SOLAKE - An econometric model for Sustainable Revival of lakes tied together with solar renewable energy generation.

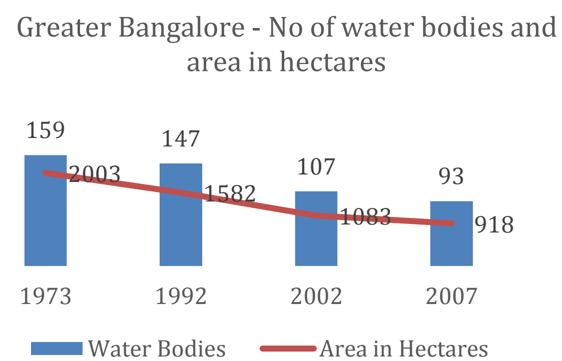
Abstract

This paper analyses how lakes and water bodies in the country, specifically in the cities, are in a state of disrepair and increasingly becoming extinct. Since lakes and water bodies have a very important role to play in maintaining the groundwater level and providing open spaces for the community, many attempts have been made to revive them, but they have not sustained because of their humongous costs to revive (build) and survive (maintain). This paper attempts to provide an environmentally sustainable and economically viable approach to revive lakes and at the same time generating renewable solar energy to self-sustain its ecosystem & generating income by selling extra power produced to Govt. This paper is a collaborative effort to bring together technologies and techniques from solar power plant design and implementation, revival and rejuvenation of water bodies, waste water treatment and ground water recharging and econometric modelling to establish a financially feasible self-sustaining model for revival of lakes and urban water bodies.

Idea

The central idea of this paper is to revive the lakes in a sustainable manner and develop a collaborative ecosystem for generating solar energy. By combining lake ecosystem development with solar energy generation, we hope to create a long term sustainable solution for all stakeholders. This idea is within our grasp because of the contemporary advancements in the solar power generation, experiments conducted in lake revival, available techniques for waste water treatment and ground water recharging.

There were a lot of lakes in Karnataka. They were constructed in the sixteenth century by damming the natural valley systems. However, the effect of urbanization has taken heavy toll on the lakes. The lakes in Bangalore have been largely encroached for urban infrastructure. A study by Ramachandra TV and Uttam Kumar indicate the extent of decline in lakes and water bodies in the Greater Bangalore area.

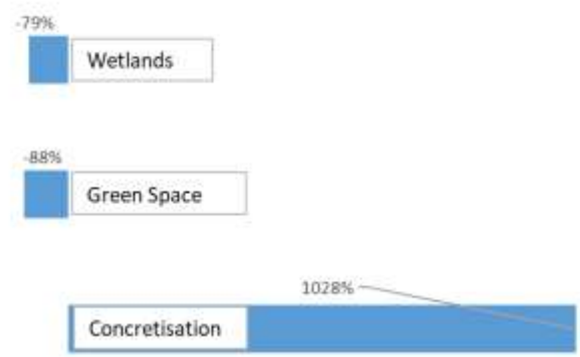


Due to urban development many lakes have been converted to bus stands, Golf courses, playgrounds, and residential colonies. Though there are differences in the numbers and extents of the tanks/lakes, all the studies on lakes accept the fact that there is a sharp decline in the number of lakes and the extent of lakes in the city.

Our plan consists of reviving lakes using sewage water treatment and botany. Then a diverse ecosystem will be set up near the lake, thereby creating a beautiful park and an extravagant recreational spot for the people living in nearby localities. Solar Panels will be set up above the lake. The energy generated would be distributed to the nearby localities through the main power grid. The lake will contribute to maintaining the ground water level, and a water harvesting system will be set up along the banks of the lake to make the most of the rain and the storm water run off from nearby areas. This will also help in controlling incidents of flooding.

Pollution

Urbanization has resulted in concretisation, impacting natural resources leading to a decline in green spaces and wetlands, higher air pollutants and a sharp decline in the groundwater table. Geo-visualisation of likely land uses in 2020 and 2025 reveals a calamitous picture of 93 per cent and 98.5 per cent of Bangalore landscape filled with paved surfaces (urban cover) and a drastic reduction in open spaces, water bodies and green cover.



