Implemented by

In coordination with:

Transforming Gandhinagar to a 100% RE city (Solar City)

Report on potential assessment of distributed solar in Gandhinagar

November 2022

Contents

1 Introduction

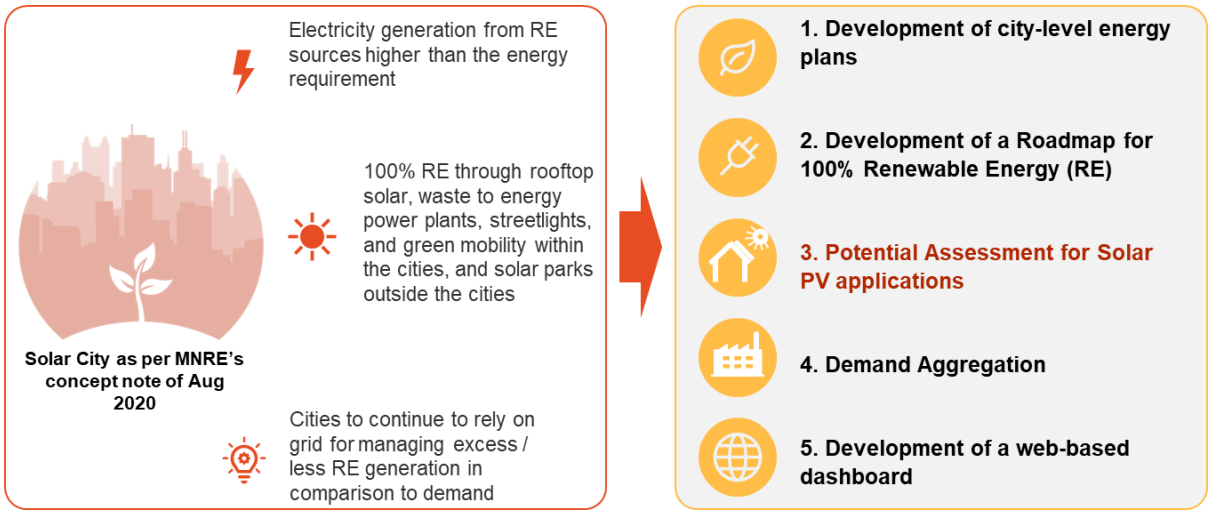
1.1 Background

Hon´ble Prime Minister Shir Narendra Modi has desired that each Indian State should have at least one solar city where all houses have rooftop solar energy plants, and all electricity needs of the city are fully met from Solar Energy or other renewable energy sources. To be declared as a 'Solar City' the generation of electricity from various renewable resources in the city should be equal to or more than the power needs of the city.

In continuation with a concept note issued by the Ministry of New and Renewable Energy (MNRE), each of the states in India were suggested to initially identify one city to be developed as a 'Solar City'. Based on the same, Govt. of Gujarat has identified Gandhinagar to be the city which is to be developed as Solar City.

Duetsche Gesellschaft für Internationale Zusammenarbeit (GIZ), in coordination with MNRE and various City Nodal Agencies (CNA) is supporting several cities in India on their way to becoming Solar Cities, including the city of Gandhinagar in Gujarat. This report is prepared under the GIZ project on "Transforming Indian cities to 100% RE". The project consists of five output areas, out of which output 3 corresponds to the distributed solar potential assessment.

Figure 1: Introduction to 100% RE City concept and Project Outputs



1.2 Objective of potential Assessment

The objective of potential assessment is to measure the overall solar rooftop potential of the city comprising of solar potential assessment of various category consumers such as residential, government etc. The potential assessment activity is carried out to understand the energy requirement of the city that can be fulfilled from solar rooftop and to identify the remaining RE Capacity requirement that has to installed outside city periphery for transformation of city in 100% RE/ Solar City.

2 Methodology adopted

The potential assessment was undertaken in a phase wise manner, consisting of four phases:

- Phase 1: Study of the city profile in terms of building types, Rooftop type, density of the buildings etc.
- Phase 2: Satellite Mapping of City Area (as per Municipal Corporation Boundary Limits)
- Phase 3: Physical Site Survey
- Phase 4: Drone Survey of Selected Sample Areas in City for Data Validation of Satellite Mapping

2.1 Phase 1: Study of the city profile

A small team of experienced consultants was formed, and visual survey was carried out to study the building profile of the cities. The exercises were carried out to identify the building types, type of rooftop profile, density of the township, etc.

