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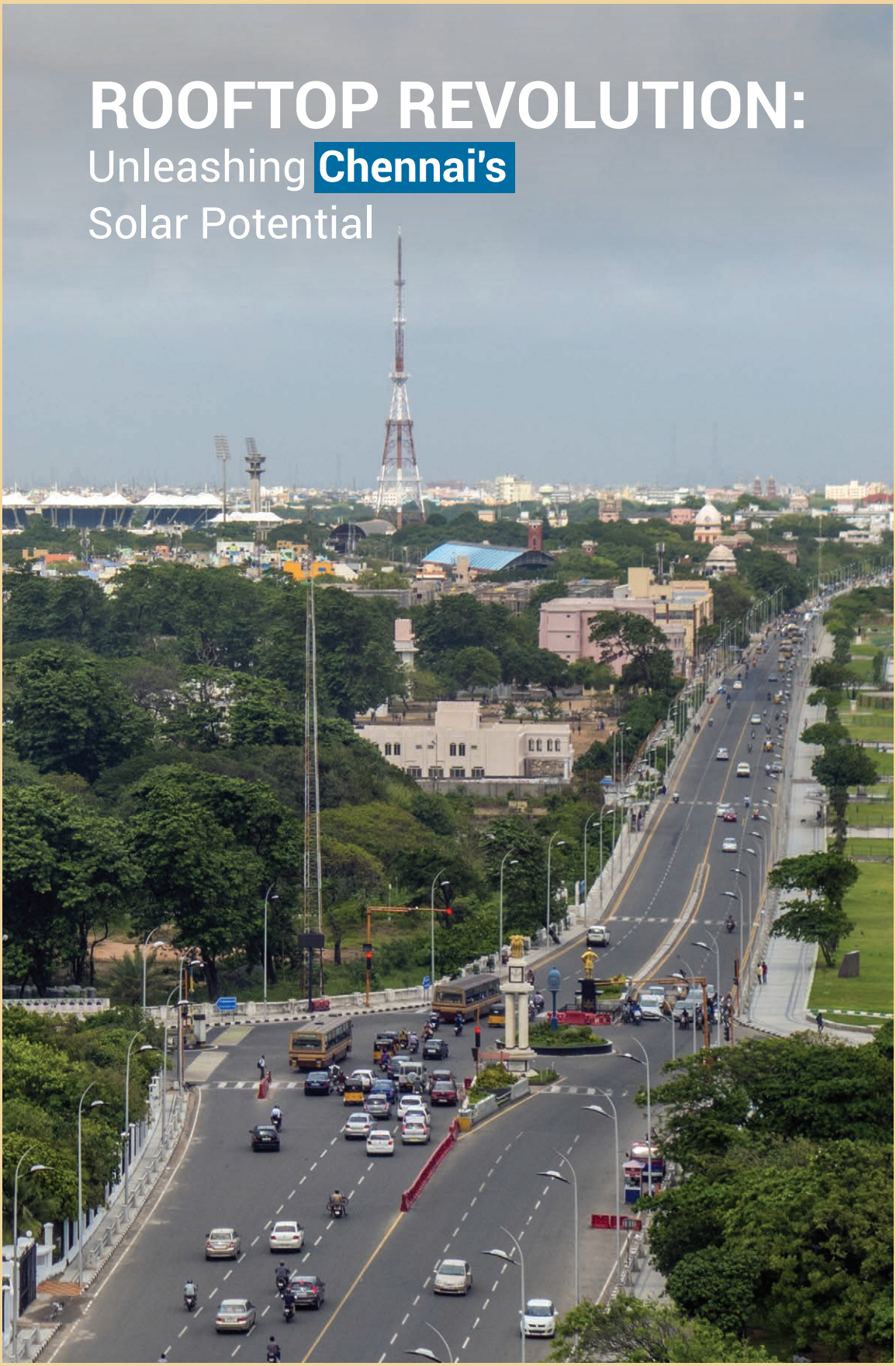
ROOFTOP REVOLUTION:

