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Energy Intensive Water Management to Achieve Zero Carbon Footprint: A Case Study in Semi-Arid Region, India

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Abstract. This study looks into areas around the NCT region that have deep soil conditions along the Yamuna River and are known for having groundwater resource potential. The site selected has a complex land use mix, including residential, administrative, and industrial setups along with a warehouse and other supporting facilities.

As assessment of onsite water demand is made on the basis of liter per day demand for various functions within the site and an estimation of water availability on site with respect to surface and groundwater resource potential as well as. The potential for rainwater harvesting and recycled water potential is also assessed. The study makes suggestions regarding reversing improving the declining groundwater table conditions, which are burdened because of overexploitation/overextraction.

Corresponding to the actual demand and reduced demand of water, an estimation of the carbon footprint for water based energies is estimated. This is further supported by solar exposure analysis for assessing the entire site potential for harnessing solar energy. This helped in proposing on site renewable energy generation possibilities along with groundwater improvement. This leads to the innovative idea of an energy intensive site with zero carbon footprints for water pumping systems.

Keywords. *water recycling, rainwater harvesting, stage of groundwater development, carbon footprint*

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1. Introduction

The area around Delhi NCT includes areas like Sonipat, Panipat Noida, and greater Noida, which are situated in the deep soil conditions along the Yamuna River and have enormous groundwater resource potential. In this area, there are not many groundwater quantity and quality problems except for salinity issues in a few patches. This is compared to areas on the western part of the NCR region, such as Gurgaon and Faridabad, which are occupied by a complex hydrogeological condition in which there are a lot of problems regarding groundwater quantity and quality. In the case of Sonipat, groundwater occurs in alluvium and the underlying weathered / fractured quartzites. Alluvium comprises sand silt, kankar, and gravel, which form the principal groundwater bearing horizon.

In the quartzite format ion, which occurs in the north-western part of the district, groundwater occurs in weathered and jointed fractured horizons. Weathering and fracturing has resulted in format ion of semi-consolidated sand beds (BADARPUR SANDS), which form potential aquifer zones. This quartzite format ion has not been explored for groundwater occurrence. In alluvium, granular zones are evenly distributed in entire thickness, which is negligible near the quartzite outcrops to over 350m in the eastern parts near the Yamuna River.

In recent years, the water level has declined due to overexploitation of groundwater resources. This is due to many factors such as a growing number of tube wells, low spacing between them, and high tube well density as well as less infiltration due to an increase in covered areas by buildings, road networks, etc.

The soils of Sonipat district are classified as tropical and brown sails that exist in major parts of the district. The area comprises almost flat plains traversed by one ridge running N-S to NNE-SSW direction and divides the alluvium into two parts. The major river is the Yamuna River, which is a perennial river.

1.1 Site Description

The site being developed as a warehouse complex in Sonipat is on grant Trunk Road, Sonipat, Haryana. The site was designed for a 1134 person occupancy with cold storage facilities, warehouses, administration, and residential buildings spread over 23.0 acres of area.

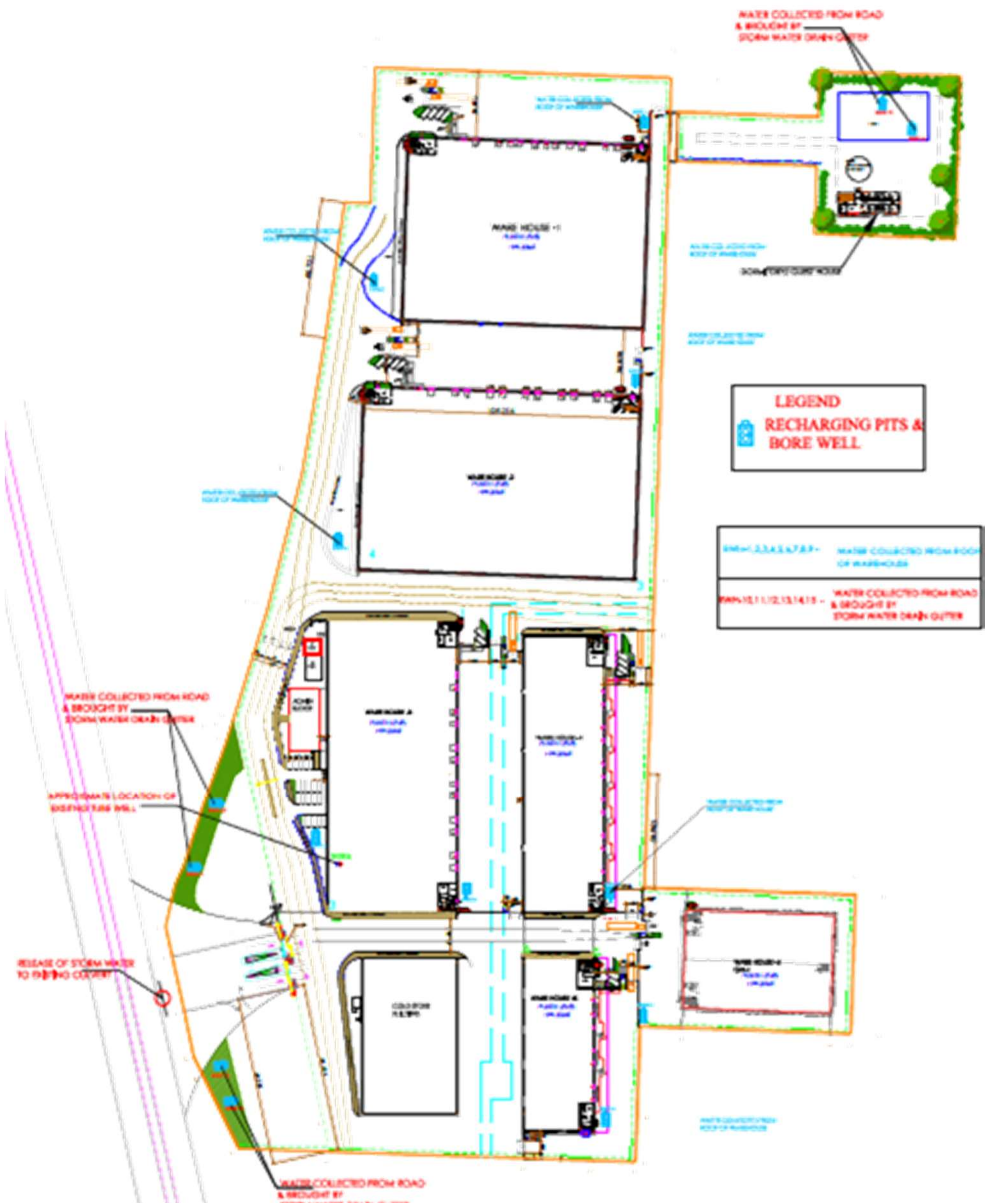

Figure 1: Site Plan ASGON Pvt. Ltd. Sonipat, India (Author, 2014)

1.2 Temperature

Temperature data for the last six years from 2006 to 2011 was collected from the Indian Meteorological Department and an average rainfall of these six years was considered for calculation of water losses due to high temperature, which depicted that pre-monsoon months are the hottest months recorded with a maximum temperature of 41.5 C in the months of June, July, and August. This is generally followed by rain, thus lowering the peak temperatures that otherwise cause heavy water losses due to evaporation and evapotranspiration.

Summers in Sonipat remain very hot and dry. The season of summer starts from April and lasts until June, while bringing about a very steep rise in temperatures. The maximum temperature may ascend to 47.7°C, and the minimum temperature is recorded as 3.9°C. Winters in Sonipat are very cold and damp. The season lasts for four months: November, December, January, and February. During winters, the maximum temperature rises to 3.9°C. However, there might be a sudden drop in the temperature level during the nights. The minimum winter temperature remains around 8°C. Sometimes, cold days are accompanied with heavy fog and winter sleets/hail.

1.3 Humidity

Humidity data for the last six years from 2006 to 2011 was collected from the Indian Meteorological Department. Humidity is highest during the rainy months. The highest humidity of 81% has been recorded in the month of August and a minimum of 24% in the month of May has been recorded. Thus, May is the driest month with the least humidity.

1.4 Rainfall

Sonipat experiences moderate rainfall during the rainy season, with the average rainfall recorded at 596 mm. However, isolated rains occur throughout the year. The southwest monsoon reaches the city around mid June and brings frequent spells of rain until October. Mild drizzles are recorded during the months of December through January. The southwest monsoon causes heavy rain to fall in the region in the rainy months starting from the last week of June to the end of September. The frequency of rain is highest in the months of July and August, reaching up to 338.8 mm in the month of August 2010, causing flooding in many low lying areas.

