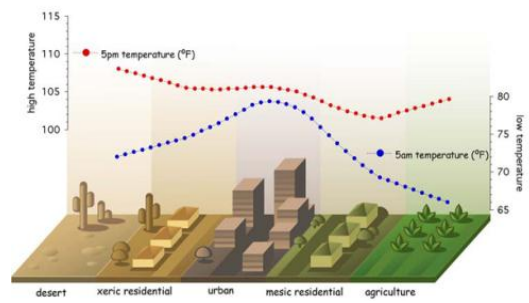
Evapo-transpiration & shading from the plant cover reduced up to **90%** in solar gain and Indoor temperature decrease of 3-4°C may be attained.



In internal building temp by 4°C may reduce electricity consumption

2. Small air conditioners for the heat sensitive PV elements

3. Urban Heat Island Effects



4. Reduce air born pollutants Less dirt on the photovoltaic panels equals **better performance** and less maintenance.

5. Reduce energy budgets (reducing heating & cooling costs) of individual buildings

SUBJECT	GREEN ROOF	CONVENTIONAL ROOF
Volume retention	10-35% during wet season,65-100% during dry season	None
Improved water quality	Retains atmospheric deposition and retards roof material degradation Reduced volumes reduce pollutant loading	No
Air quality	Filters air, stores carbon, increases evapotranspiration	None
Habitat	For insects and birds	None
Livability	Buffer noise, offers passive recreation	None
Costs	Highly variable from Rs 3200-7740 /Sqm new construction and Rs 4500-12,900 /sqm	Highly variable from Rs 1300-6420/sqm
Durability	Waterproof membrane protected from solar and temperature exposure lasts more than 20 years.	lasts less than 20 yrs

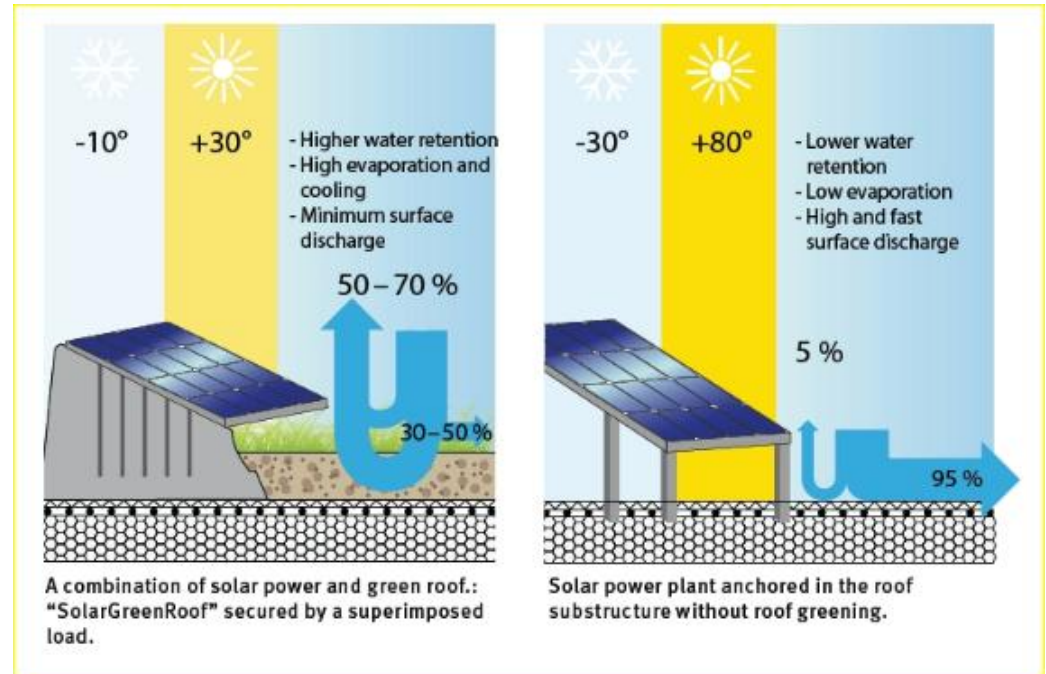
6. Shade imposed by panels may enhance the biotic productivity of green roofs.

