"Feasibility of floatovoltaics in India"

A Dissertation report submitted in partial fulfilment of requirements for Masters of Business Administration, Energy Trading

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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I take this opportunity to express my gratitude to all my classmates and friends who have played an important role in the success of this project.

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Mentor Certificate

This is to certify that the dissertation report entitled **"Feasibility of floatovoltaics in India"**, submitted by **Sawan Sharma** to **UPES** for partial fulfilment of requirements for **Masters of Business Administration (Energy Trading)** is a bonafide record of the dissertation work carried out by him under my supervision and guidance. The content of the report, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

(Mr. Navdeep Bhatnagar) Date:

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EXECUTIVE SUMMARY

This study was conducted to analyze the feasibility of floating solar photovoltaic. The constant depletion of the fossil fuels and increasing demand of energy focuses us to renewable energy sources which are eco-friendly, unlimited and sustainable for the environment. Solar power generation has advantages as compared to generation of electricity by other means.

Power crisis is one of the biggest challenge in India. Indian Government has set a target to generate 100GW of solar power by 2022. To achieve this target it requires availability of land for installing solar PV panels but the problem is the requirement of land which is scarcely available in the world and its cost. Floating Solar PV will resolve this issue. Floatovoltaics installed on large reservoirs & other water bodies' possess significant potential as they will not only decrease the cost of the land but also will raise generation efficiency with the cooling effect of water.
This study will provide the technical details of floating solar power plants. The advantages and challenges of installing of floatavoltaics will be presented in the study.

For Development of floatovoltaic systems, it is necessary to find suitable location for the installation. Floatovoltaics can be installed on large reservoirs and dams. This study will provide the potential of FSPV in reservoirs in India. The cost economics of implementing such projects will also be presented.

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CHAPTER-1

INTRODUCTION

1.1 Indian Power Sector:

India which has the fifth largest power generation portfolio in the world and current renewable energy participation is 44.812 GW which includes 27.441 GW of Wind Energy and 8.062 GW of Solar power installed capacity in the country. The total installed capacity of power stations in India is 315,426.32 MW as of February 28, 2017. The Power Ministry has target to generate 1,229.4 billion units in FY2017-18.

India has third largest installed capacity of solar power and fourth largest of wind power and 14.7% of total capacity is contributed by renewable energy. India has a target to generate 175 GW of renewable power by 2022 including 100 GW from solar power, 60 GW from wind power, 10 GW from biomass power and 5 MW from hydro power.
The Power Ministry has target to generate 1,229.4 billion units in FY2017-18.

In international climate talks, the government had stated that India will achieve 40% cumulative electric power capacity from non-fossil fuel-based energy resources by 2030 with the help of transfer of technology and low cost international finance, including from Green Climate Fund.

Investment Scenario in Power Sector:

- India's Sterlite Grid partners with US – Burn & McDonell for power transmission project in Kashmir.
- SunEdison plans to develop 15 gigawatts (GW) of wind and solar projects in India by 2022.
- The World Bank will provide 1 billion US dollar for solar Energy Projects.
- Gail India limited partners with California-based Bloom Energy Corporation to develop natural gas-based fuel cell power generation.
- French power company EDF Energies will invest 2 billion US dollar in renewable energy projects in India.
- NTPC will invest Rs 2,648 crore for development of 3 coal blocks in Odisha.