In recent years, the lakes have shrunk considerably due to encroachment. Nearly 2/3rd of the lakes are sewage fed, with 72% showing a loss of catchment area. Unchecked and widespread dumping of garbage is choking the lakes. The vacant plots along the banks of the lake serve as dumping sites. Many of these plots are not fenced and people unscrupulously dump garbage in these plots at night. Caretakers of the plots then set fire to the piles of garbage, instead of disposing it properly. The problem is aggravated when the untreated industrial effluents and untreated sewage water from the nearby localities are let into the lakes.

Analysis of Historical attempts - failures and success

In recent years, the management of lakes, traditionally done by the government agencies, witnessed experimentation by the Lake Development Authority with a limited public-private sector participation, which has proved controversial and resulted in almost a reversal of the policy.

Many lake revival projects have been attempted in the past, but only a handful have seen the light of the day. Lakes like Konasandra and Puttenahalli situated in Bangalore have been successfully revived. It was possible because of the cooperation by the people living near the lakes and their donations. All the work was done by those people, but this model cannot be implemented for reviving other lakes because every lake has a different set of people living around it and every lake has its own problems. For example, some lakes have horrendous amounts of garbage whereas some lakes have very high concentrations of chemicals. Also, community needs and participation vary greatly by location.

Some Lakes which were rejuvenated, are being maintained poorly due to long term recurring expenses.

Why Solar-Lake Project?

Our Solar-Lake Project seamlessly tackles the above-mentioned problems and also generates clean and renewable solar energy. There is a solar power generation plant on top, the project is economically feasible.

The clear benefits of this project are:

1. Unutilized areas will be used for Solar Power Generation.
2. The look and feel of the lake will be substantially improved.
3. Lakes will be Protected from encroachment.
4. Recharging of ground water and flood control
5. Development of aquatic life
6. The lake area will become highly useful for the public for exercise and recreation.
7. Water evaporation can be controlled from which ground level water will be improved.
8. Local employment creation for Solar Lake Park Maintenance.
9. Each lake will have power generating stations along with lake & environment protection.
10. Issues of vector-borne and various other diseases will reduce significantly.

The process of sustainable lake revival will be carried out in two distinct parts viz. (1) lake revival, (2) Development of solar power plant.

Lake Revival

For the revival of the lake one or more of the following actions would need be carried out, depending upon the specific lake in consideration:

1. Bed cleaning and removal of debris from the lake bed – will also be required for solar plant civil works.
2. Setting up of one or more stage biofiltration plants at all incoming points in the lake, to ensure treated water enters the lake body.
3. Planting aquatic plants like canna, water spinach, and vetiver to absorb the excess nutrients and harmful chemicals.
4. After some time, fishes will be released into the lake, which will improve the lake ecosystem, as the fishes will naturally cleanse the lake.
5. Development of rain water harvesting system.
6. Artificial islands (using the mud dug from the lake) and/or floating islands (fishing nets would be used to bind plastic bottles and waste collected from the lake to floating islands), both these islands will be filled with the aforementioned plants.
7. Footpath and gardens will be developed alongside the lake for the public. People can exercise (jog, walk, sprint, cycle) or come with their family/friends and enjoy a peaceful walk.
8. Development of inner lake area with proper leveling and grading, and the development of the Lake peripheral area with Proper Slope.
9. Construction of Fencing at the entire periphery.
10. For the maintenance of the lake and the footpath, 2-3 gardeners will be employed. They will make sure that the vegetation around the lake is healthy.
11. 3-4 security guards will be employed for securing the entire solar lake park; they will make sure that nobody litters the footpath or throws garbage in the lake.

During the initial years, the water level of the lake will be maintained using treated water (after biofiltration from the nearby apartment and/or municipal water treatment plants). The excess treated water, which is used within the community for watering gardens and flushing toilets, will be released in the lake. After the initial years, the lake will be rain-fed. All the storm drain canals will have a net to catch the sewage before it enters the lake.