2.2 Phase 2: Satellite mapping of city area

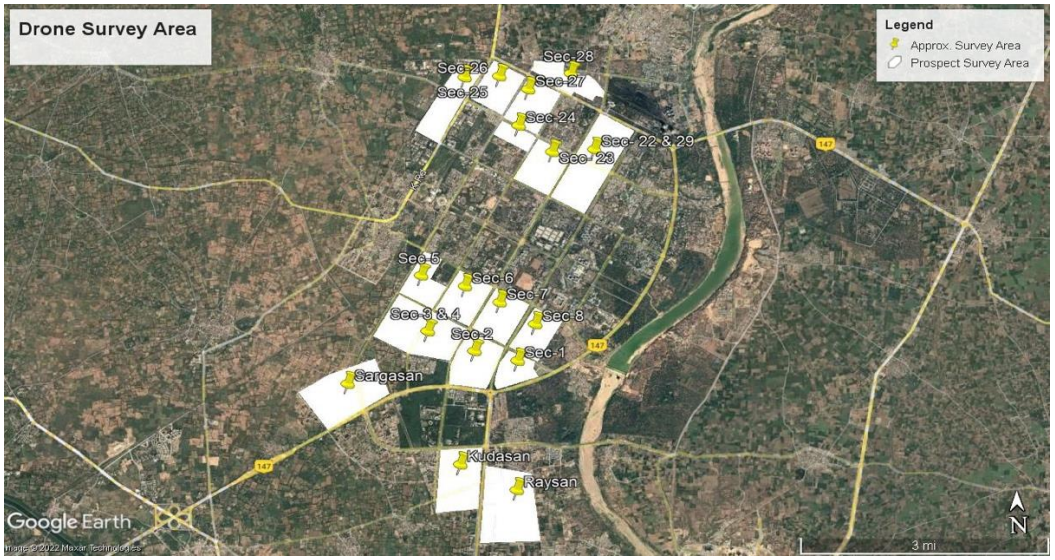
The assessment exercise was based on satellite map and software simulations, with additional field verification for government and public buildings. Potential assessment of selected areas through use of satellite map and software simulations was carried out. The areas were identified after segregating into the following categories:

a) Residential
b) Industrial
c) Government
d) Commercial
e) Open spaces

The following process was adopted to carry out this activity:

Step I: Gandhinagar city area was divided among the various geographical zones having different set profile. The division of the zones was based on geographic boundaries and density of the buildings within the area.

Figure 2: Zoning of the city



Step II: Tagging of all the buildings within the city, was done by using Satellite mapping via Sun Analyzer Tool to estimate the area and the rooftop Solar PV Potential of the same.

Step III: While tagging the buildings, Consultants/ Engineers had taken the Area, coordinates, category (i.e. government/ residential/ commercial/ industrial) of that particular building.

Step IV: A calculated correction factor was added in the solar capacity of the building. This correction factor was with respect to the category. Below mentioned correction factor were utilized for identification of solar capacity for the tagged building based on the category of the building. The correction factors are identified based on walk through of a few locations, and after analyzing multiple roof satellite images.

Table 1: Correction Factor

Type of Building	Correction Factor[1]
Residential/ Open Space	30% of total roof area
Government	50% of total roof area
Commercial	50% of total roof area
Industrial	70% of total roof area

Step V: Based on the experience and industry practice an area requirement factor of **10 sq. mt./ kWp** of rooftop solar system was applied on the available area for installation to identify the capacity of solar rooftop that can be installed. Similar area factor has been considered for potential assessment by physical and drone survey as well.

Figure 3: Classification of Roof in Map-view

2.3 Phase 3: Physical Site Survey (only for select list of Government buildings)

Initially a master list of Government buildings was prepared for undertaking physical Site Survey, based on the following methodology:

- **Step I:** The project team have visited the various state Government departments

[1] *The Correction Factor was calculated through the comparative Analysis on a sample size of 30 buildings (different categories) by the physical site survey & Sun Analyzer assessment (satellite image analysis). Variation in the project capacity has been defined as the error of margin ("Correction Factor") for the respective building category and applied to the whole population of the respective building category.*

in the city to gather the list of their departmental buildings that could be utilized to install rooftop solar PV systems.