1.5 Solar Insolation and Sun Path Diagram for **Latitude**: +28.99 (28°59'24"N) and **Longitude**: +77.01 (77°00'36"E)

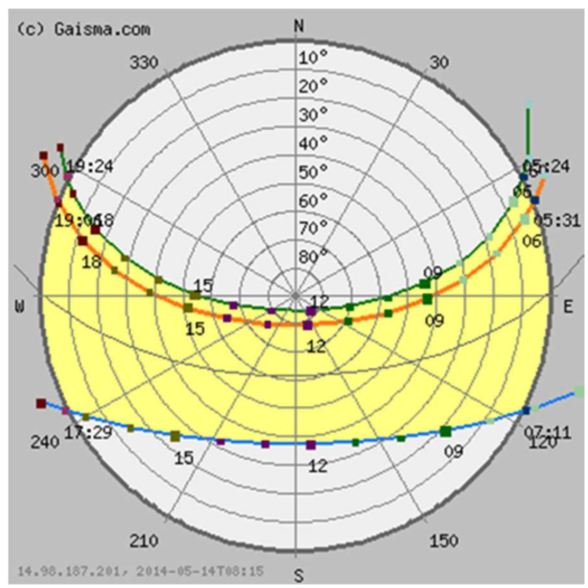

Figure 2: Sonīpat, India - Sun path diagram (Gaisma)

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	3.36	4.36	5.56	6.53	7.00	6.34	5.51	4.93	5.18	4.86	4.08	3.31
Clearness, 0 - 1	0.56	0.60	0.63	0.64	0.63	0.56	0.49	0.47	0.56	0.62	0.64	0.59
Temperature, °C	12.33	15.36	21.07	26.26	29.32	29.91	27.76	26.57	25.04	22.08	17.91	13.72
Wind speed, m/s	2.76	3.09	3.31	3.78	4.24	4.51	3.86	3.20	3.01	2.21	1.96	2.41
Precipitation, mm	19	15	16	8	16	51	222	255	110	20	5	8
Wet days, d	1.2	1.2	1.4	0.8	1.4	3.0	8.7	8.5	3.2	0.8	0.3	0.8

Figure 3: Sonīpat, India - Solar energy and surface meteorology, (Gaisma)

2. Scope of Study

a) To Analyze Factors Effecting Rate of Water Demand

b) Assessment of Water Demand and Water Availability

c) Estimation of Water Resources Including Groundwater, Rainwater, and Recycled Waste Water

d) Estimation of Renewable Energy Resources on Site

e) Assessment of Carbon Footprint of Water – Use on Site

f) Preparation of a comprehensive water management plan by taking into account the water demand, water availability, water reuse, and recycling as well as on this basis exploring the possibility of efficient conjunctive use of water.

3. Methodology

a) The study area was divided into different zones as a macro and micro level grid pattern, according to the physiographic condition. The macro level study is done for general vision of the sub-surface strata, and the micro level study is for the localized details.

b) The meteorological department's rainfall data were used for the rainfall intensity and pattern calculations in and around the study area.

c) The isohytal maps, which represent the points of equal rainfall, were also taken into consideration in order to establish the relation between rainwater restoration potential and rainfall in the study area.

d) The water level fluctuation in the area is studied through the data available for Uttar Pradesh. The groundwater quantity and quality potential is also studied through the geophysical investigations in the area.

e) The hydro-botanical studies suggest the types of plants that best suit the soil and environment of the area and help in the conservation of water resources.

f) The increase or savings in energy use and related emissions, relative to the reduction in main water demand (and wastewater to be treated).

g) Solar Energy Potential Assessment considering Standard Conditions for accessing the possibility of Solar Water Pumping within the site area.

4. Analysis and Discussions

The conjunctive use involves the coordinated and planned operation of both surface water and groundwater resources to meet water requirements in a manner in which water is conserved. Coordinated use of surface water and groundwater does not preclude importing water, as required, to meet growing needs. The basic difference between the usual surface water development with its associated groundwater development and a conjunctive operation of surface water and groundwater resources is that the separate firm yields of the former can be replaced by the larger and more economic joint yields of the latter.

Management by conjunctive use requires physical facilities for water distribution, artificial recharge, and for pumping. The procedure requires careful planning to optimize use of available surface water and groundwater resources.

A conjunctive use management study requires data on surface water resources, groundwater resources, and geologic conditions. Data on water distribution systems, water use, and waste water disposal are also necessary.

This conjunctive use management plans in the proposed site area requires the data regarding:

- Water requirement of the study area
- Water availability in and around the study area

4.1 Water Demand in the Study Area

Optimum economic development of water resources in an area requires an integrated approach that coordinates the use of both surface water and groundwater resources.

Management of the groundwater basin in an area needs development and utilization of subsurface water. The groundwater extraction water wells remain functional only if there exists a balance between water recharged to the aquifers from the surface sources and water pumped from the aquifers by wells.

Typically, the development of water supplies from groundwater begins with a few pumping wells scattered all over the area. With the passage of time, more wells are drilled, and the rate of extraction increases. As a result, the aquifer discharge increases to its recharging capability. Continued water extraction without a management plan could eventually deplete the groundwater resource. By regulating inflow and outflow from the basin, an underground reservoir can be made to function beneficially and indefinitely as a surface water reservoir.

Therefore, lack of management of major groundwater resources cannot be permitted if adequate ongoing water supplies are to be provided.

a) Factors Affecting the Rate of Water Demand

The demand for water varies from town to town, and factors which may affect the rate of demand of water are as follows:

Climatic Conditions

The consumption of water depends on the climatic conditions of the place. In warm countries like India and particularly the NCR, the amount of water required in summer will be much more than in the winter, as more watering of gardens, bathing, air-conditioning, watering of parks and fountains etc. is done. Therefore, the consumption increases in the summer season.

Habits of People

The consumption of water depends upon the economic status of the consumers and will differ widely in different localities in the same city. In wealthier localities, the consumption per capita will be high while in slum areas, a common tap may serve several families, and thus the consumption per capita would be low.

Efficiency of the Water Supply System

Efficiency of the waterworks will affect consumption. Leaks in mains, unauthorized connections, etc. increase losses and affect consumption.

Quality of Water

The consumption of water varies directly with the quality of water. If the quality is good, then the consumption will be high while the consumption will be low if the water has an unpleasant odor or taste. Such is the case of saline water or sewage water leakages in the main water supply.

b) Assessment of Water Demand

The water demand is assessed on the criteria of the type of building and the nature of the water usage pattern. The three major categorizations within site premises are as follows:

- The water demand for six warehouses along with the cold storage for an estimated population of 638 persons is calculated considering only the ground floor area to be on the safer side. However, if any additional special requirement of water is there for cold storage, the said can be considered while designing the cold storage.
- For Admin 288 person and Sec. cabins 32 Persons, an overhead water tank will be provided including the firefighting demand and the provision of future expansion considering 10% extra.
- A guest house with a capacity of 176 persons is provided with a separate overhead tank in view of its residential nature and water usage, which also includes the requirement of hot water.

The water demand of the project is detailed in the table below (Table 1).

4.2 Assessment of Water Availability

The available water resources on site, including groundwater and surface water, through the installation of tube wells and rainwater harvesting, respectively are calculated as follows:

Table 1

Water Demand for ASGON Pvt. Ltd. Sonipat (Author, 2014)

Description	Occu-pancy	Cold Water Requirement						Hot Water Req		Gross Water Req
		Flushing		Domestic Water		Drinking				
		Lpcd	Lpd	Lpcd	Lpd	Lpcd	Lpd	Lpcd	Lpd	Lpd
Ground Floor (Ware Houses, 1 To 5 & Cold Stor-ages)	638	15	9570	30	19140	10	6380	0	0	35090
Admn. Building	288	15	4316.4	30	8632.8	10	2877.6	0	0	15826.8
Ground Floor - Sec. Cabins	32	15	480	30	960	10	320	0	0	1760
Guest House	176	45	7920	90	15840	10	1760	30	5280	30800
Total			22286.4		44572.8		11337.6		5280	83476.8
Total (rounding off to nearest Kld)			22		45		11		5	83