Development of Solar Power project

Development of solar power project at the specific area of the part will consist of following key activities:

- Foundation and Construction of Elevated Solar Mounting Structure including Civil works within the lake.
- Installation of Solar Module on the Structure with minimum 2 meters clearance from the Ground Level / water level.
- Execution of evacuation line to evacuate the power at the nearest Substation.

The solar panels would significantly reduce the water evaporation. In the Annexure V, we have provided a 3 dimensional view of the SOLAKE module mounting and foundation and structure that has been planned for this project.

Suggested approach for Public Private Participation (PPP)

The proposal of SOLAKE is being sent to BBMP / Karnataka Renewable Energy Development Limited (KREDL) / Karnataka Lake Conservation and Development Authority (KLCDA). Likely approach steps for PPP involving stakeholders can be as follows :

- Develop a standard PPP document including bid process management and contract documents, to be used for various lakes.
- Identify a dedicated agency which will run this process and act as a single window for the PPP process and the bidder.
- Appointing an advisory committee for each lake comprising of eminent citizens of the area / RWAs and government officials.
- For each lake a DPR to be prepared in consultation with the advisory committee. The DPR to clearly highlight the works that need to be undertaken for lake revival, area development and solar project.
- Conducting Bid process management and select preferred developer.
- Selected developer to develop the lake under the overall guidance and supervision of the advisory committee.

The entire project would be developed under the Renewable Energy Service Company (RESCO) model, where the power generated from the project would be purchased by BBMP/ government departments under a long-term power purchase contract of 25 years. The price would be discovered through the competitive bidding process. Further, the municipality / BBMP / KREDL will obtain special dispensation approval from the regulatory commission for allowance of virtual net metering, whereby power generated from the project would allow BBMP/ Government department to set off its consumption at another place within the Distribution Company area.

Before opening up the project for private bidding, the BBMP / Municipality will carry out a comprehensive Detailed Project report (DPR) to enumerate the project components viz location, area for the solar project, and other determinant factors. A government undertaking such as KREDL/ KLCDA can act as a central agency for conceptualizing the projects, conducting the bidding process, obtaining the necessary approvals, ensuring the execution of PPAs, and managing the projects on behalf of the government during construction and lifetime operation of the project. KREDL/KLCDA may charge a fee as a percentage of tariffs from the project for its efforts and services.

For calculating the feasibility in the paras below, we have considered Samethanahalli lake, located in Bengaluru Karnataka as an example. Lake on the google map is shown along side.

Estimated cost and financial feasibility of the Project

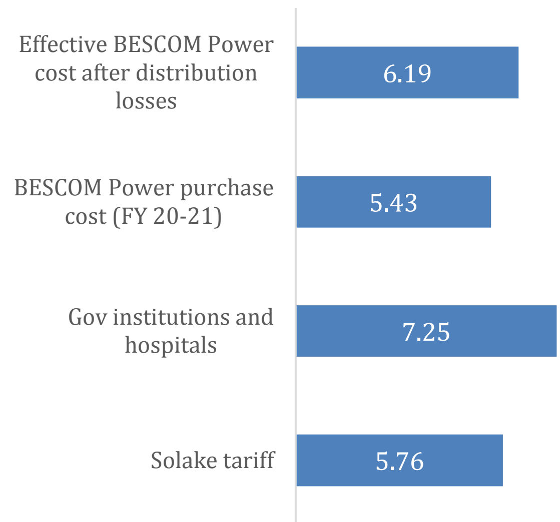
Indicative project cost and economic analysis has been carried out with the following assumptions. This lake is spread over 44 acres, about 17 hectares. Following can be the possible configuration for development and revival of the lake:

1. 3 hectares for park, fencing, walking track, etc.
2. 2 hectare for lake water management, filtration system, debris collection, etc.
3. 10 hectares for solar panel installation in the shallow part of the lake - can accommodate a 10 MW project
4. 12 hectares for the lake with water.
5. Assuming an average water depth of 1 Meter - the total volume of water in the lake would be around - 120,000 KL.
6. Assuming a seepage and evaporation loss of 20 mm per day = 2400 KL per day. This is equivalent to water discharge from a 25 lakh sq feet society.
7. The generation from the solar project is estimated to be 1.5 Mio Unit per MWp.