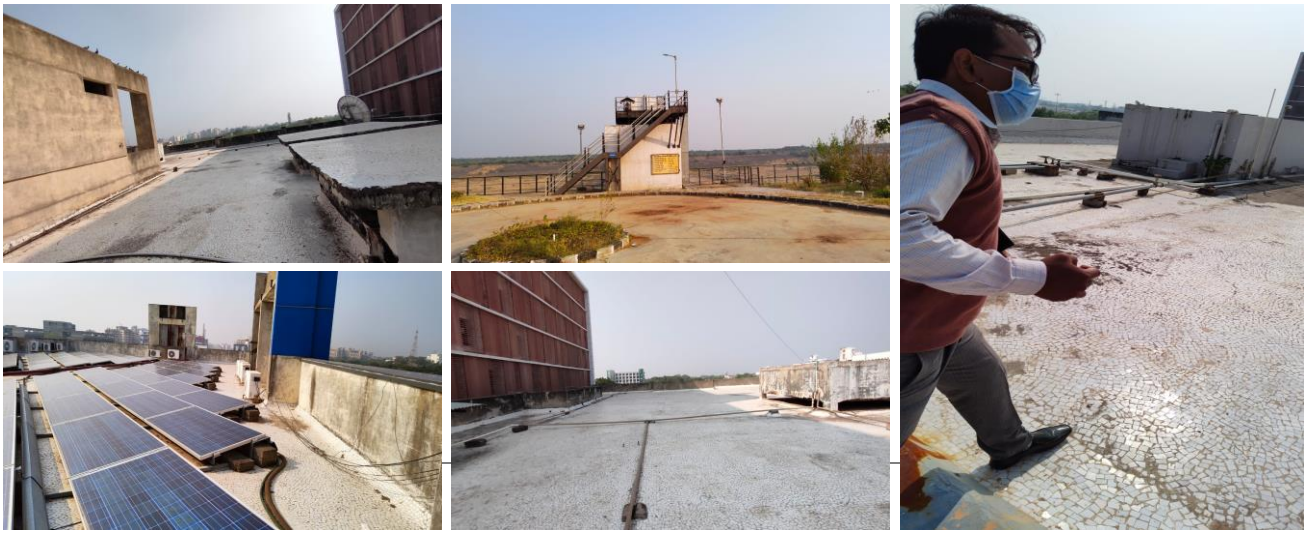
- **Step II:** The project set-up a communication channel with the City Nodal Agency (CNA) [City-Coordinator for the project & point of contact from CNA] to get the required details of the government buildings in the city area. A list was gathered from the DISCOMs inside the city area having the details of all the electricity connections
- **Step III:** A limit of minimum 25 kW was considered on the Contract Load to shortlist the buildings for survey and all the buildings having the contract load above 25 kW was considered for the physical site surveys.
- **Step III:** A Master List was prepared of the electricity Connection details for the Government Buildings in the City.

The physical site surveys were done by visiting each location by the consultants by following the methods described below

- **Step I**: The project team reach the location to enter the building for the execution of site survey and captured photos of the building front and relevant places for solar installation.
- **Step II**: The consultants showed the Authorization Letter to relevant officials of building and gathered the required details such as
    a) Department of Office/Building Ownership
    b) Contract Load/ Sanctioned Load
    c) Height of Building (No. Of Floors)
    d) Roof Type
    e) Measurement of Rooftop Area (Length & Breadth)
    f) Google Tag the Location of the Building
    g) Contact Detail for Reference
    h) Copy of Electricity Bill/ Account Number
- **Step III:** Capturing photos of the sites, and additional aspects such as:
    a) Electricity bill
    b) At least four photos of roof
    c) Photo of electricity meter
    d) Photo of interconnection location

Step V: Further using Sun Analyzer, software potential assessment and Shadow Analysis was carried out.