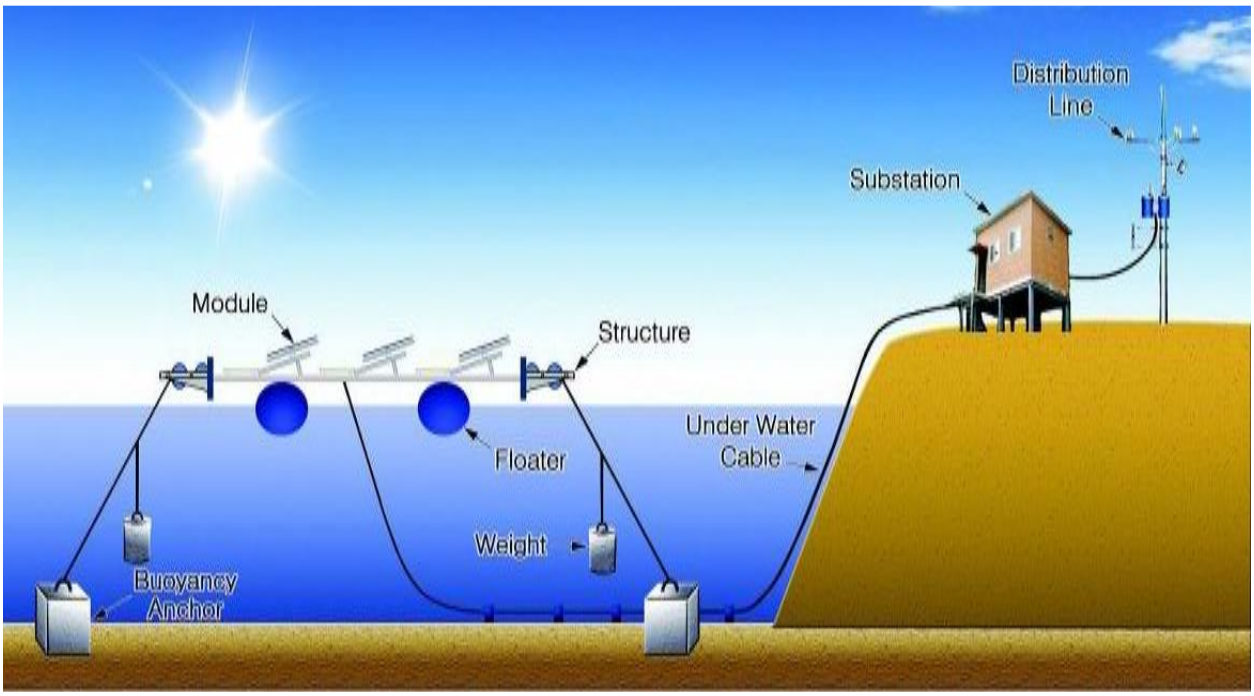
1.2 Floatovoltaics:

Floatovoltaics refers to solar panel arrays that are designed to float on water. Floatovoltaic systems are ideal for dams, reservoirs and lakes. Floatovoltaics is a combination of photovoltaic plant technology and floating technology. This is new power generation technology which can replace photovoltaic plants which are installed on land, rooftops etc.

The part of floatovoltaics systems includes floating system, mooring system, PV system and underwater cables:

Fig. 1

Floating photovoltaic plant outline



1. Floating system: The floating structure and floater which helps in installing photovoltaic module.
2. Mooring system: Mooring system helps in water level fluctutation.
3. Photovoltaic system: These are photovoltaic generation equipment which are installed on the floating system.
4. Underwater Cable: The cables transfers the generated power to the substation.

As floatovoltaics are installed on surface of water, due to which panels remains cool, and because of that rise of temperature of these panels is very less as compared to that on rooftop.