A detailed estimate of the likely cost is provided at Annexure-I.
The assumptions of capital structure for the project and the return expectations are provided at Annexure-II.
Further the financial feasibility analysis of the provided is detailed at Annexure III.

Conclusions and Recommendations

A modeling of levelized tariff based on the assumptions provided above, indicate a tariff of INR **5.76 per unit** for the 25-year life of the project. This compares well with the tariff currently charged by BESCOM to government run and aided hospitals and educational institutions and effective power purchase cost of BESCOM as shown along side.



This power purchase cost is significantly lower than the tariff bescom charges government departments and industrial and commercial consumers. Since the power generation is near the load, no transmission and wheeling losses are expected here. Further it is assumed here that KERC will grant a special dispensation of virtual net metering for these projects. Effective power purchase cost for BESCOM is Rs. 5.40 per unit for FY 2020-21. After adjusting for distribution losses, the effective power purchase cost for BESCOM is Rs. 6.19 per unit. The project is not only financially and economically attractive for the stakeholders, but it is also creating an ecosystem with a strong legal commercial structure that can stand for 25 years. There is an effective savings of nearly Rs. 1.85 per unit to the government institutions.

The project is beneficial to all stakeholders, also creating an economically and self-sustainable model for long term rejuvenation of the lake-ecosystem. It provides the following clear economic benefits to each stakeholder:

- BBMP / Municipality – the municipality is no longer required to invest money and effort in the lake. Further, it gets a fully developed lake ecosystem, strengthening its overall performance.
- Residents/community – The residents would benefit the most from the project. They will not only get a well-developed park cum lake, but it will also increase the water level of the area. It will also significantly improve the overall security of the area, as well as real estate perception.
- Flood control – Rejuvenation of the lake, along with the improvement in their water holding capacity, can significantly control flooding that many parts of Bangalore witness annually during rainy seasons.
- DISCOM – DISCOM will get power right at the point of consumption, bringing it significant savings in transmission and distribution losses. In the future, when costs of storage come down, these projects can also be combined with storage to enable peak power supply and reduce DISCOM costs associated with transmission and distribution infrastructure.
- Government – The government will be the biggest winner, as the project not only conserves its money but also brings savings to its departments in annual electricity purchase cost.

- Developer – Developer gets to develop a new and well-conceptualized project, operate them for 25 years, and get returns for its investors.
- Real Estate – The overall improvement of the look and feel of the area, will act as a natural growth enabler for the real estate and prices in the area.
- Carbon Sequestration – the lake ecosystem overtime builds and absorbs a large quantum of carbon in the form of green matter, which gets sequestered and buried under the lake. It is estimated that the wetland eco-system can hold nearly two to three times higher carbon then forest ecosystem.
- Larger community – The lake ecosystem will potentially create significant amount of long term direct and indirect employment of people working for the lake and solar plant maintenance as well as businesses serving residents visiting the lake. Additionally, many of the large lakes will also carry potential to provide fish, water for irrigation as well as drinking.

The economic values of above nonmarket goods and services should be measured in monetary terms to recognize true economic contribution, maximize long term benefits, and increase investment in conservation. However, in this paper, we have not attempted to calculate the economic value of goods and services that a well-developed lake ecosystem can provide, but kept our focus on developing a financially viable business model that enables a sustainable thriving lake ecosystem.