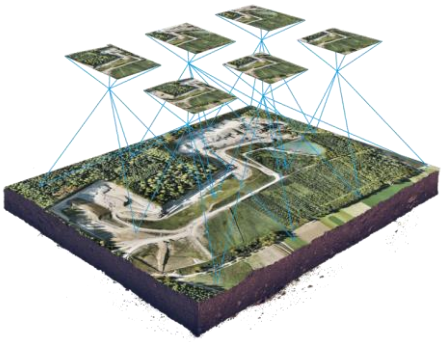
Figure 4: Physical Site Survey



2.4 Phase 4: Drone survey of selected sample areas for validation of results

Step I: Sample area was identified for carrying out the drone survey. The selected area was of 7.5 sq. km among two land parcels. The selection of area was based on the zone as per DGCA guidelines and maps, number of buildings, density of the buildings, requirement of approvals for survey etc.

Figure 5: Illustrative image of sample area identification



Step II: Once the area was selected for the survey, identification of the zones (as per Ministry of Civil Aviation) defining the level of approvals required to fly the zones was checked.

Step III: Appropriate permissions was taken from local administration for flying the drone or unmanned aerial vehicle (UAV) in the selected area.

Step IV: Flight Planning: The next step was to code the programming in the drone/UAV to create the flight plan for capturing the high-density images of the required area. This was for the automated movement of the drone for capturing the data.

Figure 6: Illustrative image of flight planning

Step V: During the drone survey an RGB camera was utilized to capture photographs of the ground several times from different angles, and each image is tagged with coordinates.

Step VI: Data Processing: This was the most important part of the survey. Photogrammetric processing of the raw aerial photographs was carried out to generate **High Density Point Cloud (HDPC)** of the complete survey area. The data was accurately geo-referenced using the Ground Control Point (GCP) network and the following outputs were generated:

- Highly detailed Orthophoto in Geo-tiff format (Ortho Map)
- Digital Surface Model in Geo-tiff format

Step VII: The Geo-tiff format image was further imported to Sun Analyzer software and

further data processing shall be carried out for rooftop potential assessment.

Figure 7 : Drone Survey

2.5 Change in Project Capacities: Satellite Imagery v/s Drone Imagery Analysis

The rooftops area in the city of Gandhinagar has been divided into the following categories

1. Residential
2. Industrial
3. Commercial
4. Government
5. Open Spaces
6. Un-tagged

The difference between the satellite imaging and drone surveys shows that 2,36,336 buildings were covered with satellite imaging which improved to 1487 after the validation through drone survey.

Figure 8: Satellite v/s Drone Imaging

Satellite Images **Drone Images**

Table 2 : Total Buildings Tagged

Sun Analyzer - Shadow Calculator		
City	**Total Potential**	**Total Building**
DATA BEFORE DRONE SURVEY		
Gandhinagar	**75,090 kWp**	12,073
DATA AFTER DRONE SURVEY | Zone Surveyed by Drone: 1,2,3,4,5,6,8,11,23,24,30,32 & 42		
Gandhinagar	**78022 kWp**	11,735

A. Residential buildings

The huge portion of the area surveyed through drone in the city of Gandhinagar has residential buildings in it. The details of the usable rooftop area, shadow area and potentials for the residential buildings is shown below in the table

Table 3: Residential rooftop - Results before and after drone survey

Residential				
Building	**Usable Area (m^2)**	**Shadow Area (m^2)**	**Total Area (m^2)**	**Total (kWp)**
DATA BEFORE DRONE SURVEY				
11,430	2,101,483	51,129	2,152,612	63,045
DATA AFTER DRONE SURVEY				
11,182	2,108,878	89,535	21,98,451	63,259

B. Commercial buildings

There is a huge increase 1300% in the identification of the commercial buildings for tagging with the images captured through the drone surveys. The details of the usable rooftop area, shadow area and potentials for the commercial buildings is shown below in the table

Table 4: Commercial rooftop - Results before and after drone survey

Commercial				
Building	**Usable Area (m^2)**	**Shadow Area (m^2)**	**Total Area (m^2)**	**Total (kWp)**
DATA BEFORE DRONE SURVEY				
259	157,949	18,378	176,327	7897
DATA AFTER DRONE SURVEY				
344	1,85,854	17,789	203,643	9,287

C. Industrial buildings

There is a 15% increase in the total industrial buildings tagged via drone imaging compared to the satellite images. The details of the usable rooftop area, shadow area and potentials for the Industrial buildings is shown below in the table