Unleashing Chennai's Solar Potential



Solar Panels at Holy family hospital, Delhi India.
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PRINCIPAL AUTHORS

Gujarat Energy Research and Management Institute
Akhilesh Magal
Aniket Baregama
Kavish Shah
Yashraj Gore

Greenpeace
Pujarini Sen
Ashish Fernandes

STUDENT CONTRIBUTORS
Aditya Soni
Ankita Sharma
Bhatt Manan Nitinbhai
Bhavin Bhatt
Joshi Jaykumar Ashokbhai
Kanojia Janak Rameshbhai
Mihirkumar Rameshbhai Lad
Modi Brij Yogeshkumar
Mrunmayee Unawane
Naik Dhaval Rajesh
Nikunj Jamanbhai Usadadia
Paneliya Sagar Chandubhai
Parth prajapati
Shah Vatsal Jayendrabhai
Uma Sanjogbhai Sahare
Vansh Ajay Pandya
Vishwakumar Gautamkumar Bhavsar

DESIGN
Penmi Rungsung / Greenpeace

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PREFACE

In the run up to the Paris climate talks in 2015, India announced a goal of having 100 GW installed solar capacity by 2022, of which 40 GW would come from rooftop solar/distributed sources. No other country at a similar position on the development ladder has such ambitious clean energy targets, and this has allowed India to justifiably lay claim to a leadership position in tackling the global climate challenge.

India remains energy-deficit, with hundreds of millions having no or inadequate access to electricity. At a time when pollutants from fossil fuels have created an air quality crisis across virtually every Indian city, the ability to generate electricity without contributing to the air pollution problem is invaluable. Solar (and wind) energy is vital to meet India's goal of ensuring electricity access to all households, without also worsening the country's air quality through fossil fuel combustion. On the climate front, if humanity is to successfully keep global temperature rise as close to 1.5°C as possible, India will have to do its part to reduce the carbon intensity of its growth, even as it works to improve the quality of life of its poor. In a year when climate change influenced weather events have exacted a devastating toll in India and across the world, the win-win benefits to constraining the growth in India's carbon emissions is clear.

Solar-powered Reverse Osmosis plant, in Kotri village, Rajasthan.
© Prashanth Vishwanathan / Greenpeace

Since the 100 GW solar target has been announced, utility-scale solar in India has progressed well, with costs falling and installations growing fast. However, progress in the rooftop/distributed segment has been slow, with less than 1,861 MW[1] installed as of September 2017. While growth rates are high, this is from a virtually non-existent base, and at the current trajectory, India will fall far short of the 40 GW target by 2022. This is despite significant policy incentives at the national level (30% capital subsidy) and at regional levels in terms of net metering/feed in tariffs.

Achieving the rooftop solar goal is in many ways more vital than the utility-scale goal, as distributed solar offers grid resilience, avoids AT&C losses and broadens the community of direct solar beneficiaries, all critical to building the energy system of the future. Greenpeace believes that much more needs to be done to educate consumers of the benefits of going solar, to smoothen bureaucratic wrinkles standing in the way of faster solar adoption and harness the power that states and distribution companies wield in support of India's ambitious solar goals.

Towards this end, Greenpeace India is launching a multi-city programme to spread awareness among residents and small business owners of the advantages of going solar. This report's analysis of the rooftop solar potential of Chennai, conducted by GERMI, is a part of this effort. We hope the results, and the methods explained in the report, help spur a faster, deeper uptake of solar rooftops by citizens across India.