The total number of lakes spread over an area of 3500 Acres in BBMP area (Annexure-IV), are 42 in number. Assuming 25% of these lakes are revived with a coverage of 40% of the lake area for solar projects, it has a solar pv potential of **138 MW** and generation potential of **207 Mio Units. This has the potential to create an annual savings of nearly Rs. 380 Mn in total to the government departments in electricity cost, in addition to enjoying the benefits of clean renewable power.**

Annexure-I – Project Cost assumptions – Capital and Operating

System/equipment/activity	Units/Area	Cost
Water Harvesting System (Capital)		
Rain Water Harvesting System	2 per ha	4,00,000 per system
Sewage Treatment Plant	2 units	30,00,000 per system
Walking/Tracking Path	1200 x 1.5 m	Rs. 1000 per Sq M
Cleaning & Excavation (0.5m)	12 ha	500,000 per hectare
Solar Power Plant	10 MW	
Solar Power Generation System (Capital) per 1MWp DC		
Solar Modules	450Wp x 2250 Nos	2.0 Crore/MWp
Inverter	160kW x 5 Nos	0.2 Crore/MWp
Mounting Structure	Elevated Structure	2.2 Crore/MWp
Balance of System	Balance of System	0.6 Crore/MWp
Operating cost		
Lake management	12 Ha	3 Lakhs / Ha/ per annum
Solar plant Operation and Maintenance	10 MW	4.5 Lakhs / MWp
Operating cost escalation		3% per annum

SOLAKE - Capital cost				
	Unit	number	cost in Rs	Total
Solar system	Rs/ MW	10	5,00,00,000	50,00,00,000
Rain water Harvesting system	2 per hectare	12	8,00,000	96,00,000
Sewge treatment plant	2 units	2	40,00,000	80,00,000
Walking track	per Sq m	1800	1,000	18,00,000
cleaning & excavation	per hectare	12	5,00,000	60,00,000
Total capital cost				52,54,00,000

Annexure-II – Project capital Structure and operating Assumptions

SOLAKE - Operating and capital structure assumptions		
Total MWs	MWs	10
Generation per MW	Units	15,00,000
Gen degradation		0.70%
Operating cost solar	per MW	4,50,000
Operating cost others	per Hectare	3,00,000
No of hectares		12
Operating cost escalation	Annual	3%
Debt		75%
Equity		25%
Cost of debt		11%
Equity return		18%
Debt Tenor	Years	15
Discount rate		12%

Annexure III – Financial Feasibility Analysis

Year	Power Gen	Debt EMI	Return on Equity	Annual Main.	Total cost	Effective Tariff	Discount Value	Levellised Tariff
1	15000000	₹ 5,47,98,658	₹ 2,40,26,388	8100000	₹ 8,69,25,045	₹ 5.80	₹ 1.00	5.76
2	14895000	₹ 5,47,98,658	₹ 2,40,26,388	8343000	₹ 8,71,68,045	₹ 5.85	0.89	
3	14790735	₹ 5,47,98,658	₹ 2,40,26,388	8593290	₹ 8,74,18,335	₹ 5.91	0.80	
4	14687200	₹ 5,47,98,658	₹ 2,40,26,388	8851088.7	₹ 8,76,76,134	₹ 5.97	0.71	
5	14584389	₹ 5,47,98,658	₹ 2,40,26,388	9116621.361	₹ 8,79,41,667	₹ 6.03	0.64	
6	14482299	₹ 5,47,98,658	₹ 2,40,26,388	9390120.002	₹ 8,82,15,165	₹ 6.09	0.57	
7	14380923	₹ 5,47,98,658	₹ 2,40,26,388	9671823.602	₹ 8,84,96,869	₹ 6.15	0.51	
8	14280256	₹ 5,47,98,658	₹ 2,40,26,388	9961978.31	₹ 8,87,87,024	₹ 6.22	0.45	
9	14180294	₹ 5,47,98,658	₹ 2,40,26,388	10260837.66	₹ 8,90,85,883	₹ 6.28	0.40	
10	14081032	₹ 5,47,98,658	₹ 2,40,26,388	10568662.79	₹ 8,93,93,708	₹ 6.35	0.36	
11	13982465	₹ 5,47,98,658	₹ 2,40,26,388	10885722.67	₹ 8,97,10,768	₹ 6.42	0.32	
12	13884588	₹ 5,47,98,658	₹ 2,40,26,388	11212294.35	₹ 9,00,37,340	₹ 6.48	0.29	
13	13787396	₹ 5,47,98,658	₹ 2,40,26,388	11548663.18	₹ 9,03,73,709	₹ 6.55	0.26	
14	13690884	₹ 5,47,98,658	₹ 2,40,26,388	11895123.08	₹ 9,07,20,169	₹ 6.63	0.23	
15	13595048	₹ 5,47,98,658	₹ 2,40,26,388	12251976.77	₹ 9,10,77,022	₹ 6.70	0.20	
16	13499882		₹ 2,40,26,388	12619536.07	₹ 3,66,45,924	₹ 2.71	0.18	
17	13405383		₹ 2,40,26,388	12998122.16	₹ 3,70,24,510	₹ 2.76	0.16	
18	13311546		₹ 2,40,26,388	13388065.82	₹ 3,74,14,454	₹ 2.81	0.15	
19	13218365		₹ 2,40,26,388	13789707.8	₹ 3,78,16,096	₹ 2.86	0.13	
20	13125836		₹ 2,40,26,388	14203399.03	₹ 3,82,29,787	₹ 2.91	0.12	
21	13033955		₹ 2,40,26,388	14629501	₹ 3,86,55,889	₹ 2.97	0.10	
22	12942718		₹ 2,40,26,388	15068386.03	₹ 3,90,94,774	₹ 3.02	0.09	
23	12852119		₹ 2,40,26,388	15520437.61	₹ 3,95,46,825	₹ 3.08	0.08	
24	12762154		₹ 2,40,26,388	15986050.74	₹ 4,00,12,439	₹ 3.14	0.07	
25	12672819		₹ 15,53,76,388	16465632.26	₹ 17,18,42,020	₹ 13.56	0.07	