Table 5: Industrial rooftop - Results before and after drone survey

Industrial				
Building	**Usable Area (m^2)**	**Shadow Area (m^2)**	**Total Area (m^2)**	**Total (kWp)**
DATA BEFORE DRONE SURVEY				
11	1912	110	2022	133.84
DATA AFTER DRONE SURVEY				
64	44,877	287	45,161	3,141

D. Government buildings

There is an addition of 50% more the government building roof spaces in the area surveyed through drones. The details of the usable rooftop area, shadow area and potentials for the government buildings is shown below in the table.

Table 6: Government building rooftop - Results before and after drone survey

Government				
Building	**Usable Area (m^2)**	**Shadow Area (m^2)**	**Total Area (m^2)**	**Total (kWp)**
DATA BEFORE DRONE SURVEY				
359	80,280	3,576	83,856	4014
DATA AFTER DRONE SURVEY				
145	46,789	2,064	48,853	2,335

The summary of the data compared between satellite imaging and drone imaging has shown below in the table

Table 7: Summary of results before and after drone survey

	Before Drone		**After Drone**		% Change (Capacity)
	Total Buildings	**Total Potential (kWp)**	**Total Buildings**	**Total Potential (kWp)**	
Residential/ Open Space	11430	**63044.49**	11,182	**63,259**	↑ 3%
Industrial	11	**134**	64	**3,141**	↑ 303%
Commercial	259	**7897**	344	**9,287**	↓ 11%
Governmental	359	**4014**	145	**2,335**	↑ 44%
Total	12,073	**75,090**			↑ 7%

The following conclusion is derived out the drone survey:

1. Due to high quality images captured through drones, the boundaries were marked properly which has resulted in the increase/decrease of the overall capacity from 11% decrease in Commercial to 303%increase in Industrial category.

2. Identification of shadow casting objects and area impacted by the objects results in change of available area for installation. This impact is observed in all the categories of the buildings. Hence, category wise increase is observed and added in the correction factor of residential, Commercial, Government and Industrial categories.

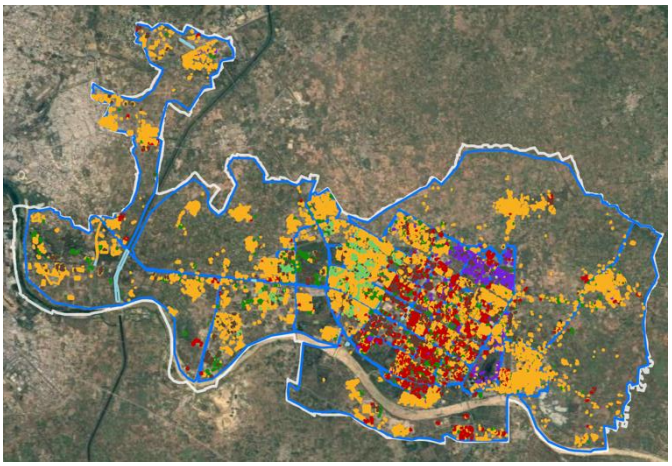
3. In the Industrial category, due to unclear image and closely constructed buildings, the separation was not identified in the satellite images. But in the drone images a clear identification was made between two buildings which resulted in the increase of industrial buildings. Hence, because of this one of observation and being an outlier, the delta increase in the correction factor is also taken as 303%