[1] *http://bit.ly/2DgReWX Bridge to India*

EXECUTIVE SUMMARY

This report is a Chennai specific summary of the larger report titled, "Assessing the Rooftop Solar PV Potential of Hyderabad and Chennai". It is comprised of the final results of rooftop solar PV capacity for the city under Greater Chennai Corporation (GCC). These results can specifically be useful for EPC contractors, RTPV consultants and scientific scholars. In order to get a full understanding of the methodology developed for RTPV estimation under this project, please refer to the detailed comprehensive report mentioned earlier.

A key observation in the state of Tamil Nadu is that the deployment of rooftop solar PV is lackluster despite existing policies and regulations that support rooftop solar. If deployment rates do not significantly increase, it is unlikely that that India's rooftop solar PV (RTPV) deployment target of 40 GW by 2022 will be met. Chennai, by virtue of being a Tier 1 city, is representative of most locations in India from where most demand for RTPV solar is likely to arise.

A much more fundamental question to be asked is whether India's cities can host the 40 GW target; or quite simply, "Are there adequate roofs on which 40GW of RTPV systems can be installed?". A methodology has been developed as a part of this project to estimate the rooftop PV potential of Chennai and Hyderabad. As mentioned earlier, the methodology is described in the comprehensive report titled "Rooftop PV Potential Assessment of Hyderabad and Chennai". Although the methodology relies on satellite imagery and land use maps that are unique to the cities, it can easily be replicated across other cities with a few minor modifications. The methodology uses freely available tools such as Google Earth, Google Maps, Wikimapia, etc. that are open source and accessible to all with an internet connection and a computer. This would aid other groups to quickly replicate this study for their own cities.

Our estimates show that the **total rooftop solar potential of Chennai is 1.38 GW**. Some of the major landmarks that have a sizable potential are listed below:

- Railway station roofs can hold 3,582 kW
- Metro station roofs can hold 1,696 kW.
- Bus Depot roofs can host approximately 938 kW of solar PV.
- The Chennai International Airport can host approximately 889 kW of rooftop solar.

The results are reported (see Annexures) across each zone of each city and across different consumer categories such as commercial, industrial, multipurpose use, public and semi public, residential and transportation. The aim of classifying results by zones is to help local municipalities estimate their potential and engage with citizens to accelerate the rooftop PV revolution. The category wise classification would help potential developers and EPC[2] companies target their clients quickly. For the same reason, the largest contributors to the rooftop PV potential in the transportation sector (bus depots, railways, metro stations, airport) are listed out in the annexure. We hope that this level of granularity of results will aid policy makers, the industry and advocacy groups target the relevant audience and accelerate the deployment of RTPV in India.

Is India's 40GW solar rooftop goal feasible?

In these results we looked at what these numbers mean in the larger context of India's 40 GW solar rooftop goal. We compare these numbers with other rooftop potential studies carried out for the cities of Delhi, Mumbai and Patna. We also try to draw inferences based on urban patterns . Example:, "how much rooftop PV can a city hold?". Based on a thumb rule estimate of megawatt potential of RTPV per square kilometer, we estimate the potential of all tier 1 and 2 cities of India. We gauge that all of India's tier 1 and 2 cities can host over 62 GW of RTPV. Since it would be foolhardy to assume that the entire potential is realizable in the near term owing to a host of factors such as affordability, awareness and technical feasibility, we look at current adoption rates (i.e. number of roofs that have RTPV systems). We have sampled three neighborhoods in Germany and one in San Francisco to understand how many rooftops in a given neighborhood have RTPV systems installed. Our rudimentary analysis shows that this ranges from 5-24% of all roofs that have solar PV potential. It may be assumed that India's RTPV adoption rate in the near term would be far below that of such affluent neighbourhoods. Assuming an average adoption rate of 10% over the next 5 years, we are looking at a total installed solar PV capacity of about 6 GW by 2022 or so in Tier 1 and Tier 2 cities. A significant portion of the 40 GW by 2022 distributed solar target would therefore need to come from smaller towns, rural and semi-rural locations, grid connected solar pumps and other distributed solar applications, which might necessitate other incentivising schemes.