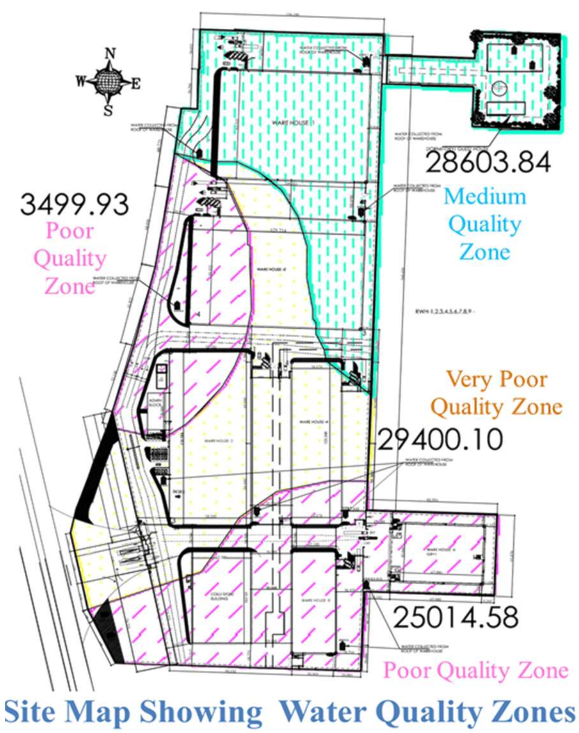

Figure 4: Groundwater Availability Map (Author, 2014)

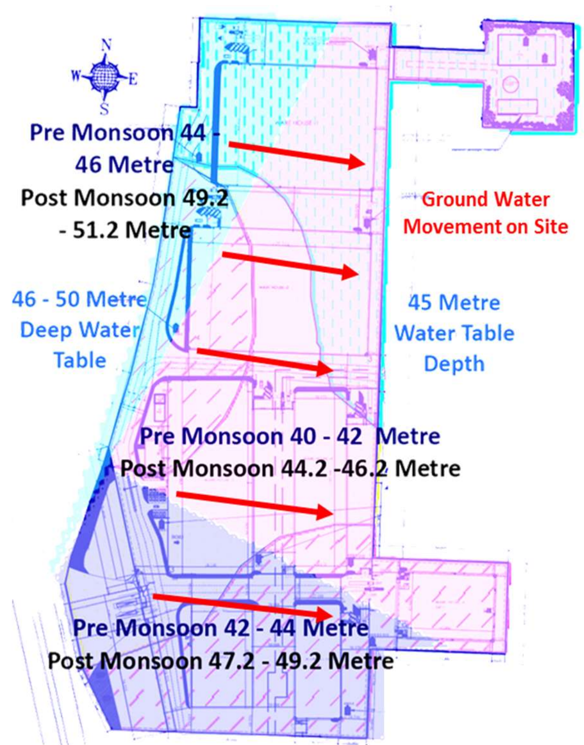

Figure 5: Site Water Level Fluctuation Map (Author, 2014)

Table 1

Ground Water Potential Zone Wise Availability at ASGON Pvt. Ltd. Sonipat (Author, 2014)

	Ground Water Potential Zone	Area of Open Space (m2)		Specific Yield	Water fluctuation Level	Ground Water Availability Q=AxWl-FxSp.yld
Zone 1	Medium Quality Ground Water Zone	28603.84	Silty Sand	0.2	3.2	18306.4576
Zone 2	Poor Quality Ground Water Zone	13499.93	Sandy Formation	0.18	5.2	12635.93448
Zone 3	Very Poor Quality Ground Water Zone	29400.1	Clay Kankar	0.17	4.2	20991.6714
Zone 4	Poor Quality Ground Water Zone	25014.58	Weathered Formation	0.16	2.9	11606.76512
					Total Ground Water Potential	63540.8286
					70% Extractable	44478.58002
					M3/day	121.8591

a) Groundwater Quantity

Depth-to-Water Level

The depth-to-water level in the study area is shallowest in the eastern side, and deeper water tables occur towards the road side. The shallowest water table occurs at a depth of 45 m below the existing ground level. The deepest water table occurs at the depth of 46-50 m b.g.l.

Water Level Fluctuation

The maximum water level fluctuation of 5.2 m is seen towards the road side, and the minimum fluctuation was recorded near the eastern side as 4.2 m.

Groundwater Movement

The groundwater flow in the study area is from the road to eastern side.

b) Groundwater Estimation

The groundwater potential is the capacity of the aquifer or groundwater reservoir to discharge water. This capacity or potential is low in areas lying in the southern and southeastern part. High potential area occur in the northwestern part, and in between the two lies the area with medium groundwater potential.

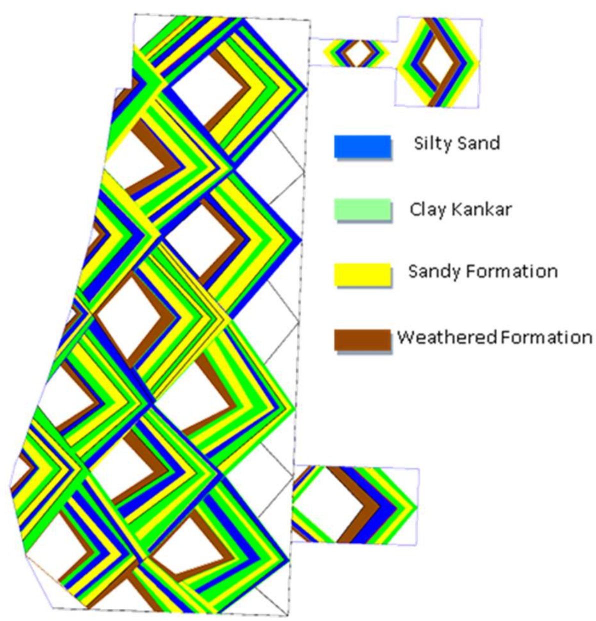

Figure 6: Fence Diagram of ASGON Pvt. Ltd. Sonipat (Author, 2014)

Table 2

Rain Water Potential ASGON Pvt. Ltd. Sonipat, India (Author, 2014)

Buildings/ Locations	Area in Sq.m	Average Intensity of Rain Fall – 20 mm Rainfall Potential Q= C*I*A in cu.m.	Flooded Intensity of Rain Fall – 100 mm Rainfall Potential Q= C*I*A in cu.m.	Yearly Average Intensity of Rain Fall – 596 mm Rainfall Potential Q= C*I*A in cu.m.
Rainwater Potential of Roof Top (C=0.9)				
Guest House	260.85	4.6953	23.4765	139.91994
Warehouse -1	8962.93	161.33274	806.6637	4807.715652
Warehouse -2	10316.9	185.7042	928.521	5533.98516
Warehouse -3	7630.06	137.34108	686.7054	4092.764184
Warehouse -4	6750.88	121.51584	607.5792	3621.172032
Warehouse -5	2473.75	44.5275	222.6375	1326.9195
Warehouse -6	2925.22	52.65396	263.2698	1569.088008
Cold Storage	2961.24	53.30232	266.5116	1588.409136
Admin Block	364	6.552	32.76	195.2496
Total	42645.83	767.62494	3838.1247	22875.22321
Rainwater Potential of Pathways (C=0.75)				
Paved Pathway-1	361.83	5.42745	27.13725	161.73801
Paved Pathway-2	394.59	5.91885	29.59425	176.38173
Paved Pathway-3	397.52	5.9628	29.814	177.69144
Paved Pathway-4	87.24	1.3086	6.543	38.99628
Paved Pathway-5	75.91	1.13865	5.69325	33.93177
Paved Pathway-6	293.21	4.39815	21.99075	131.06487
Paved Pathway-7	1610.3	24.1545	120.7725	719.8041
Total	3220.6	48.309	241.545	1439.6082
Rainwater Potential Road Area (C=0.7)				
Total Road Area in Asphalt	50399	705.586	3527.93	21026.4628
Rainwater Potential Green Area (C=0.3)				
Green Area 1	347.66	2.08596	10.4298	62.161608
Green Area 2	768.58	4.61148	23.0574	137.422104
Green Area 3	467.73	2.80638	14.0319	83.630124
Total	1583.97	9.50382	47.5191	283.213836

Table 3

Total Rain Water Potential at ASGON Pvt. Ltd. Sonipat (Author, 2014)

Intensity of Rainfall	Roof Top	Pathways	Road Areas	Green Areas	Total Potential
20mm	767.62494	48.309	705.586	9.50382	1531.0238
100mm	3838.1247	241.545	3527.93	47.5191	7655.1188
596mm	22875.223	1439.6082	21026.4628	283.213836	45624.508
Total Area	42645.83	3220.6	50399	56813.87	54810.651