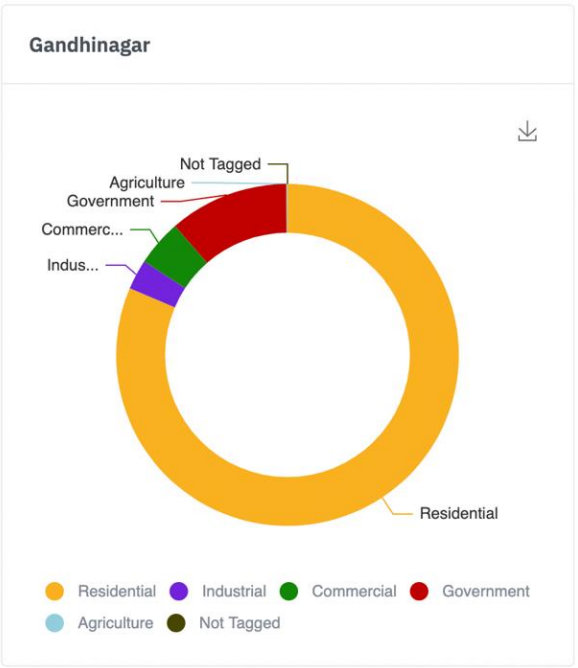
3 Conclusion

The Overall potential assessment of solar rooftop capacity identified for the city in initial phase using satellite imagery is 308 MW. The potential was estimated using the Sun Analyzer software (Satellite Imagery), Physical Survey and Drone Survey. Details of category wise potential assessment has been presented below with details of each zone on category basis is attached in annexure.

Table 8: Solar rooftop potential as per satellite map based analysis

Category	Solar RT Potential (kW)
Residential	1,71,119
Industrial	36,122
Commercial	35,518
Government	57,634
Open Space	8,155
	3,08,548





However, the below mentioned change in correction factor was applied to potential of respective category based on change in potential identified post drone survey.

Table 9: Change in Correction Factor post drone survey

Type of Building	Correction Factor	Changed Correction Factor	% Change in Correction Factor
Residential/ Open Space	30% of total roof area	31% of total roof area	3% ↑
Government	50% of total roof area	72 % of total roof area	44% ↑
Commercial	50% of total roof area	44% of total roof area	11% ↓
Industrial	70% of total roof area	282% of total roof area	303% ↑

The change in correction factor was applied to whole population (overall category potential) to finalize the category wise potential of solar rooftop, which indicates a r**ooftop solar potential of 651 MW in the city of Gandhinagar.**

Table 10 : Final Solar Rooftop Potential

Category	Solar rooftop potential (kW) (based on initially estimated Correction Factor)	Solar rooftop potential (kW) (After change in Correction Factor)
Residential	1,71,119	1,75,509.31
Government	36,122	52,024
Commercial	35,518	31,448
Industrial	36,122	1,45,528
Open Space	8,155	8,155
	3,08,548	**4,12,666**

4 Annexure-1: Summary of zone wise area and estimated solar capacity

4.1 Residential Buildings[2]

	Residential					
Zone	Total Building	Building - R	Usable Area - R (m2)	Shadow Area - R (m2)	Total Area - R (m2)	Total - R (kWp)
Zone 1	1494	1487	134243	6680	140923	4027
Zone 2	1509	1478	118277	5309	123586	3548
Zone 3	1227	1134	114015	7118	121129	3420
Zone 4	114	105	48558	381	48939	1456
Zone 5	310	295	229854	10661	240515	6895
Zone 6	894	850	84292	6586	90878	2528
Zone 7	588	336	21785	568	22353	653
Zone 8	1764	1726	175697	12720	188459	5270
Zone 9	436	435	60010	4101	64111	1800
Zone 10	422	246	36984	1524	38508	1109
Zone 11	904	855	103440	6133	109573	3103
Zone 12	304	113	11106	580	11686	333
Zone 13	620	250	29798	918	30716	893
Zone 14	21	0	0	0	0	0
Zone 15	743	413	30803	649	31452	924
Zone 16	991	772	71861	483	72344	2155
Zone 17	1587	817	89728	3661	93389	2691

[2] Total Area and shadow Area is determined through Sun Analyzer Software.

	Residential					
Zone	**Total Building**	**Building - R**	**Usable Area - R (m2)**	**Shadow Area - R (m2)**	**Total Area - R (m2)**	**Total - R (kWp)**
Zone 18	1245	382	39316	1562	40878	1179
Zone 19	769	512	45588	955	46543	1367
Zone 20	1161	815	74693	16	74709	2240
Zone 21	782	650	61452	2035	63487	1843
Zone 22	115	58	49436	1765	51201	1483
Zone 23	331	300	139908	13227	153135	4197
Zone 24	266	252	170734	4829	175563	5122
Zone 25	1171	688	67321	1719	69040	2019
Zone 26	1402	1093	86215	2168	88383	2586
Zone 27	914	429	47951	0	47951	1438
Zone 28	1545	1323	132541	3050	135591	3976
Zone 29	1306	1285	112183	70	112253	3365
Zone 30	898	818	383399	11416	394815	11501
Zone 31	612	554	705392	11651	717043	21161
Zone 32	120	46	17080	0	17080	512
Zone 32	1570	1504	334494	2055	336549	10034
Zone 33	1813	1740	433522	3272	436794	13005
Zone 34	1314	1139	239099	8788	247887	7172
Zone 35	1382	1305	259897	1840	261737	7796
Zone 36	1191	1085	209879	2788	212667	6296
Zone 37	2699	2561	361321	241	361562	10839
Zone 38	315	29	1654	118	1772	49