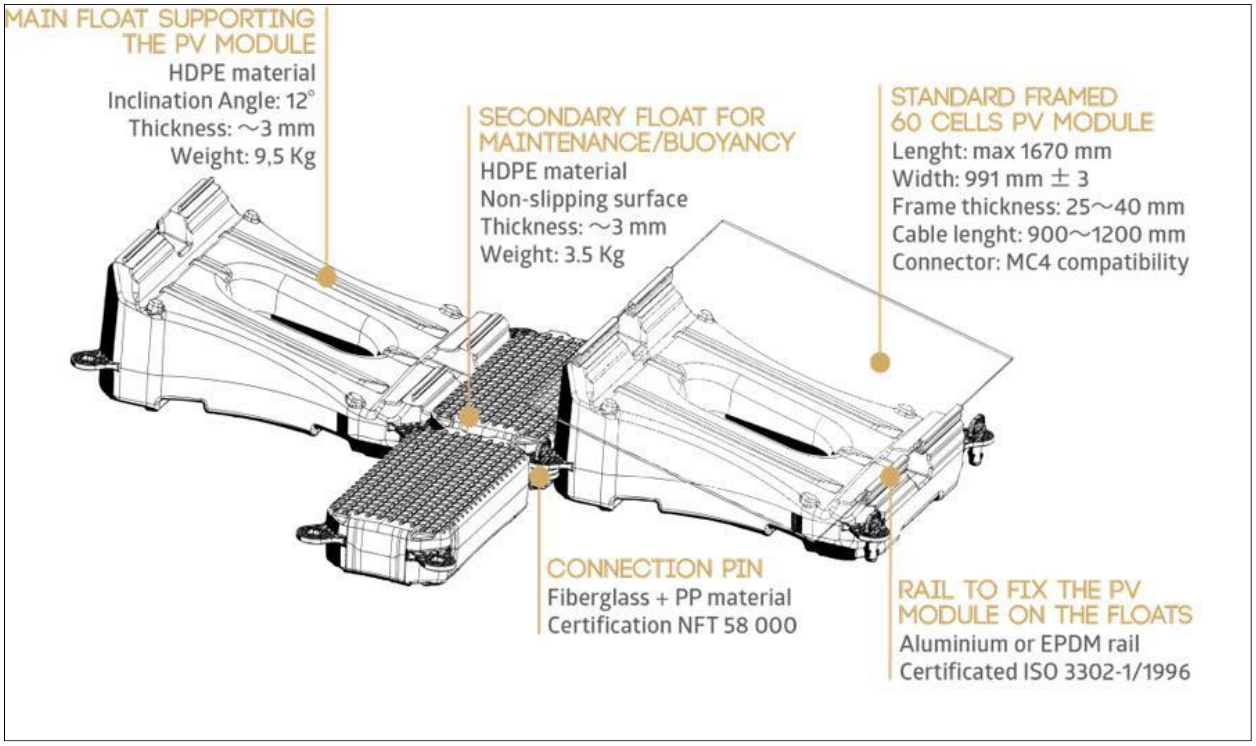
Characterstics of floating structures:

- Material should be non-toxic, salt water resistant, UV rays resistant and should be recyclable.
- Structures should hold the temperatures from -60°C to 80°C.

Materials used for the modules of structures are stainless steel element and plastic float element. The plastic structures are made by LUPOLEN 5261Z or PEAD material but the cost PEAD is high due to which HDPE (High Density Poly Ethylene) material is used as these are less costly and highly reliable.

Fig. 2

HDPE Structure



Properties of HDPE:

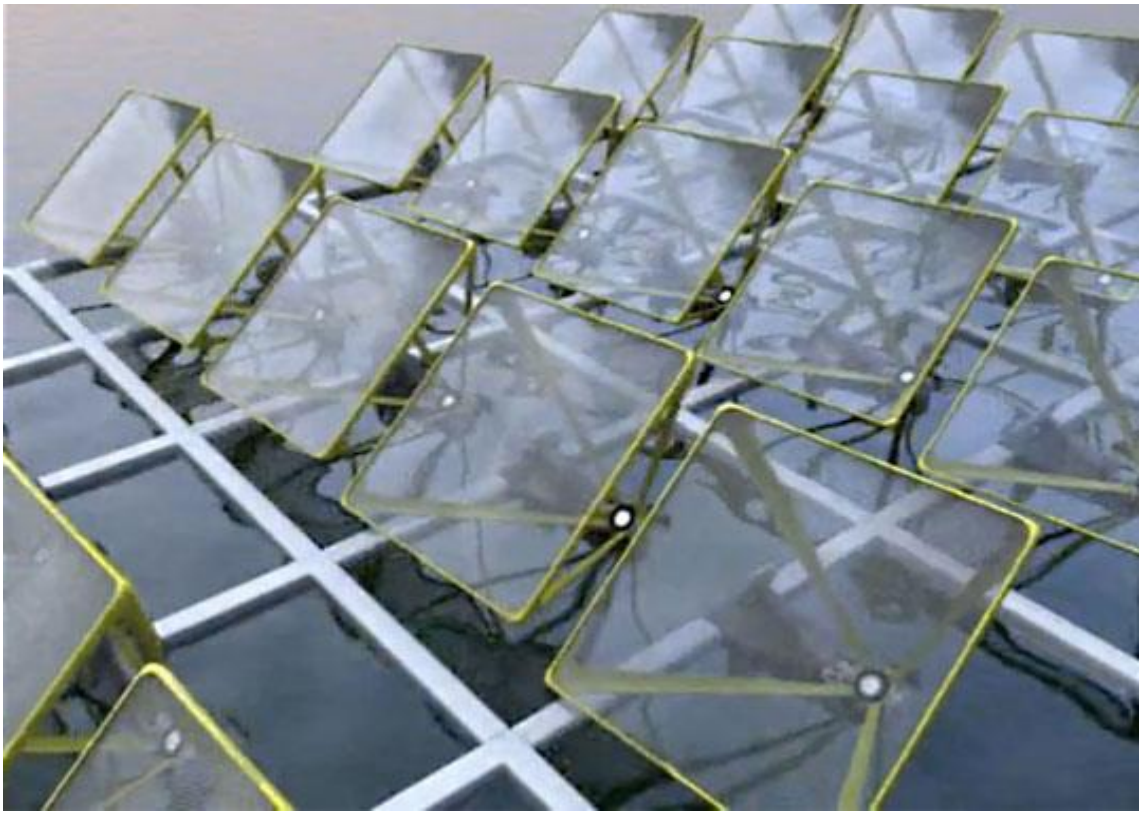
- Corrosion & UV radiation resistant and can withstand for more than 20 years.
- Remains stable upto the wind speed of 118 mph
- HDPE structures designed in such a way that they can be easily deployed
- Cost of HDPE structure is very less as compared to PEAD and zinc coated stainless steel.