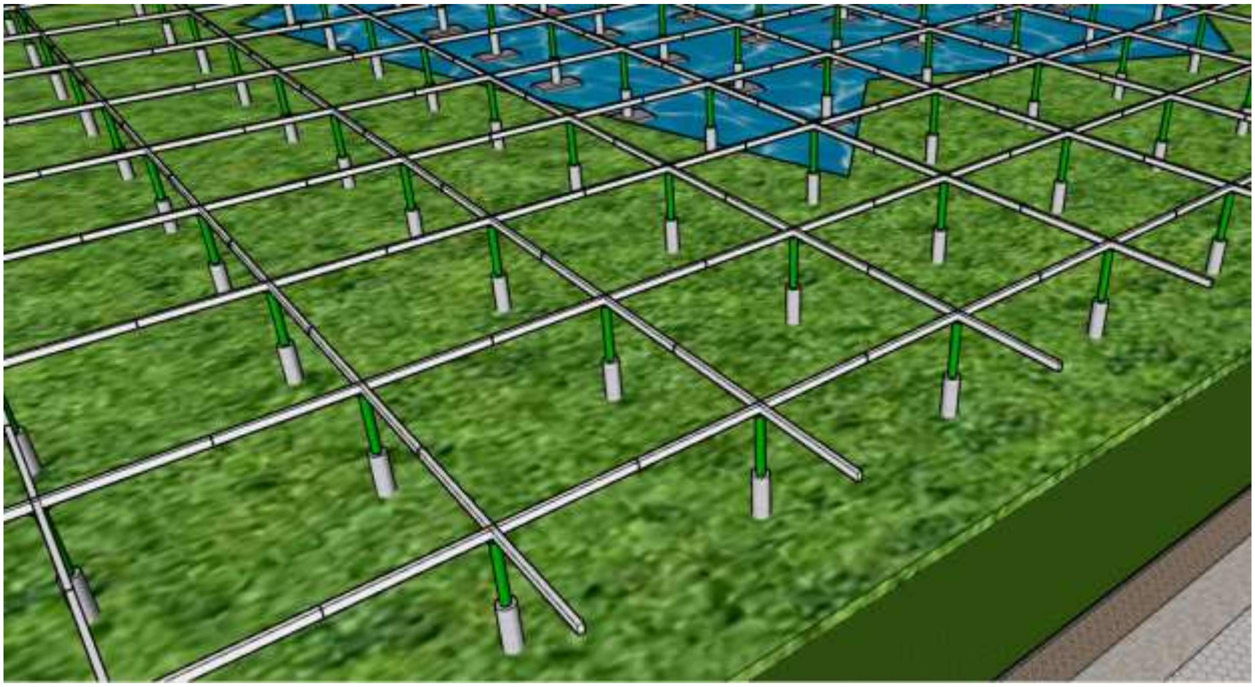
Annexure-IV – Indicative List of lakes

SL.no	Description	Area (m2)	Area (acres)	Google Co-ordinates
1	Agara lake	297,923	73.6	12°55'15.6"N 77°38'27.6"E
2	Hullimavu lake	420,704	104.0	12°52'07.6"N 77°36'12.8"E
3	Allalasandra Lake	141,191	34.9	13°05'29.0"N 77°35'15.2"E
4	Amrutahalli Lake	77,255	19.1	13°03'42.0"N 77°35'54.9"E
5	Begur lake	274,238	67.8	12°52'34.2"N 77°37'51.1"E
6	Bellandur Lake	3,200,000	790.7	12°56’3.00”N 77°39’46.0”E
7	Benniganahalli Lake	53,598	13.2	12°59'50.7"N 77°39'57.6"E
8	Chelekere Lake	41,119	10.2	13°01'36.3"N 77°38'42.7"E
9	Devasandra Lake	47,554	11.8	13°00'17.1"N 77°41'37.0"E
10	Doddabommasandra Lake	350,118	86.5	13°03'53.1"N 77°33'43.4"E
11	Doddanekundi Lake	384,295	95.0	12°58'31.3"N 77°41'17.3"E
12	Gangadhar Kere	58,287	14.4	13°00'49.6"N 77°41'04.1"E
13	Hebbal Lake	566,560	140.0	13°02'49.4"N 77°35'16.4"E
14	Hormavu Agara lake	102,965	25.4	13°02'09.9"N 77°39'30.8"E
15	Hosakerehalli Lake	186,073	46.0	12°55'32.9"N 77°32'02.5"E
16	ISRO Layout Lake	18,317	4.5	12°53'53.3"N 77°33'15.3"E
17	Jakkur Lake	476,909	117.8	13°05'10.3"N 77°36'37.8"E
18	Kaggadasapura Lake	137,875	34.1	12°58'55.6"N 77°40'13.9"E