	Residential					
Zone	Total Building	Building - R	Usable Area - R (m2)	Shadow Area - R (m2)	Total Area - R (m2)	Total - R (kWp)
Zone 40	1690	1414	239048	2613	241661	7171
Zone 41	661	545	77240	0	77240	2317
Zone 42	343	332	54887	2420	57307	1646

4.2 Government Buildings

	Government				
Zone	Building - G	Usable Area - G (m2)	Shadow Area - G (m2)	Total Area - G (m2)	Total - G (kWp)
Zone 1	2	1065	157	1222	53
Zone 2	12	2216	7	2223	110
Zone 3	15	2573	0	2573	128
Zone 4	2	1582	22	1604	79
Zone 5	3	1210	116	1326	60
Zone 6	14	2303	130	2433	115
Zone 7	203	46241	5332	51573	2312
Zone 8	11	1269	16	1285	63
Zone 9	1	36	0	36	1
Zone 10	143	137023	2708	139731	6851
Zone 11	33	9571	1161	10732	478
Zone 12	178	137168	17003	154171	6858
Zone 13	270	74101	5291	79392	3705
Zone 14	18	9877	1267	11144	493
Zone 15	197	60516	5490	66006	3025

	Government				
Zone	Building - G	Usable Area - G (m2)	Shadow Area - G (m2)	Total Area - G (m2)	Total - G (kWp)
Zone 16	159	32460	509	32969	1623
Zone 17	545	69227	2498	71725	3461
Zone 18	702	91665	4302	95967	4583
Zone 19	185	32409	637	33046	1620
Zone 20	170	39858	7820	47678	1992
Zone 21	109	15201	415	15616	760
Zone 22	5	4134	2568	6702	206
Zone 23	2	240	0	240	12
Zone 24	0	0	0	0	0
Zone 25	394	61797	1034	62831	3089
Zone 26	171	26297	111	26408	1314
Zone 27	84	20507	118	20625	1025
Zone 28	20	16030	1101	17131	801
Zone 29	9	1736	431	2167	86
Zone 30	5	2920	0	2920	146
Zone 31	10	23675	9812	33487	1183
Zone 32	9	9676	455	10131	483
Zone 32	35	11403	0	11403	570
Zone 33	52	22431	1288	23719	1121
Zone 34	142	63266	2486	65752	3163
Zone 35	25	13481	373	13854	674
Zone 36	61	40191	6431	46622	2009

	Government				
Zone	Building - G	Usable Area - G (m2)	Shadow Area - G (m2)	Total Area - G (m2)	Total - G (kWp)
Zone 37	86	17719	0	17719	885
Zone 38	268	22297	1341	23638	1114
Zone 40	101	25592	319	25911	1279
Zone 41	3	1326	0	1326	66
Zone 42	2	761	0	761	38

4.3 Commercial Buildings

	Commercial				
Zone	Building - C	Usable Area - C (m2)	Shadow Area - C (m2)	Total Area - C (m2)	Total - C (kWp)
Zone 1	5	772	0	772	38
Zone 2	19	3121	105	3226	156
Zone 3	75	18622	1320	19942	931
Zone 4	7	1709	62	1771	85
Zone 5	12	5828	167	5995	291
Zone 6	29	5467	189	5656	273
Zone 7	49	10067	1063	11130	503
Zone 8	27	6135	219	6354	306
Zone 9	0	0	0	0	0
Zone 10	27	14682	20	14702	734
Zone 11	14	4295	0	4295	214
Zone 12	13	2415	73	2488	120
Zone 13	68	20191	178	20369	1009