1.3 Types of Floating solar photovoltaic:

- **LSA, Liquid Solar Array:** LSA was developed by Sunengy. It is a PV concentrator which uses lightweight plastic concentrators that float on water. A thin plastic focusing concentrator lens rotates to track the sun both daily and seasonally. A minimal amount of silicon photovoltaic cells are housed in a PV container that sits in the water where the cells are kept cool and efficient, through convective heat flow to the surrounding water. During bad weather conditions, the lens are protected by rotating it under the water to avoid damage in high wind.

Fig. 3

Liquid Solar Array



- **Solaris Synergy** offers individually floating modules contained within a light-weight tension based, floating grid, provides self-regulation of panel angle under varying wind loads, allowing the installation of the system in regions of very high wind speed, even up to hurricane levels .The system is agnostic as to water depth and unaffected by changes in water level. The structure has a very low physical profile providing a minimal visual impact. The open structure of the system ensures adequate aeration of the water as well as natural light penetration and presents no hazard to underwater life.

- **Novation's 'Solar-Islands'** are floating platforms designed to be compatible with both photovoltaic panels as well as concentrating solar thermal (CST) technologies. Three are in the process of being built in Switzerland. The island consists of an outer torus and a membrane, on which the solar receivers are placed with longitudinal cables to hold them aligned in position. Below the membrane, a small overpressure of typically less than 1% of the atmospheric pressure is applied (still representing 100 kg/m2), carrying the load of the solar receivers and allowing the solar island to rotate and align its receivers to the sun, via azimuth tracking. This element is crucial for concentrated solar or CPV receivers, which have to be constantly and precisely aligned with the sun's perpetual movement.

- **Smart Floating Farm** by Forward Thinking Architecture is a solar energy & Polyculture based solution, a highly productive floating ecosystem. It is a flexible one able to adapt its dimensions to the local food production needs and can be located close to many mega-cities or dense populated areas with a physical water access (sea-lakes-rivers).

- **Tracking Type FSPV** - where the azimuth and altitude of the sun is tracked to receive the sunlight perpendicular to the module surface. The tracking type PV is a high efficiency generation system that produces a greater amount of electricity by adding real-time sun-tracking function to the PV module.