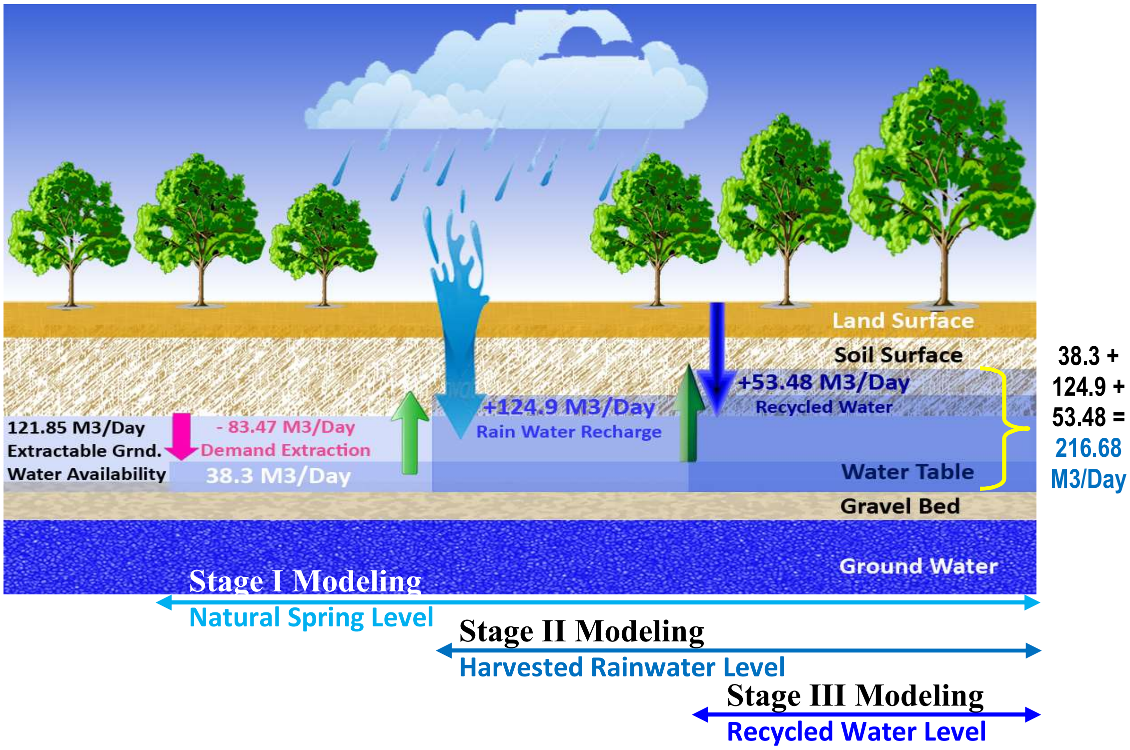

Figure7: CASE A - Water Level Improvement Map through Recharge (Author, 2014)

4.3 Rainwater Potential Estimation

Since the area has experienced flooding and water logging, even in the natural ground, it is obvious that the flooding and water logging will further increase due to an increase in the run-off condition. This will occur after the commissioning of the warehouses and other buildings. Therefore, 100 mm data may be considered for effective control on the water logging and flooding issues. Therefore, the calculations are made considering the average rainfall intensity of 20mm, flooding intensity of 100mm, and yearly average intensity of 596mm separately for the Rooftop, Pathway, Green Open, and Road Areas (Asphalt Road), with respective factor of Coefficient.

4.4 Recycled Water Assessment

At least 80% of the total used water can be recycled and reused within the site, especially for flushing and landscaping or other domestic purposes. While considering only flushing and domestic water for recycling water quantity, it is approximately a 8134.536 m3/yr requirement for flushing and a 16269.1 m3/yr requirement for domestic water use, which can be recycled on site. This makes a net volume of 24403.608 m3/yr (66.8592 m3/day) out of which only 80% can be used, which makes it 19522.8864m3/yr (53.48m3/day).

Table 4

Stage of Ground Water Development at ASGON Pvt. Ltd. (Author, 2014)

Total Water Demand	83476.8 LPD OR 30469.032 M3/Year			SWD	
Total Ground Water Potential	44478.58 M3/year	90103.08807	109625.97	68.5027085	Grey
Rainwater Potential	45624.508 M3/year			33.8157467	White
Recycled Water Potential	19522.8864 M3/year			27.79362478	White

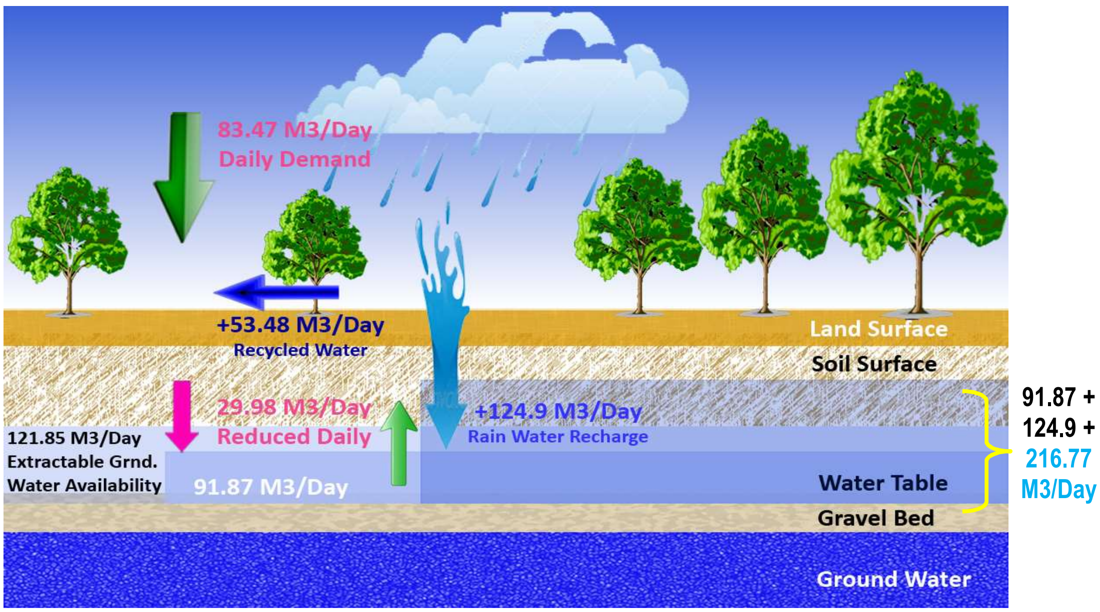

Figure8: CASE B - Water level Improvement Map through Demand Reduction (Author, 2014)

4.5 Stage of Groundwater Development

As per the stage of Groundwater Development (SWD) Nabard's Norm, SWD = Draft / Availability*100

<65%	White Category
>65% - 85 %<	Grey Category
>85%	Black Category

5. Hydro Monitoring Modeling for Water Piezometric Analysis

A Piezometric surface is the imaginary surface to which groundwater rises under hydrostatic pressure in wells or springs (Webster). Hydro monitoring is done to monitor a network in order to support science- based water resources management decisions (USGS).

Therefore, hydro monitoring modeling has been done for the site and a total groundwater potential 63540.8286 M3/year with an extractable quantity of 70% was determine, which equals 44478.58002 M3/year and 121.85 M3/day.

However, the daily water demand is 83.47 m3/day (30469.032 M3/year), extracted from ground water, which is fulfilled with a groundwater potential of 121.85 m3/day (44478.58 M3/year) extractable quantity on a daily basis with a leftover balance of 38.3 m3/day available in the aquifer after extraction.

Further, an addition of 124.9 m3/day of harvested rainwater will bring it up to (38.3 m3/day + 124.9 m3/day) 163.38 m3/day.

Which can be further uplifted and improved with the addition of a recycled water quantity of 53.48 m3/day (19522.8864 M3/year), making it (163.38 m3/day + 53.48 m3/day) 216.86 m3/day.

This makes a clear addition of 95 m3/day of water into the 121.85 m3/day available quantity of groundwater level. Thus, it helps improve the level at the groundwater table and establishes CASE A for study.

Otherwise, the recycled water can also be used to reduce total fresh water demand. The recycled quantity is (83.47 m3/day – 53.48 m3/day) 29.98 m3/day, thereby reducing the quantity of water extracted from the groundwater table, which will reduce the energy required to pump water from the ground. This establishes CASE B for study.