Consequently,

when having to make a decision about either of these solutions, it is important to note how the combination of both roof solar panels and a green (vegetated) roof,

can offer extended benefits that are

- ✓ FINANCIAL
- ✓ ENVIRONMENTAL
- ✓ ARCHITECTURAL



Private and Public benefits

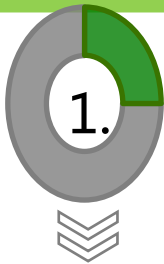
Scale of Development	values associated with the construction			
	Economic	Social	Environmental	Aesthetic
Private Development (apt/single family dwelling)	Reduction energy costs	Outdoor gathering space	Clean air, free of pollution	Aesthetic pleasure for the owner
Public Development (Institutional, Municipal infrastructure, Industrial & Ecology)	Reduction in energy Costs Moderation of internal temperature	Healthy Work environment Lower air pollution thus health benefits for users Bio-remediation: Native grasses & plants rid the soil of contaminants	Microclimate formulation Water management system storm water runoff reduction Protection from UV radiation Urban heat Island Mitigation Ecosystem restoration Providing habitats for native plants, birds & insects.	Communal & neighbourhood appreciation

POTENTIAL OF GREEN ROOFS & SOLAR PANELS IN CASE OF DELHI

CASE EXAMPLE : DELHI

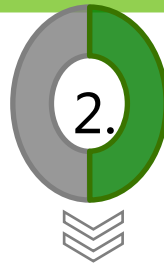
Delhi is the city that has claimed to be the world's greenest capital.

- The electricity demand in very high as we compare with the other states,
- Delhi requires **6,000 MW** in **summer** its more than 17 states required this ultimate results in the shortage of power.



ENERGY SAVING

Combining the energy savings from a roof garden



BOOST PERFORMANE

Together with the boost effect on the performance of photovoltaic panels



REDUCE COST

Can help reduce solar panel costs



CONCLUSION

can offer extended benefits that are

- ✓ FINANCIAL
- ✓ ENVIRONMENTAL
- ✓ ARCHITECTURAL

Solar, as a locally available, environmentally friendly and increasingly viable source of power can provide Delhi with an attractive long-term power supply option

DELHI Hot – Arid Region

The regions are characterized by clear sky, dry atmosphere, extended periods of **overheating** large diurnal temperature range.

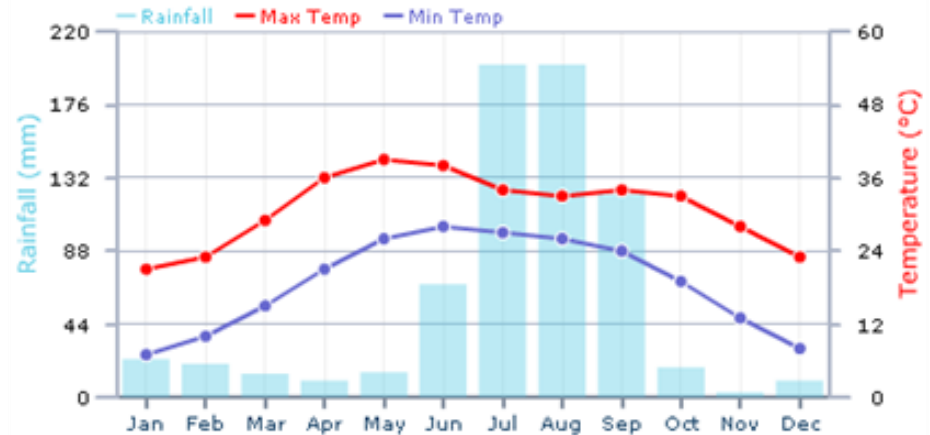
Climate data for Delhi

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	21.1 (70)	24.2 (75.6)	30.0 (86)	36.2 (97.2)	39.6 (103.3)	39.3 (102.7)	35.1 (95.2)	33.3 (91.9)	33.9 (93)	32.9 (91.2)	28.3 (82.9)	23.0 (73.4)	31.4 (88.5)
Average low °C (°F)	7.3 (45.1)	10.1 (50.2)	15.4 (59.7)	21.5 (70.7)	25.9 (78.6)	28.3 (82.9)	26.6 (79.9)	25.9 (78.6)	24.4 (75.9)	19.5 (67.1)	12.8 (55)	8.2 (46.8)	18.8 (65.8)
Rainfall mm (inches)	20.3 (0.799)	15.0 (0.591)	15.8 (0.622)	6.7 (0.264)	17.5 (0.689)	54.9 (2.161)	231.5 (9.114)	258.7 (10.185)	127.8 (5.031)	36.3 (1.429)	5.0 (0.197)	7.8 (0.307)	797.3 (31.39)
Avg. rainy days	1.7	1.3	1.2	0.9	1.4	3.6	10.0	11.3	5.4	1.6	0.1	0.6	39.1
Sunshine hours	213.9	217.5	238.7	261.0	263.5	198.0	167.4	176.7	219.0	269.7	246.0	217.0	2,688.4

Source :www. envis.org

Highest temperature - April, May & June

Highest rainfall - July, August & September



Thus, **April to September** is the crucial time period for **vegetation** to withstand from **harsh climate of summer** and proper **storm water system** .