1.4 Existing or planned floating solar photovoltaic plant:

- 350 MW pilot FSPV project is to be installed at the Balbina hydroelectric plant in the Amazon, Brazil.
- Kyocera is in the process of building 13.5 MW in Japan on a reservoir behind the Yamakura Dam.
- India state utility KSEB has commissioned a 10 KW plant in Kerala. The generated power will be transferred to KSEB grid.
- National Hydro Power Corporation will set up 50 MW floating solar photovoltaic project in the southern state of Kerala.
- A floating solar power plant of 10 KW is executed at Rajarhat near Kolkata. The pilot project has 10 KW capacity.
- NTPC installed India's largest floating power plant with 100 KWp at Kayamkulam in Kerala.
- 2.3MW installation was constructed in Hyogo Prefecture, Japan.
- Sheeplands farm, United Kingdom, has 200KWp of floating solar PV plant which comprises of 800 Trina panels.
- Maeno-ike, Hyogo Prefecture, Japan Type on Irrigation pond for rice agriculture 3,392 panels Water surface: 2.43 ha, Island surface: 0.91 ha Coverage ratio: 37% World's first floating PV plant built on a pond dedicated to agriculture.
- Kawagoe, Saitama Prefecture, Japan, 2786 panels (255Wp Yingli modules) Water regulation pond Water surface: 1.90 ha Island surface: 0.81 ha, Coverage ratio: 43
- Piolenc, France on Reservoir formed from gravel extraction quarry 64 panels (235 GESolar modules) Grid connected in February 2011.
- United Utilities will install Europe's biggest floating solar power system on a reservoir near Manchester.
- Okegawa, Saitama Prefecture, Japan PV modules: 4 536 panels (260w JA solar modules) Rainwater control pond Water surface: 3.07 ha Island surface: 1.22 ha Coverage ratio: 40% Grid connection in July 2013.
- First floating solar plant with 2000 panels was installed on Ochang Dam in South Korea.

Fig.4

Kyocera Floating farm in Japan

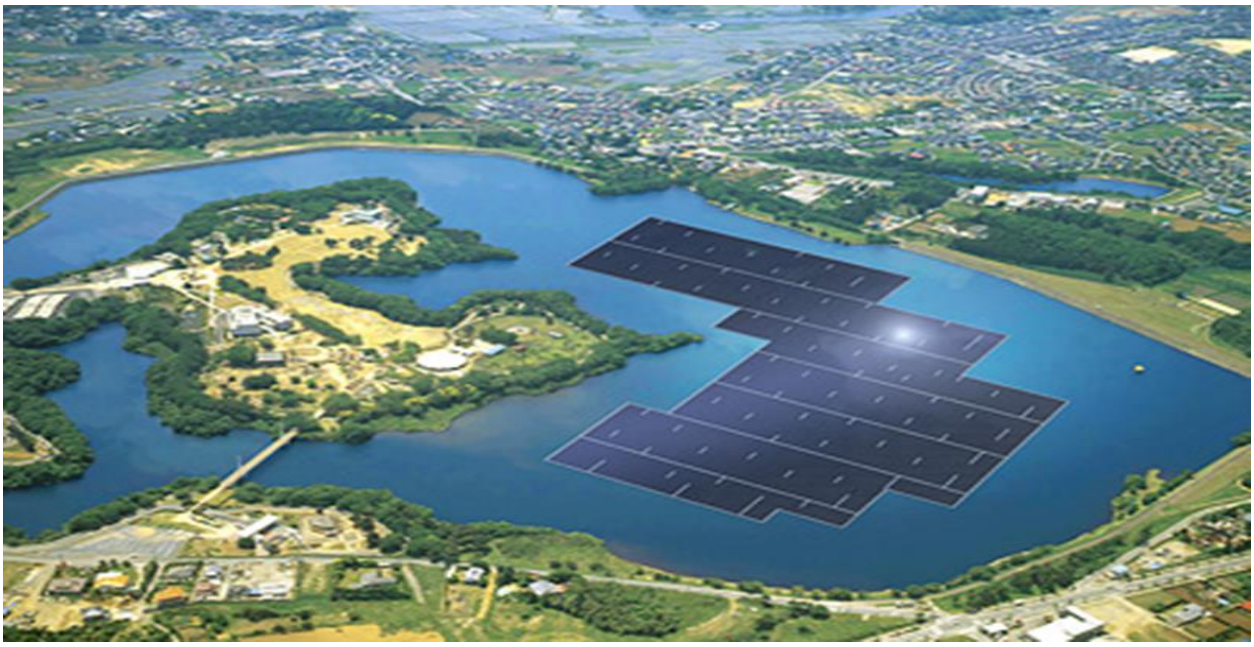


Fig.5

Chapter 2:- Literature Review:

- http://economictimes.indiatimes.com/industry/energy/power/kolkatas-college-develops-solar-power-generation-system-on-waterbodies/articleshow/33472736.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

  Published by: Debjoy Sengupta

  Title: Kolkata's college develops solar power generation system on waterbodies

  Published on: 09 April 2014

  This article explains about the pilot project of floatovoltaics developed in Kolkata and tells about the places which could be used for using this technology and also about the cost for using this technology.