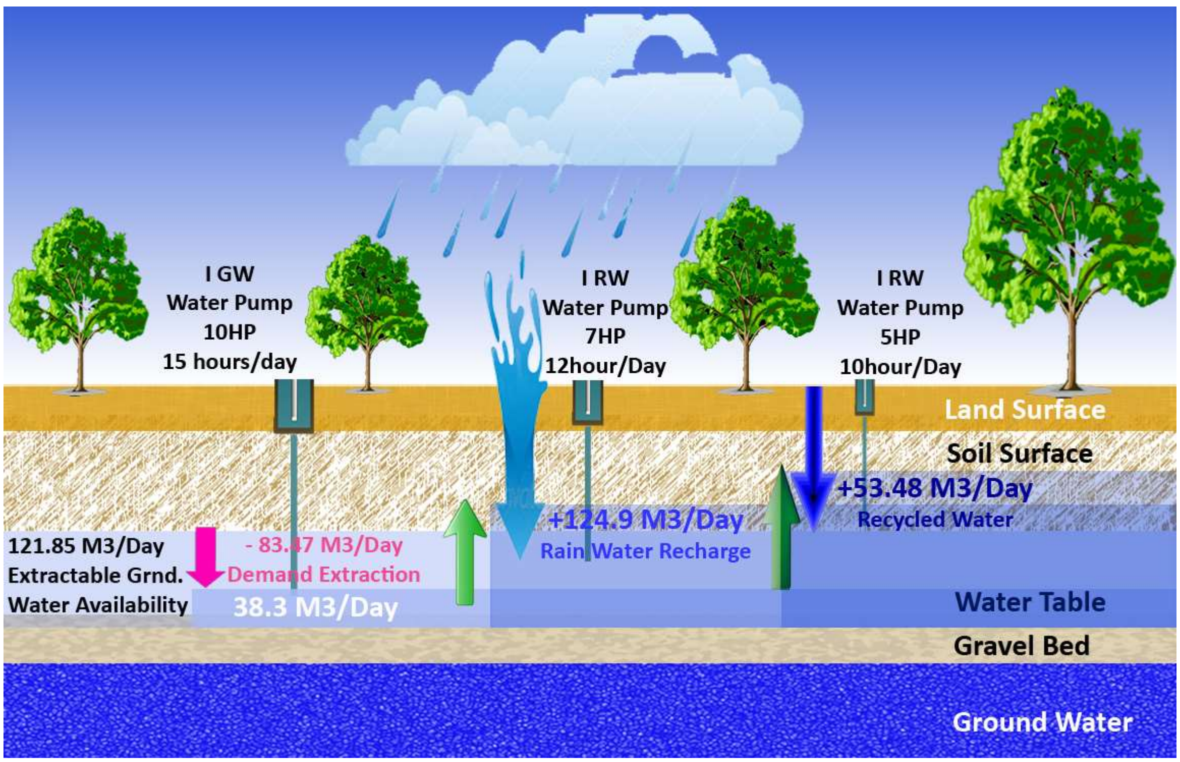

Figure 9: CASE A - Water level Improvement via Rain water Harvesting & Recycled water (Author, 2014)

Table 5

Comparative Carbon Footprint for Water Level Improvements – CASE A (Author, 2014)

I Ground Water	Gross Water Demand	I Rain Water	Gross Water Demand	I Recycled Water	Gross Water Demand
Water Demand LPD	83476.8	Water Demand LPD	83476.8	Water Demand LPD	83476.8
For Estimated Operation of 15hrs.	5565.12	For Estimated Operation of 12hrs.	6956.4	For Estimated Operation of 10hrs.	8347.68
Gallons/Hours	1224326.4	Gallons/Hours	1530408	Gallons/Hours	1836489.6
No. of Pumps	61.21632	No. of Pumps	76.5204	No. of Pumps	91.82448
Assuming Submersible KSB Pump Wattage as 10horse Power = 776watts	7760	Assuming Submersible KSB Pump Wattage as 7horse Power = 776watts	5432	Assuming Submersible KSB Pump Wattage as 5horse Power = 776watts	3880
Energy Consumed In Watts	475038.643	Energy Consumed In Watts	415658.8128	Energy Consumed In Watts	356278.9824
Watts to Kwh	7125.57965	Watts to Kwh	6234.882192	Watts to Kwh	5344.184736
Kwh for 365 Days	2600836.57	Kwh for 365 Days	2275732	Kwh for 365 Days	1950627.429
Electricity = 0.85 kg CO_2 per KWh, Source: CO_2 emission factor database, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm	2210711.09	Electricity = 0.85 kg CO_2 per KWh, Source: CO_2 emission factor database, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm	1934372.2	Electricity = 0.85 kg CO_2 per KWh, Source: CO_2 emission factor database, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm	1658033.314

6. Carbon Footprint of Water Use

Energy consumption can generate GHG emissions as a result of either combustion of fossil fuels in electricity generating stations or from burning oil or natural gas directly at the point of use. The greenhouse gas emissions, reported as equivalent carbon dioxide (CO2e)4 associated with generating power, are used in conjunction with the energy intensity of water use to calculate a carbon footprint; the grams of CO2e generated to extract, treat, and distribute 1 m3 of water; and to collect and treat 1 m3 of wastewater. Electrical energy use is converted to a carbon footprint (kgCO2e/m3) using a GHG emission factor (gCO2e/kWh). This factor is determined by the unique proportion of fossil-fuel fired electricity generation in each province (Mass, 2009).

The pumping energy for the distribution of treated water is common in the majority of systems with the exception of short retention grey water systems or raised rainwater storage tanks (the latter of which has not been considered in detail in this study). Rainwater harvesting systems do not normally include energy intensive treatment; however, it has been observed that in some cases, UV disinfectant systems are added to the system post filtration. The calculation model base assumptions do not assume the presence of a UV disinfectant component for any of the generic rainwater systems.

In this study, operational carbon is taken to be the emissions associated with electricity use for any pumping and treatment, calculated as follows:

- Operating carbon footprint = sum of energy use for (pumping + treatment) x electricity emissions factor
- The accuracy of operational calculations depends on the accuracy of assumptions made about the electricity use for pumping and treatment (Parkes, 2010).

Considering that the carbon emission factor for India is 0.85 (Green Clean Guide, 2011), the energy assessment for actual and reduced water demand is calculated for different cases with projected carbon emissions.

6.1 Description CASE A

For the gross water demand on site, it is 83.47 m3/day (30469.032 M3/year), assuming a 10HP water pump working for 15hours/day in order to extract groundwater available at 45metres depth. The energy consumed is 2600836.57 KWH annually with a carbon footprint of 2210711.09 $kgCO_2$.

However, 124.9 m3/day (45624.508 M3/year) of harvested rainwater and its subsequent recharging to the aquifer helps in uplift the groundwater table. Therefore, assuming a 7HP water pump working for 12hours/day extracting groundwater at a depth of 42 meters, the energy consumed is 2275732 KWH annually with a carbon footprint of 1934372.2 $kgCO_2$.

This can be further reduced by the addition of a treated recycled water quantity of 53.48 m3/day (19522.8864 M3/year) on site to be allowed to recharge the groundwater table. This would improve and uplift the groundwater table up to approximately 40 meters. Therefore, assuming a 5HP water pump working for 10hours/day, the energy consumed is 1950627.429 KWH annually with a carbon footprint of 1658033.314 $kgCO_2$.

Therefore, with CASE A, the study achieves a reduction of 55267.77714 $kgCO_2$ annually, which is approximately a 25% reduction in extraction of gross water demand through groundwater level improvements via recharge through rainwater harvesting and recycled water on site.

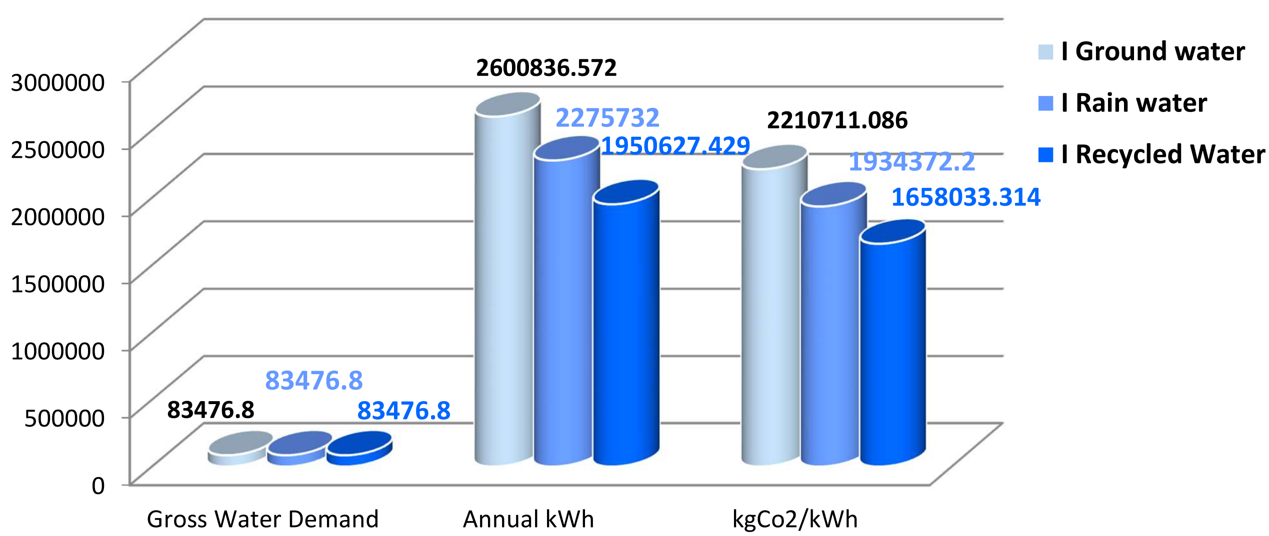

Figure 20: Comparative CASE A (Author, 2014)