	Commercial				
Zone	**Building - C**	**Usable Area - C (m2)**	**Shadow Area - C (m2)**	**Total Area - C (m2)**	**Total - C (kWp)**
Zone 14	3	340	0	340	17
Zone 15	67	19027	592	19619	951
Zone 16	52	8919	111	9030	445
Zone 17	156	34570	2621	37191	1728
Zone 18	148	30484	480	30964	1524
Zone 19	67	9775	142	9917	488
Zone 20	39	11627	0	11627	581
Zone 21	12	1484	15	1499	74
Zone 22	52	80785	3724	84509	4039
Zone 23	29	30006	559	30565	1500
Zone 24	14	10603	684	11287	530
Zone 25	79	12239	403	12642	611
Zone 26	91	11114	233	11347	555
Zone 27	32	11889	0	11889	594
Zone 28	17	6230	0	6230	311
Zone 29	12	2311	0	2311	115
Zone 30	74	80322	14064	94386	4016
Zone 31	44	82391	10626	93017	4119
Zone 32	1	418	0	418	20
Zone 32	29	13100	420	13520	655
Zone 33	15	10534	695	11229	526
Zone 34	26	11484	256	11740	574

	Commercial				
Zone	Building - C	Usable Area - C (m2)	Shadow Area - C (m2)	Total Area - C (m2)	Total - C (kWp)
Zone 35	45	24651	483	25134	1232
Zone 36	45	38307	2165	40472	1915
Zone 37	42	13634	329	13963	681
Zone 38	18	1519	26	1545	75
Zone 40	141	39405	532	39937	1970
Zone 41	32	14818	101	14919	740
Zone 42	9	5456	0	5456	272

4.4 Industrial Buildings

	Industrial				
Zone	Building - I	Usable Area - I (m2)	Shadow Area - I (m2)	Total Area - I (m2)	Total - I (kWp)
Zone 10	4	1781	38	1819	124
Zone 13	32	15099	330	15429	1056
Zone 15	66	25770	1687	27457	1803
Zone 16	7	510	0	510	35
Zone 17	68	11715	251	11966	820
Zone 18	7	1312	0	1312	91
Zone 20	136	66593	0	66593	4661
Zone 21	11	1747	0	1747	122
Zone 25	1	254	0	254	17
Zone 26	39	4951	1692	6643	346

	Industrial				
Zone	Building - I	Usable Area - I (m2)	Shadow Area - I (m2)	Total Area - I (m2)	Total - I (kWp)
Zone 27	365	129726	0	129726	9080
Zone 28	185	131630	3844	135474	9214
Zone 32	64	44877	284	45161	3141
Zone 33	5	5689	0	5689	398
Zone 34	5	1501	0	1501	105
Zone 35	7	4353	0	4353	304
Zone 37	8	6151	0	6151	430
Zone 40	33	9259	92	9351	648
Zone 41	81	53252	2829	56081	3727
Zone 42	0	0	0	0	0

4.5 Open Spaces

	Open Space				
Zone	Building - OS	Usable Area - OS (m2)	Shadow Area - OS (m2)	Total Area - OS (m2)	Total - OS (kWp)
Zone 3	3	168	0	168	5
Zone 10	2	44898	0	44898	1346
Zone 11	2	9280	0	9280	278
Zone 16	1	85	0	85	2
Zone 17	1	58	0	58	1
Zone 18	6	1106	0	1106	33
Zone 19	5	705	0	705	21
Zone 20	1	110	0	110	3

	Open Space				
Zone	**Building - OS**	**Usable Area - OS (m2)**	**Shadow Area - OS (m2)**	**Total Area - OS (m2)**	**Total - OS (kWp)**
Zone 25	9	8971	42	9013	269
Zone 26	3	459	0	459	13
Zone 30	1	540	0	540	16
Zone 31	4	189868	0	189868	5696
Zone 33	1	3212	0	3212	96
Zone 34	2	11742	0	11742	352
Zone 37	2	497	0	497	14
Zone 40	1	343	0	343	10

Technical partners for this report:

Deloitte.

aha solar

Disclaimer:

This report uses data collected from multiple sources. GiZ does not verify authenticity of the third party data and data sources separately. The relevant information sources and references have been duly acknowledged in this report.

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