Source: Bridge To India analysis

¾ Electricity supplied from outside- used in shopping malls, Delhi Metro and health facilities

Rely on environmentally unsustainable fuels like coal

A shift from centralized, fossil fuel based power sources to decentralized, renewable sources like **Solaris**

BRIDGE TO INDIA ESTIMATES ROOFTOP SOLAR POTENTIAL OF DELHI

To be 2.5 GW (refer). Out of this, 26% potential exists in the government/ public sector, 25% in commercial/ industrial sector and 49% in domestic sector.

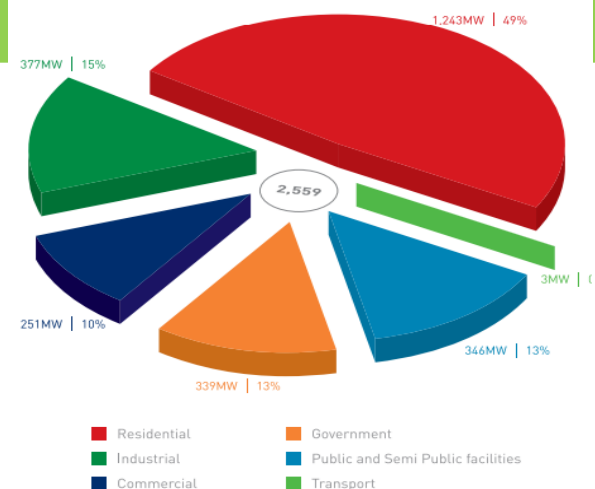
Suitable Area for Roof Top Garden

Residential areas as per municipalities governing them	Total built area/ raw rooftop area (km2)	Total qualified area after 20% discount for old rooftops (km2)	Solar suitable roof top area (km2)
Area under the MCD	79.2	63.32	12.6
Area under the NDMC	8.6	6.9	1.4
Area under the Delhi Cant.	5.3	4.3	0.85
TOTAL	93.1	74.5	14.90

Source: Bridge To India analysis

Theoretically, the total land area on which Delhi is built could support **123 GW of solar PV**. Therefore, **2 GW** requires only **1.6% of the city's land**.

Figure 7: Potential of rooftop solar power generation in Delhi for different land area types (MW)