Table 6

Energy Assessment for Water Demand at ASGON Pvt. Ltd. (Author, 2014)

	Total Flushing Demand	Recycle Water Replacing Flushing Demand	Total Domestic Demand	Recycle Water Replacing Domestic Demand	Total Drinking Demand	Hot Water Requirement	Gross Water Demand	Reduced Water Demand
Water Demand LPD	22286.4	66781.44	44572.8	77.76	11337.6	5280	83476.8	16695.36
For Estimated Operation of 15hrs.	1485.76		2971.52	5.184	755.84	352	5565.12	1113.024
Gallons/Hours	326867.2		653734.4	1140.48	166284.8	77440	1224326.4	244865.28
No. of Pumps	16.34336		32.68672	0.057024	8.31424	3.872	61.21632	12.243264
Assuming Submersible KSB Pump Wattage as 10horse Power = 776watts	7760		7760	7760	7760	7760	7760	7760
Energy Consumed In Watts	126824.4736		253648.9472	442.50624	64518.5024	30046.72	475038.643	95007.72864
Watts to Kwh	1902.367104		3804.734208	6.6375936	967.777536	450.7008	7125.57965	1425.11593
Kwh for 365 Days	694363.993		1388727.986	2422.721664	353238.8006	164505.792	2600836.57	520167.3143
Electricity = 0.85 kg CO_2 per KWh, Source: CO_2 emission factor database, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm	590209.394		1180418.788	2059.313414	300252.9805	139829.9232	2210711.09	442142.2172

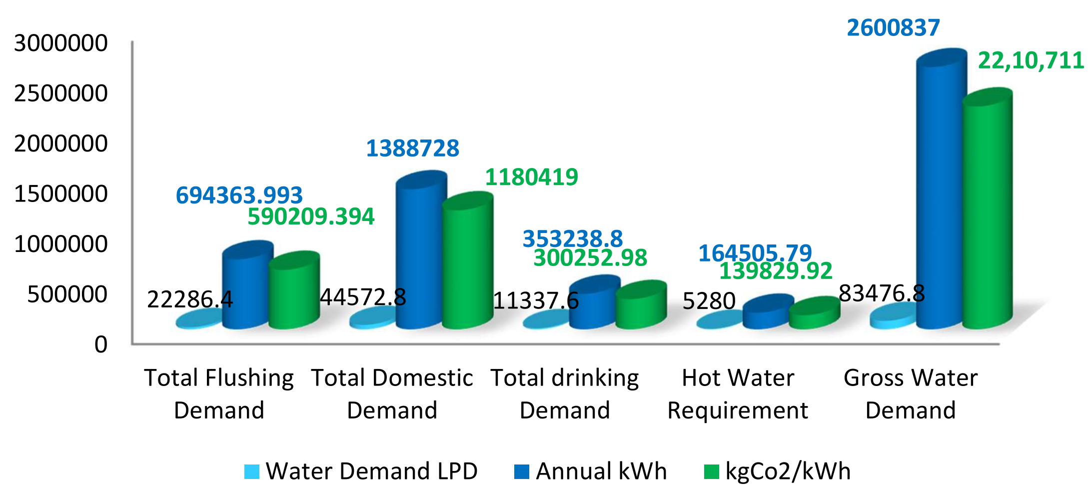

Figure11: CO2 Footprint of Energy Consumed in Watts to meet Respective Water Demands at ASGON Pvt. Ltd. (Author, 2014)

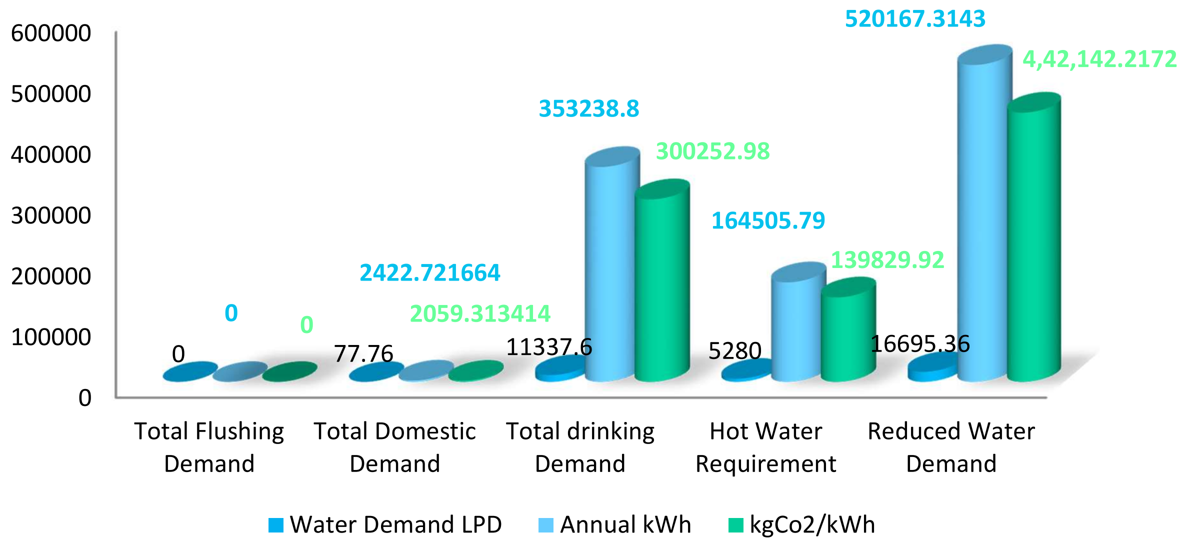

Figure12: CO2 Footprint of Energy Consumed with Reduced Water Demands at ASGON Pvt. Ltd. (Author, 2014)

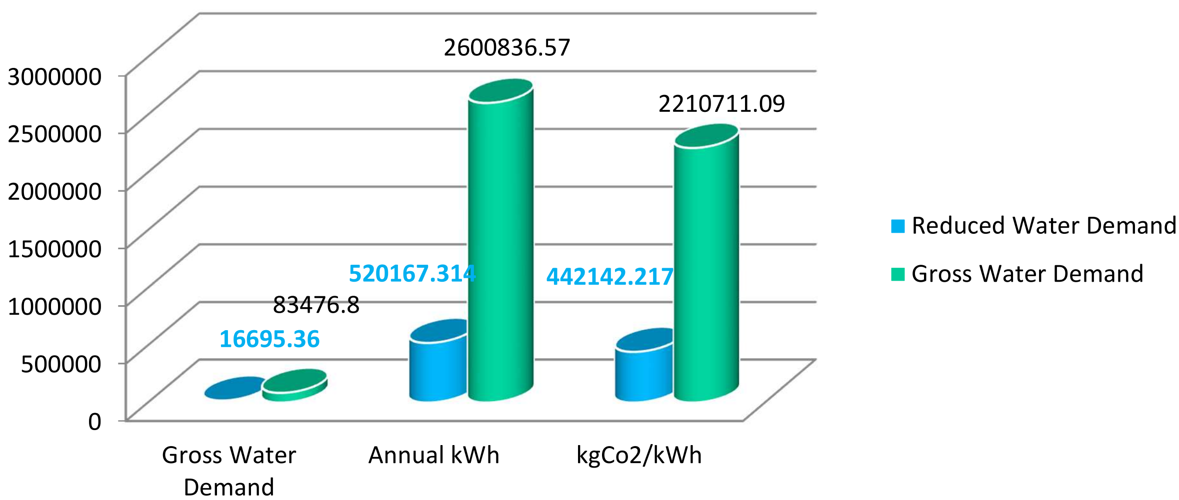

Figure13: Comparative for CO2 Footprint at ASGON Pvt. Ltd. (Author, 2014)

Table 7

Comparative Carbon Footprint for Water Level Improvements and Demand Reduction – CASE B (Author, 2014)

I Ground Water	Reduced Water Demand	I Rain Water	Reduced Water Demand
Water Demand LPD	16695.36	Water Demand LPD	16695.36
For Estimated Operation of 15hrs.	1113.024	For Estimated Operation of 12hrs.	1391.28
Gallons/Hours	244865.28	Gallons/Hours	306081.6
No. of Pumps	12.243264	No. of Pumps	15.30408
Assuming Submersible KSB Pump Wattage as 10horse Power = 776watts	7760	Assuming Submersible KSB Pump Wattage as 7horse Power = 776watts	5432
Energy Consumed In Watts	95007.72864	Energy Consumed In Watts	83131.76256
Watts to Kwh	1425.11593	Watts to Kwh	1246.976438
Kwh for 365 Days	520167.3143	Kwh for 365 Days	455146.4
Electricity = 0.85 kg CO_2 per KWh, Source: CO_2 emission factor data-base, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm	442142.2172	Electricity = 0.85 kg CO_2 per KWh, Source: CO_2 emission factor data-base, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm	386874.44

6.2 Description CASE B

In the case of recycled water on site, a recycled water quantity of 53.48 m3/day (19522.8864 M3/year) is utilized to offset actual water demands. A daily water demand of 83.47 m3/day (30469.032 M3/Year) will lead to a significant reduction of 29.98 M3/day (10942.7 M3/year) that will be extracted from the available groundwater quantity.