- http://www.thehindubusinessline.com/specials/clean-tech/its-time-for-floatovoltaics/article8641432.ece

  Published by: M RAMESH

  Title: It's time for floatovoltaics

  Published on: May 24, 2016

  This article explains about the challenges that can be faced for using floatovoltaics in India. This article explains about the benefits of using floatovoltaic technology.

- **https://www.psmarketresearch.com/market-analysis/floating-solar-panels-market**

  Published by: PS market research

  Title: Floating solar panel market

  Published on: November 2015

  This article explains about the factors that are creating ample growth oppurtunities for floating solar panel markets. This article also explains about the countries taking initiatives to develop floating solar power plants.

- http://sustainableenergy.org/floatovoltaics-a-solution-for-water-and-energy-conservation/
  Published by: PS market research
  Title: Floatovoltaics- A solution for water and energy conservation?
  Published on: Mar 5, 2016
  This article explains about the cost of deployment of floatovoltaics. This projects gives details about the current project.

- http://timesofindia.indiatimes.com/city/kozhikode/Floating-solar-plant-at-Banasura-Sagar-reservoir-inaugurated/articleshow/50673564.cms
  Published by: K R Rajeev
  Title: Floating solar plant at Banasura Sagar reservoir inaugurated
  Published on: Jan 21, 2016
  This article explains about current project set up at Banasura Sagar reservoir in Wayanad.

- http://economictimes.indiatimes.com/industry/energy/power/ntpc-installs-indias-largest-floating-solar-pv-plant-in-kerala/articleshow/57577004.cms
  Published by: Debjoy Sengupta
  Title: NTPC installs India's largest Floating Solar PV Plant in Kerala
  Published on: Mar 10, 2017
  This article provides the detail of India's largest floating sloar PV plant installed in Kerala with a capacity of100KWp.

- http://spectrum.ieee.org/energywise/energy/renewables/japan-building-worlds-largest-floating-solar-power-plant
  Published by: John Boyd
  Title: Japan Building World's Largest Floating Solar Power Plant
  Published on: Jan 25, 2016
  This article explains about the 13.7-megawatt power floating solar plant which is to be built by Kyocera Corp. and Century Tokyo Leasing Corp.

Chapter 3:- Objective

Floatovoltaics have been gaining momentum in several other countries including US, Japan with some other in the process of implementing the projects, this technology is almost unheard of in India. There exist only a pilot project in India with no publically available studies or researches done on economics and feasibility of floatovoltaics. This research project will try to bridge this gap in information so that floatovoltaics may gain more recognition and interest.

The objective of this research **is to perform Feasibility study of floatovoltaics in India** which will determine the following sub-objectives:-

- To identify the advantages and challenges of floatovoltaics.
- To identify location suitable for the implementation of project.
- To calculate the feasibility/economics of implementing a floatovoltaic project in India.

Chapter 4:- Research Methodology

Research Type:

The research methodology used in this project is **Exploratory in nature** trying to find feasibility of floatovoltaics in India.

Data Collection:

Data for this research has been collected through secondary sources. The data was collected from various websites and from data available for floating solar power plant developed in other countries.

Research Design:

From the existing literature we have studied and analysed trends, drivers, challenges and advantages existing in the current Indian solar market as well as for floating solar.

Identification of geographically suitable areas along with calculation for the potential of floating solar PV and estimation of water saving has been done. We have reviewed five major dams for this purpose.

Calculations based on existing projects has been done to estimate the floating solar PV installation cost.

CHAPTER-5

FINDINGS AND ANALYSIS

5.1 Identify the advantages and potential challenges to floatovoltaics in India.

- **Trends of solar energy in India:**

  In India solar power industry is growing fast. India has achieved solar grid capacity of 12.28GW as of April 2017 as compared to 6.76 GW in March 2016. India has made a target of 100 GW of solar energy by 2022.

  In India's land area solar energy incidence is around 5000 trillion kilowatt-hours per year. Ample availability of sunlight in India have placed solar energy as a critical part of its energy industry.

  The government of India has launched various policy changes to promote solar energy. The MNRE launched Jawaharlal Nehru National solar mission, which aims to build India as a solar energy global leader. Some additional policy changes like Solar Parks Policy and Ujwal Discom Assurance Yojana are also made. The solar park policy provide financial support to set up solar parks.