[2] *Engineering Procurement and Construction*

INTRODUCTION

Description of Study Area

The study area considered for Chennai is the area under the jurisdiction of Greater Chennai Corporation (GCC[3]). Greater Chennai Corporation with the total area of 426 Square km[4]. The city under Greater Chennai Corporation (GCC) is classified into three regions named North Chennai, Central Chennai and South Chennai[5]. The area under these regions is further divided into 15 zones, consisting of 200 wards[6].

The 15 zones under GCC does not include the area of St. Thomas Mount. But for the purpose of this study we have considered it as an individual zone. Therefore this report covers a total study area of 16 zones in the forthcoming sections.

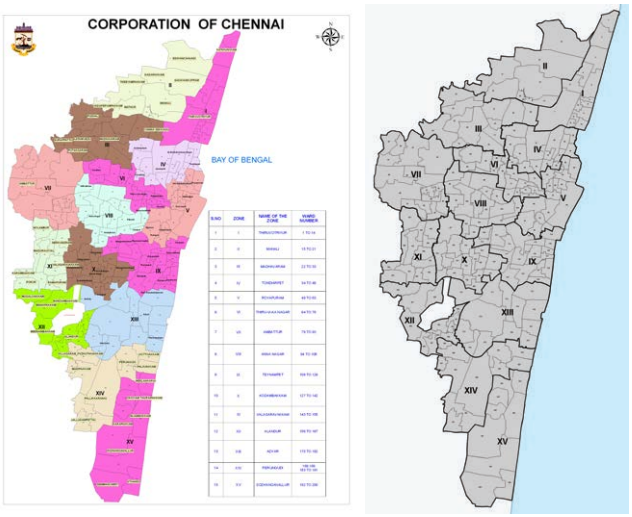

Figure 1: 15 zones and 150 wards under Greater Chennai Corporation[13]

The land use categories adapted to this study are listed as below.

Categories taken as	Building sets includes
Residential	Residential colonies, bungalows, flats, apartments etc.
Commercial	Commercial offices, shops, markets entertainment, hotels, restaurants, resort clubs etc.
Industrial	Small/medium manufacturing facilities, refineries, production factories, power plants etc.
Public and semi public	Governments offices, schools, hospitals, religious places, tourist places, public sports facilities, public art/entertainment facilities, utility facilities etc
Transportation	Bus depots, railway platforms, railway offices/residences, railway/bus workshops, metro properties, airports etc.
Multipurpose use	It includes the lands, which are used by two or more previously mentioned category buildings together in random fashion.
Military lands	Area under the boundaries of Indian armed forces. It includes their training lands, offices, residences, educational buildings, hospitals etc.
Unconstructed/ Infeasible	Burial grounds, lakes, nalahs, natural conservation area, notified heritage buildings, rivers, roads and other open spaces.

Table 1: Major Categories and the building types belongs under these categories

Solar Panels on Hospital in Bihar.
© Harikrishna Katragadda / Greenpeace

[3] *Greater Chennai Corporation, http://bit.ly/2lfg599*
[4] *"More areas to come under Chennai Corporation", The Hindu, 30 December 2009. http://bit.ly/2ieuRIo*
[5] *"Expanded Chennai Corporation to be divided into 3 regions", The Hindu, 25 November 2011. http://bit.ly/2yVMWFl*
[6] *Ramakrishnan, Deepa H (20 September 2011), "Details of merged wards online soon", The Hindu. http://bit.ly/2yZOwUx*

Solar Power: Photovoltaic Installation on University Roof.
© Tim Shaffer / Greenpeace

RESULTS

RTPV potential of Greater Chennai under GCC jurisdiction

On application of the methodology of extrapolation described in the detailed comprehensive report results in the approximate RTPV potential of each categories and across each of the zones. The table below shows the final capacities for all 16 zones by their land use categories.