Assuming an estimated operation of 15hours/day with a submersible KSB pump of 10HP extracting available groundwater at a depth of 45 meters, the energy consumed will be 520167.3143 KWH annually with a carbon footprint of 442142.2172 kgCO_2.

However, the energy consumed for the same quantity of reduced demand extracted from the groundwater table will get reduced in case of improved water level up to 42 meters (approximately) due to the addition of 124.9 m3/day (45624.508 M3/year) of harvested rainwater. This will improve groundwater levels and reduce the operation hours from 15hours/day to 12hours/day with a 7HP water pump. The energy consumed will be 455146.4 Kwh annually with a carbon footprint of 386874.44 kgCO_2.

Therefore, with CASE B, the study achieves a reduction of 55267.77714 kgCO_2 annually, which is approximately a reduction of around 12.5% when compared with 5,20,167.3143 Kwh against 4,55,146.4 KWH. This is achieved through groundwater level improvements via rainwater harvesting and demand reduction via the utilization of recycled water on site.

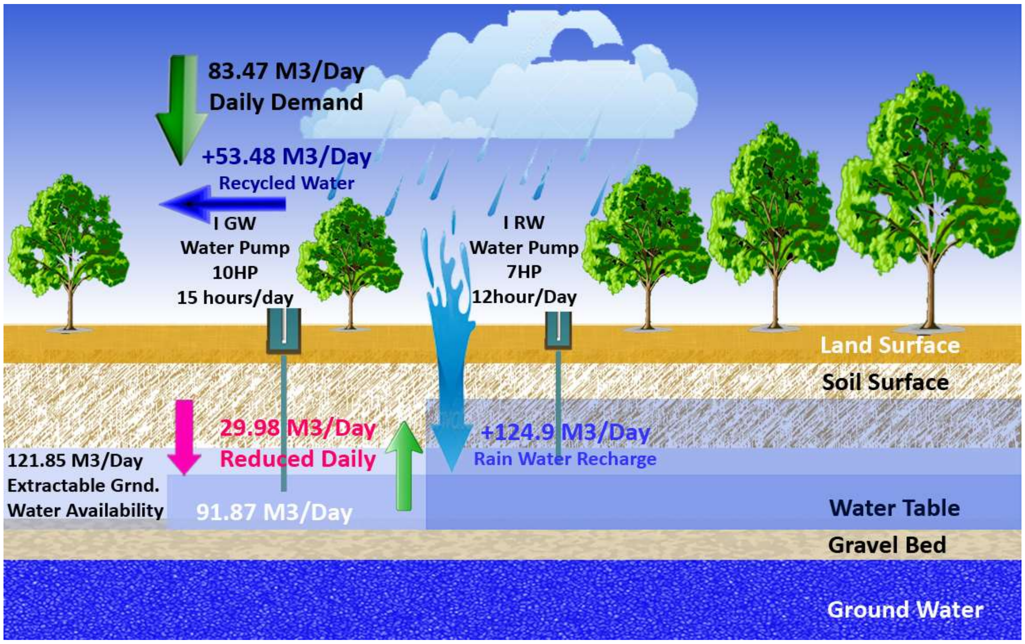

Figure 14: CASE B - Water level Improvement via Rain water Harvesting & Demand Reduction through Recycled water (Author, 2014)

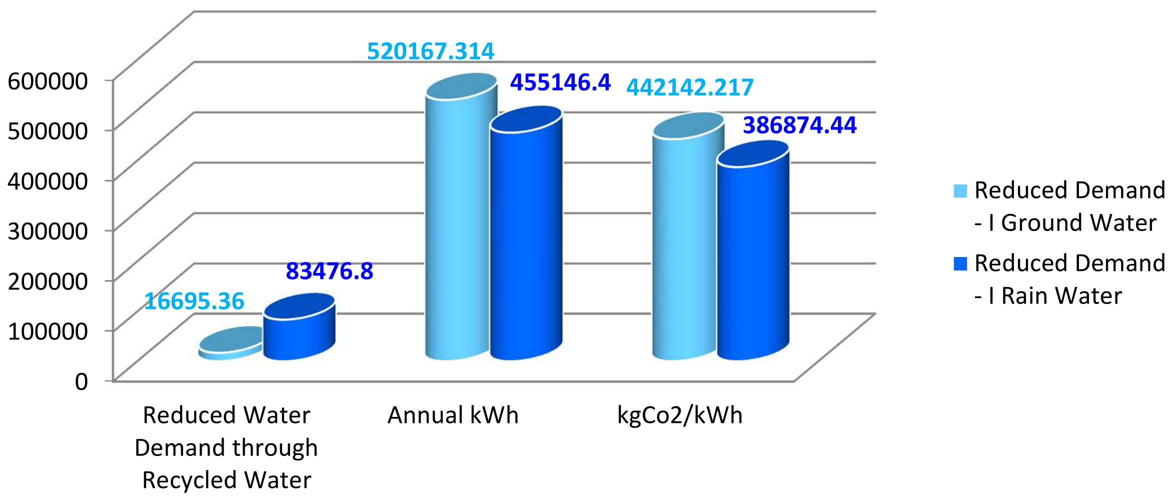

Figure 153: Comparative CASE B (Author, 2014)

7. Solar Exposure Analysis of Study Area

Solar exposure analysis has been performed for the study area using Ecotect Version 5.50 to assess solar insolation levels over the building facades and ground surface to enable the installation of solar photovoltaic panels over the built surfaces and ground surfaces available in the landscape area.

The solar radiation calculation is done using recorded direct and diffuse radiation data from the weather file and is calculated through site latitude and longitude. Given the dynamic path of the sun through the sky and changing climatic conditions, solar radiation and over-shadowing values will vary over time as well as spatially. Therefore, the annual period is considered for calculation for a time range from 8AM to 5PM with average daily values.

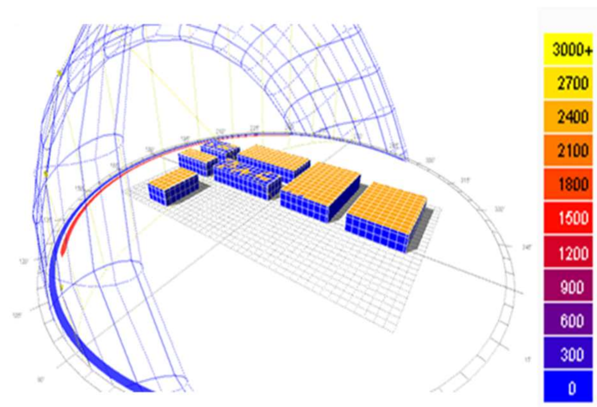

Figure 16: Roof Top Insolation Analysis ASGON Pvt. Ltd. Sonipat, India (V5.51)

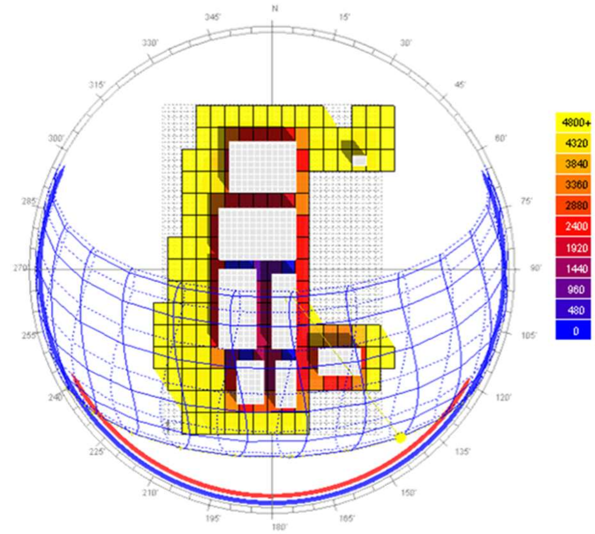

Figure 17: Available Solar Radiation at Ground Surface at ASGON Pvt. Ltd. (V5.51)