19	Kaikondrahalli Lake	170,757	42.2	12°54'48.1"N 77°40'22.7"E
20	Kalkere Lake	556,720	137.6	13°02'51.5"N 77°39'46.3"E
21	Kalena Agrahara Kere	15,763	3.9	12°51'56.5"N 77°35'23.1"E
22	Kammasandra lakes	242,702	60.0	12°49'34.6"N 77°41'42.2"E
23	Kempambudhi Lake	65,586	16.2	12°57'08.1"N 77°33'37.3"E
24	Kothnur Lake	43,231	10.7	12°52'26.3"N 77°34'46.2"E
25	KR Puram Lake	171,193	42.3	13°01'01.8"N 77°41'53.4"E
26	Lalbagh Lake	154,662	38.2	12°56'46.3"N 77°34'56.1"E
27	Madiwala Lake	888,721	219.6	12°54'21.0"N 77°36'53.0"E
28	Maragondanahalli Lake	41,841	10.3	12°49'39.1"N 77°39'42.2"E
29	Mathikere Lake	90,884	22.5	13°02'07.7"N 77°33'02.2"E
30	Munnekolala Lake Park	48,858	12.1	12°57'39.5"N 77°42'29.0"E
31	Nagavara Lake	300,934	74.4	13°02'44.8"N 77°36'18.1"E
32	Puttenahalli Lake, Yelahanka	106,328	26.3	13°06'41.7"N 77°34'35.4"E
33	Puttenahalli Lake (JP Nagar)	26,371	6.5	12°53'26.4"N 77°35'14.4"E
34	Rachenahalli Lake	375,315	92.7	13°03'50.7"N 77°36'45.0"E
35	Sankey tank	150,001	37.1	13°00'36.4"N 77°34'24.9"E
36	Sarakki lake	212,365	52.5	12°54'01.9"N 77°34'45.7"E
37	Seegehalli Lake	78,703	19.4	13°01'04.5"N 77°42'45.1"E