RTPV potential of each category in every zone (MW)						
	Comm-ercial	Indu-strial	Multi-purpose	Public and semi public	Resi-dential	Transp-ortation
Zone 1	2.48	5.08	9.89	8.87	20.96	1.90
Zone 2	1.13	2.31	4.50	4.03	9.53	0.87
Zone 3	3.30	6.76	13.14	11.79	27.84	2.53
Zone 4	4.70	9.62	18.72	16.79	39.65	3.60
Zone 5	4.99	10.22	19.88	17.83	42.10	3.83
Zone 6	3.85	7.89	15.35	13.76	32.50	2.95
Zone 7	7.39	15.14	29.45	26.41	62.38	5.67
Zone 8	5.73	11.73	22.81	20.46	48.32	4.39
Zone 9	5.73	11.73	22.82	20.47	48.34	4.39
Zone 10	5.07	10.38	20.20	18.11	42.78	3.89
Zone 11	4.30	8.80	17.12	15.36	36.27	3.30
Zone 12	2.86	5.87	11.41	10.23	24.17	2.20
Zone 13	9.14	18.71	36.41	32.65	77.11	7.01
Zone 14	5.05	10.35	20.13	18.05	42.63	3.88
Zone 15	3.51	7.18	13.97	12.53	29.59	2.69
Zone 16	0.27	0.56	1.08	0.97	2.29	0.21
Total	69.49	142.32	276.89	248.32	586.46	53.31
Grand Total	**1,377**					

Table 2: RTPV potential of each category In every zone (MW)

Solar Thermal Installation in Zurich.
© Greenpeace / Nicolas Fojtu

A comparative analysis of RTPV potential between different categories (under all 16 zones) is shown in the donut chart below. The total RTPV potential of Greater Chennai Corporation is 1.38 GW. The maximum potential is from the residential rooftop segment, which occupies nearly 46%.

Transport, commercial and industrial rooftop have the least RTPV potentials compared to the other land use categories. Although the overall number is small, the few roofs that do exist tend to be large and can accomodate significantly larger potential as compared to the residential roofs.

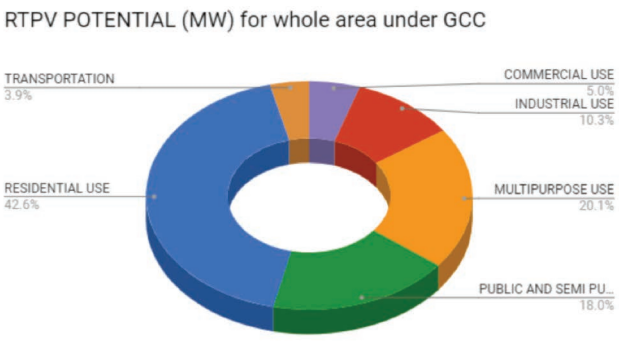

Figure 2: RTPV potential distribution under different categories for whole greater Chennai under GCC

A comparative analysis of RTPV potential between different zones (of all 6 categories) is shown in the stacked bar chart below. The highest potential of 181 MW is for the rooftops under zone 13 and 146 MW under zone 7. This is because of these zones have the largest geographical area and the largest spread of buildings under the categories of residential, multipurpose and public & semi public use. Conversely, the lack of buildings in the categories mentioned above result if low RTPV potentials in zone 16 and zone 9 which have 5.4 MW and 22.4 MW capacities respectively.