Table 8

Daily Solar Potential for the Study Area (Author, 2014)

	Average Solar Radiation (kWh/m2/day)	Calculated Roof Area Potential	Calculated Green Area Potential	Total Potential (kWh/m2/day)
Min. Insolation, kWh/m²/day	3.31	141157.697	188053.91	146400.638
Average Insolation, kWh/m²/day	5.15	219626.025	292591.431	227783.47
Max Insolation, kWh/m²/day	7	298520.81	397697.09	309608.6

Due to the limited area of landscape available in the study area, the built surfaces must be considered as power generating surfaces. Vertical surfaces don't have much solar potential to be harnessed, but the horizontal surfaces, including the building rooftops and the landscape area available, have good solar power potential of 3000+Wh (energy) and 4800+Wh (energy), respectively, as an average daily value potential. Therefore, considering the average solar insolation value for the study area, the solar power potential is calculated in Table 9.

Looking into the site situations where a very limited 56813.87m2 area is assigned as open green space, in which only 1.681% of total site area is utilized for landscaping and 42645.83m2 area is the built up rooftop area, makes it 45% of total site area. This increases the potential for roof top solar harvesting instead of ground or surface solar harvesting. Therefore, considering the worst case scenario for drinking water pumping requirement with roof top solar energy harvesting systems, the following values have been obtained with minimum, average, and maximum solar insolation values for the rooftop area only. This clearly indicates the excess availability of green energy on site by converting solar energy potential into electrical energy using crystalline solar cells with 20% conversion efficiency under STC.

Table 9

Assessment of Solar Potential - Minimum, Average, and Maximum Insolation ASGON Pvt. Ltd. (Author, 2014)

	Average Solar Radiation (kWh/m2/day)	Daily Solar Potential (kWh/m2/day)	Annual Solar Roof Area Potential (kWh/m2/year)	Considering STC corresponding Conversion efficiencies (kWH/m2/day)	Considering STC corresponding Conversion efficiencies kWh/mw/year	Roof Top Annual Potential	Actual demand	Reduced Demand
	KWH for 365 Days						26,00,836.572	5,20,167.3143
Min. Insolation, kWh/m²/day	3.31	141157.6973	51522559.51	0.662	241.63	1,03,04,511.9	7703675.331	9784344.589
Excess Energy Quantity Remaining to be used for purposes other than Water Pumping							75	95
Average Insolation, kWh/m²/day	5.15	219626.0245	80163498.94	1.03	375.95	16032699.79	13431863.22	15512532.47
Excess Energy Quantity Remaining to be used for purposes other than Water Pumping							84	97
Max Insolation, kWh/m²/day	7	298520.81	108960095.7	1.4	511	21792019.13	19191182.56	21271851.82
Excess Energy Quantity Remaining to be used for purposes other than Water Pumping							88	98

This green energy generated on site will offset the electricity used for pumping water systems in the study area while producing excess quantity, which can further be utilized for lighting or other energy intensive uses within the study area. Therefore, it becomes a Green Energy Intensive Site with Zero Carbon Footprint for water pumping systems (other energy consumption within the site have not been included in this paper).

This makes solar water pumping a feasible concept on site where the sun and solar panels provide all of the electricity needed to pump water while eliminating the need for any external power source. This makes solar water pumping a low cost water pumping option (Repository).

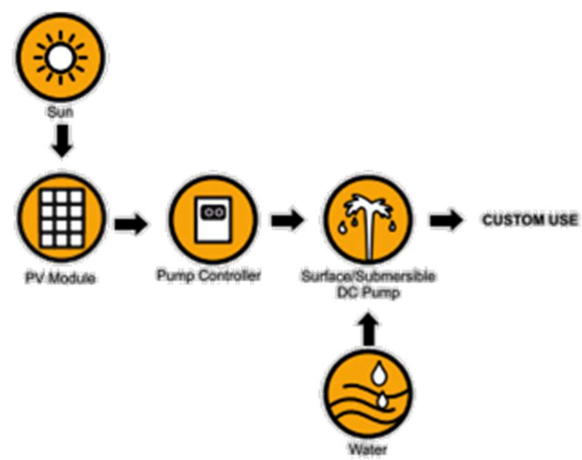

Figure 18: Solar Water Pumping System Configuration, (SunTechnics)

The following considerations have been made for obtaining the annual energy output on site:

- By convention, solar cell efficiencies are measured under standard test conditions (STC) unless stated otherwise. STC specifies a temperature of 25 °C and an irradiance of 1000 W/m2 with an air mass of 1.5 (AM1.5) spectrums. These conditions correspond to a clear day with sunlight.
- A solar panel with 20% efficiency and an area of 1 m^2 will produce 200 W at STC, but it can produce more when the sun is high in the sky and will produce less in cloudy conditions and when the sun is low in the sky (wikipedia).

8. Conclusions

In accordance with Nabard's Norm, the calculated water demand in the site area falls in the grey category of Nabard's Norm with a gross water demand of 83.4768 M3/Day (30469.032 m3/yr) against an availability of 121.85 M3/Day (44478.58m3/yr). The use of groundwater, with the recommendation of reusing recycled water for flushing and landscaping purposes, reduces the burden on fresh water sources by reducing the total water demand from 83.4768 M3/Day (30469.032m3/yr) to 16.69M3/Day (6,093.8M3 /yr). With the addition of rainwater potential, the availability is increased to 124.9 M3Day (45624.508M3/yr), and the total availability is further enhanced to 46624.50805 M3/ yr, which improves the stage of groundwater development, allowing it to fall under the white category (Figure 9).

For water recycling, it is recommended that a root zone system be used followed by other water treatment mechanisms. Solar energy can also be used for water stabilization pond to treat waste water without any chemical or electricity. Furthermore, reductions in water demand can be achieved through the application of dry land plantation for vegetation cover and a drip irrigation system for plant watering.

Rainwater harvesting is proposed to control flooding and water logging and groundwater recharging. Massive pumping out of subsurface water has caused a regular decline in the groundwater table of the area. The extraction of water has been occurring at an alarming and uncontrolled rate (which is why the output-to-input ratio is very high); therefore, rainwater harvesting is required to reduce the O/I ratio.

Because of groundwater recharging, the aquifer system of the study area will get saturated. As a result, the failure of the tube well/bore will stop because of decreasing levels of available water table, with the improvement in groundwater quality due to more percolation of rainwater other than the natural course of action for percolation. In a limited green open area of 1.61% of total site area, the need is to use infiltration devices and permeable pavements in hard open spaces in order to maximize the percolation.

The study also assesses the carbon footprint of the energy consumed in meeting the above calculated water demand on site along with the relevant reductions achieved in carbon footprints by reducing and reusing water. From an initial carbon footprint of 22,10,711.09 kgCo2/KWH for gross water demand to 4,42,142.2172 kgCo2/KWH for reduced water demand and further up to 386874.44 kgCo2/KWH through water level improvement modeling via CASE B scenario (Table 6 and Table 8). This makes a significant reduction of 80% with reduced water energy demand and 87.5% achieved through improved water level and its subsequent energy consumption in abstraction of water on site.

Therefore, it's not only reducing water demand but also reducing the energy demand on site along with the subsequent carbon emissions associated with power consumption. This makes the study area efficient in terms of energy utilization. However, a solar potential analysis is also performed to assess the onsite solar energy harnessing potential and to propose on site energy generation to make the study area energy-independent rather than energy-dependent. This makes it a green energy intensive site with zero carbon footprint for water pumping systems.

A comparison is made between the energy requirement for extracting gross water demand and the energy requirement for extracting reduced energy demand. Three different solar insolation scenarios of minimum, average, and maximum solar insolation conditions on site are considered (Table 10). The conclusion is that solar energy generates a sufficient amount of energy required for water pumping systems along with the excess amount of energy, which ranges between 75% to 98%. This energy can be used on site for purposes other than water pumping.

An integrated approach to sustainable water management not only improves the groundwater levels but also reduces water demand affecting energy consumption on site and its consequent carbon emissions. This makes the study area self sufficient for its water and energy demands. This also makes the study area eligible for programs like Renewable Energy Credits (REC) and Renewable Portfolio Standard (RPS).

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