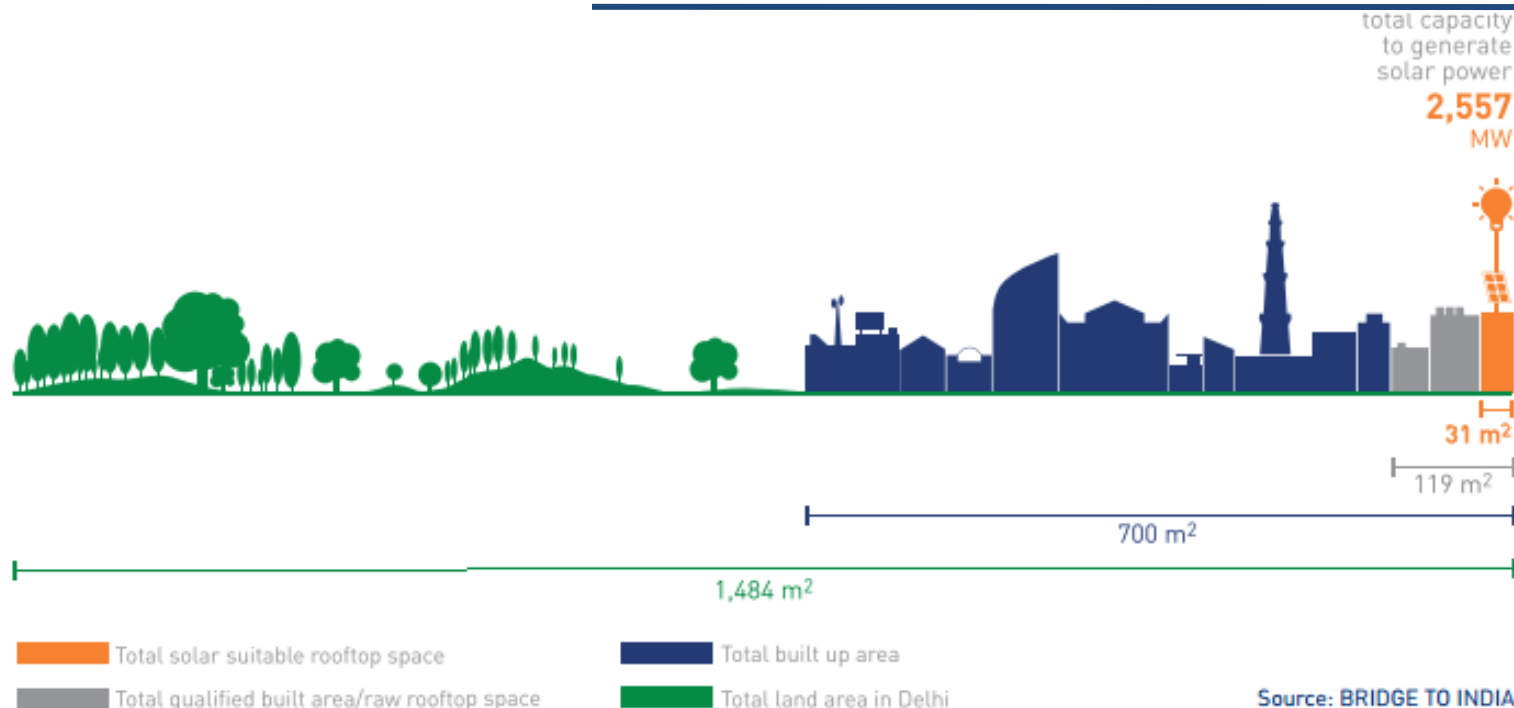


Source: DDA's Master Plan 2021, Delhi Zonal Plans and BRIDGE TO INDIA analysis

Land area type	qualified rooftop area (km ²)	suitable rooftop space
Residential	74.5	49%
Commercial	10.9	10%
Industrial	11.3	15%
Government	10.2	13%
Public and Semi Public Facilities	11.9	13%
Transport	0.2	0.10%
TOTAL	118.9	

Source: 4 DDA's Master plan 2021, Delhi Zonal Plans, Google Earth and Bridge To India analysis

Delhi can be a 2 GW solar city by 2020.



Delhi's residential buildings represent 49% of the solar potential.

Delhi's residential buildings represent 49% of the solar potential. They are followed by industrial buildings with 15% of the potential. Government buildings, commercial buildings and public and semi-public facilities have 13%, 10% and 13% of the total potential, respectively. Transport facilities such as airports and railway stations have a mere 0.1% of the potential - but can make great pilot projects. Green stretches, water bodies, historical buildings and public utilities have been excluded from the analysis.

DELHI'S POTENTIAL FOR ROOFTOP GARDEN

ASSESSMENT OF COLONIES UNDER THE JURISDICTION OF THE MCD

Colony category	Average plot size (m2)	Solar suitable area available	Income level	Principal type of housing	Quality of Construction	Qualification
A	900	180	High	Individual houses	Good	✓
B	400	80	Medium to high	Individual houses and apartments	Good	✓
C	200-600	40-120	Medium to high	Individual houses and apartments	Average	✓
D	250	50	Medium to high	Residential complexes, apartments and individual houses	Average	✓
E	100-250	20-50	Low to medium	Individual houses and apartments	Low	✗
F	150	30	Low	Individual houses and apartments	Poor	✗
G	100	20	Low	Individual houses and apartments	Poor	✗
H	50-100	Oct-20	Low	Individual houses and apartments		✗

A, B – Sundar Nagar-large sized colony, Friend's colony, west end

C – Lajpat Nagar, Punjabi Bagh, Civil Lines

D- Mayur Vihar, Paschim Vihar, Rajouri Garden

Source: Bridge To India analysis

D- Mayur Vihar, Paschim Vihar, Rajouri Garden

E- Paharganj, Yusuf Sarai, Inderpuri

FGH – Nathupura, Zakir Nagar

Source: 4 DDA's Master plan 2021, Delhi Zonal Plans, and Bridge To India analysis

RECOMMENDATIONS

1. All new and renovated flat roofs to be greened.
2. Land use along the River and Ridge should have large set backs and less dense areas.
3. Financial incentives for green roof development on private roofs.
4. Green Roof policies- Energy Conservation code that stipulates min. solar reflection standards for all new and retrofit roofs
5. Green roofs should be installed over air conditioned spaces that are heated and cooled
6. Solar panels can be incorporated with green roof which lowers down the consumption of energy.

Thank you

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