- The estimated PV potential of **Commercial** category under GCC jurisdiction is **69 MW.**
- The estimated PV potential of **Industrial** category under GCC jurisdiction is **142 MW.**
- The estimated PV potential of **Multipurpose** use category under GCC jurisdiction is **277 MW.**
- The estimated PV potential of **Public and Semi Public** use category under GCC jurisdiction is **248 MW.**
- The estimated PV potential of **Residential** category under GCC jurisdiction is **586 MW.**
- The estimated PV potential of **Transportation** category under GCC jurisdiction is **53 MW.**

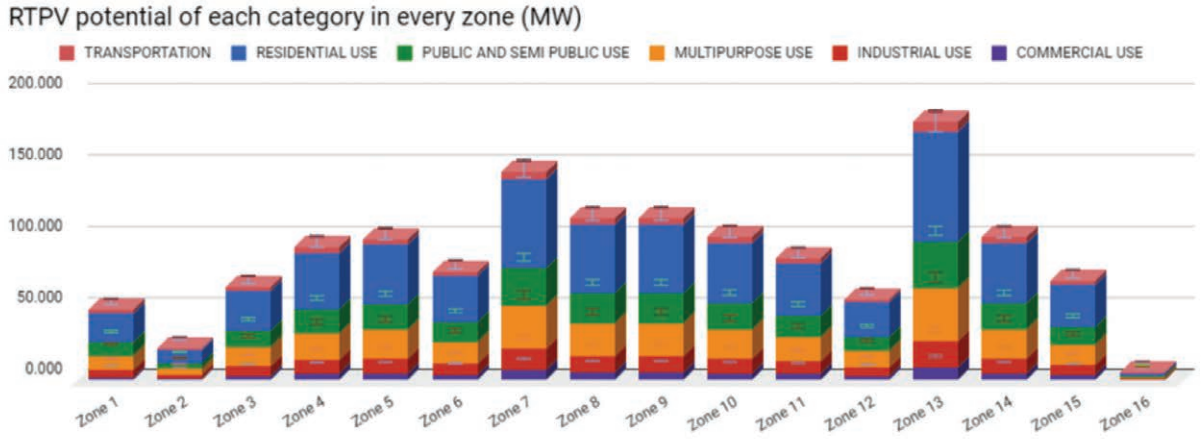

Figure 3: Category wise RTPV potential for every zone

RTPV potential of Major buildings in Transportation category

The Indian railways has committed to install 1 GW of solar power capacity by 2020. It includes the utilization of their existing assets such as railway platforms, railway buildings, workshops and trains for RTPV systems and railway lands for ground mounted systems. Indian railways intends to fulfill 10% of the total electricity demand from renewable energy. In another development, United Nations Development Program (UNDP) and Indian railways (IR) are now targeting an installation capacity of 5 GW by 2025 and are open to attracting private investment[7].

These targets are highly ambitious, and one small step in reaching this target would be to identify rooftop spaces available on all its stations, buildings and even open lands. In order to apply our work for this specific purpose, we have analyzed all the major transportation facilities in Chennai (see table below). Another reason for doing this, is the Government of India's intention to shift to electric transportation.

City	Name	Capacity (Kw)
Greater Hyderabad	Bus Depot	2,949
	Railway Station	3,187
	Metro Station	680
	Airport	714
	Total	7,530
Greater Chennai Corporation	Bus Depot	938
	Railway Station	3,582
	Metro Station	1,696
	Airport	889
	Total	7,105

Table 3: RTPV potential of transportation buildings in the jurisdictions of Greater Chennai Corporation

Conclusion and analysis of results

Our assessment shows that the RTPV potential for the city of Chennai is 1.38 GW. These results appear to be in line with earlier assessments done for the cities of New Delhi, Mumbai and for Patna . One way to understand and compare this data would be to look at the RTPV potential over the geographic spread of the city; that is, to arrive at an average MW/sq.km for most tier 1 and tier 2 cities in India. This metric, although not entirely accurate gives us a back-of-the-envelope method of arriving at the RTPV potentials of major tier 1 and 2 cities in India.

India has set itself a target of achieving 40 GW of rooftop solar installations by 2022. The key question here is whether India's cities have adequate rooftops that capable of hosting this potential (assuming that 100% of all rooftops do host RTPV systems). Based on our and earlier studies of RTPV potential assessment, we can attempt to compute the total RTPV potential of tier 1 and 2 cities in India. Given reasons of affordability and awareness, we can assume that most of the demand for RTPV systems will come from Tier 1 and 2 cities and not smaller cities, at least in the near term.