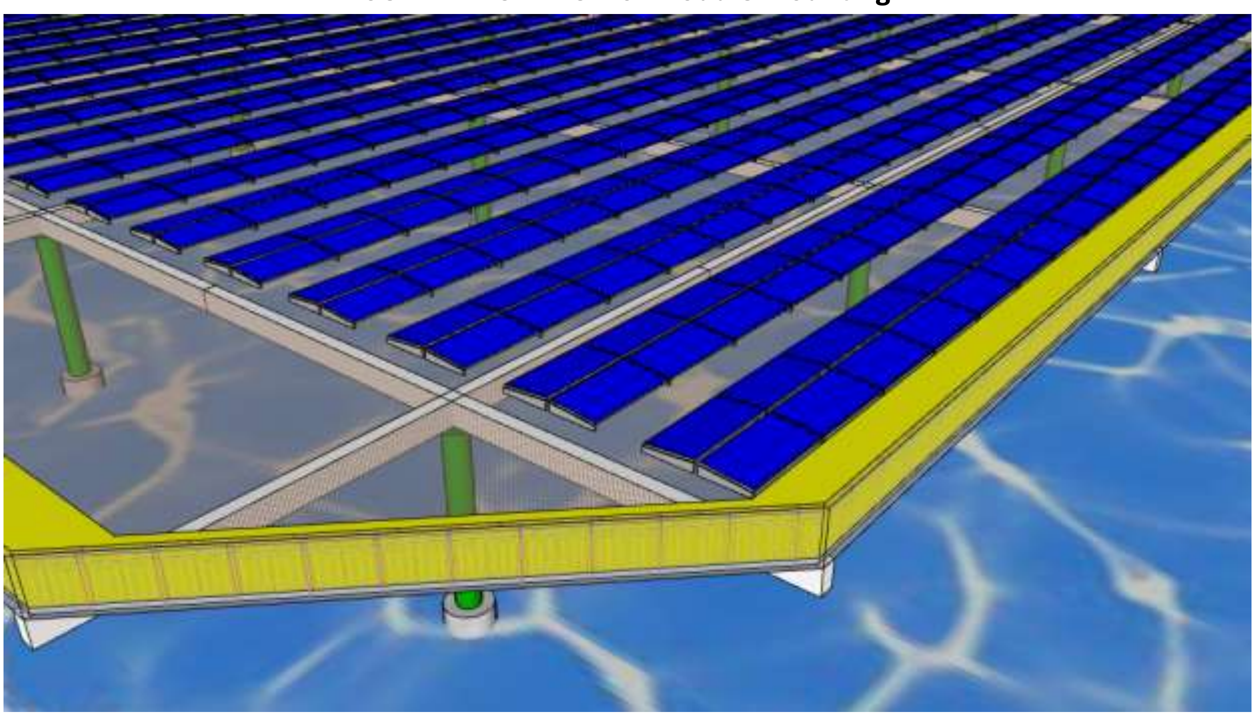
38	Thirumenahalli Lake	63,442	15.7	13°05'35.0"N 77°37'45.5"E
39	Ulsoor lake	500,720	123.7	12°58'58.7"N 77°37'13.8"E
40	Varthur Kere	1,630,000	402.8	12°56'58.7"N 77°44'28.4"E
41	Vibhutipura Lake	103,842	25.7	12°58'05.7"N 77°40'34.6"E
42	Yele Mallappa Shetty Lake	1,110,000	274.3	13°01'15.4"N 77°43'52.7"E

Annexure V

SOLAKE – Foundation and Structure View



SOLAKE – 3 D view of module mounting



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