City	Potential (in MW)	Land Area (in km2)	Solar PV Potential per unit Area MW/km2
New Delhi	2,000	1,230	1.62
Mumbai	1,720	603.4	2.85
Patna	759	297.9	2.54
Hyderabad	1,727	640	2.70
Chennai	1,385	437	3.15

Table 4: RTPV potential in per square km. area of mentioned cities[25] [26] [27]

India has 8 Tier 1 cities and 88 Tier 2 cities as per official Government statistics (see annexure VII of the full report for the complete list). In the previous data table, the RTPV potential of four tier 1 cities was mentioned. From this data, the potential distribution of RTPV across the city in per sq. km. area can be computed. On an average, this RTPV potential per square kilometer came up to approximately 2.58 MW/sq.km. for tier 1 cities. Although the RTPV potential for tier 2 cities was not studied previously in an extensive manner, the same potential (in MW/ sq. km.) is taken for further studies. This is highly optimistic approximation nevertheless helps us arrive at an estimate in the absence of concrete data.

Annexure-VII of the full report includes the approximate areas of all the listed tier 1 and tier 2 cities. Therefore it can be said that, using the potential of 2.58 MW/sq. km on the cumulative areas for all these cities (23,996.30 sq. km) the theoretically possible RTPV potential is 62 GW.

While this may sound like good news, that India's cities can in fact host the 40 GW target, it does not consider adoption factors. We looked at Germany, a country that has one of the highest adoption rate of solar rooftop systems in the world.

Based on the above assessment, the adoption rate of RTPV systems from Germany and USA range between 5% to 25%. If we assume an adoption rate of 10% for India by 2022, we arrive at a total potential of 10% of 62 GW or 6.2 GW. This number is clearly well below the 40 GW target set by the Government of India. This calls for reflection on the way ahead for India's distributed solar targets.

While RTPV needs to be strongly pushed and hurdles on approvals and subsidy mechanisms have to be eliminated, India must consider additional options to meet the distributed solar targets. These can include incentives to promote rooftop solar in smaller towns and settlements, utilisation of state transport depots and rail stations in smaller towns, grid connected solar PV pump sets etc.

[7] *Indian Railways, UNDP, "Powering Indian Railways 5 GW by 2025", http://bit.ly/2gAh7HJ*
[8] *Tobias Engelmeier, Mohit Anand, Jasmeet Khurana, Prateek Goel, Tanya Loond, BRIDGE TO INDIA, GREENPEACE, June 2013. http://bit.ly/2lFeZDt*
[9] *Akhilesh Magal, Ameya Pimpalkhare, Prof. Anil Kottantharayil, Prof. Prachi Krithi, Prachi Jadhav, Santhosh Jois, Prof. Vinit Kotak, Vivek Kuthanazhi, Bridge to India, NCPRE (IIT-B), Observer Research Foundation, IEEE Bombay Section, Centre for Urban Science & Engineering (IIT-B), "Estimating Rooftop Solar Potential of Greater Mumbai", November 2016. http://bit.ly/2z2Su0W*
[10] *Tobias Engelmeier, Jasmeet Khurana, Prateek Goel, Karan Raj Chaudri, Mudit Jain, Tanya Loond, Ankita Jyoti, BRIDGE TO INDIA, GREENPEACE October 2014. http://bit.ly/2im6U1Z*
[11] *Ministry of Finance, Govt. of India. http://bit.ly/2z3aXKz*
[12] *Adoption rate is defined as number of rooftops that have actually installed RTPV systems*

Photovoltaic Panels on Subway Station in Seoul.
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Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, The Americas, Asia and the Pacific.

It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area north of Alaska, where the US Government was conducting underground nuclear tests.This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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