- **Drivers to solar energy in India:**
  - Government provide tax holidays of 10 years for solar project.
  - Government is providing exemption from excise duties and co
  - 30% subsidy on project cost for off-grid photovoltaics.
  - Power purchase obligations for states to purchase solar power.
  - Providing loans towards concessional rates.

- **Challenges to Floatovoltaics:**
  - As floatovoltaics are mounted on water so there is risk of corrosion of components. Humidity and water are present which can cause faster corrosion of components.
  - Effects on environment i.e. water quality must be considered, and fluctuations in reservoir water levels should be taken into account while constructing the system.
  - Funding of floatovoltaics project.
  - Creating awareness among consumers about the technology and economics.

- Complexity of subsidy structure & involvement of too many agencies like MNRE, IREDA, SNA, and electricity board and electricity regulatory commission makes the development of projects difficult.

- **Advantages of Floatovoltaics:**
  - Installation of floatovoltaics over water reservoirs can increase electricity production as they are mounted on water so panels will remain cooled.
  - Floatovoltaics can improve the quality of water as due to shade ion water it will help in reduction of algae growth which will minimize the treatment.
  - Solar power plants are located in dusty area, so in comparison to them floatovoltaics will be present in low dust areas and they can always use a sprinkler to bathe themselves clean.
  - It can solve land availability problem, which is a big problem now days. Floatovoltaics does not require land and can be mounted at dam reservoirs.
  - In dam reservoir-based hydro power plants, solar power can substitute hydro based generation during day time when sun is available. In such a case, the stored water in the reservoir will serve as an effective energy storage systems.
  - Materials of floatovoltaics are recyclable.
  - Does not require heavy equipment and tools.
  - Low installation costs as compared to ground mounted solar plant.
  - Impact on environment is low as it has no impact on quality of water.
  - Reduced evaporation of water, which means billions litres of water can be saved per year

5.2 Identify geographical suitability of floatovoltaics:

For Development of floatovoltaic systems, it is necessary to find suitable location for the installation. As they are mounted on water, therefore certain factors have to be kept in mind for its feasibility like weather conditions such as speed of wind, flow of water and fog which can affect the efficiency of generating power.

The factors that must be taken into account for selection of feasible location for installation of floatovoltaics systems are:

- Factors affecting generation efficiency: solar radiation, fog, etc.
- Connection with distribution line
- Factors affecting installation and maintenance: depth of water, influx of floating matters

India has around 4,862 large dams and 173 notable lakes throughout the country.

List of some major reservoirs in India which can be suitable for installation of floatovoltaics:

Reservoir	**State**	**Reservoir Area Sq. km**
Srisailam	Andhra Pradesh	616.42
Somasila	Andhra Pradesh	211.29
Ujjani	Maharashtra	335.4
Linganamakki	Karnataka	315.64
Malaprabha	Karnataka	128.4
Hirakud	Odisha	744
Paithan	Maharashtra	399
Indira Sagar	Madhya Pradesh	913.48
Sriramasagar	Andhra Pradesh	451.81

Tungabhadra	Karnataka	378.13
Ranapratap Sagar	Rajasthan	199
Rengali	Odisha	378
Rajghat	Uttar Pradesh	2453
Matatila	Uttar Pradesh	139.84
Almatty	Karnataka	755.24
Manimata Hasdeo	Chhattisgarh	189.46
Bisalpur	Rajastha	219.36
Rihand	Uttar Pradesh	467
Kangsabati	West Bengal	125.31
Bargi	Madhya Pradesh	268.98
Gandhisagar	Madhya Pradesh	661
Tawa	Madhya Pradesh	200.66
Nagarjun Sagar	Andhra Pradesh	285.8
Cheruthoni	Kerala	59.83
Bhadra	Karnataka	116.25
Pong	Himachal Pradesh	260

List of largest lakes in India:

Lakes	**Area in Sq. Km**	**State**
Vembanad	2032	Kerala
Chilka	1164	Odisha
Shivajisagar lake	892.7	Maharashtra
Pangaong Tso	701	Jammu & Kashmir
Indirasagar lake	626	Madhya Pradesh
Pulicat Lake	451	Andhra Pradesh
Sardar Sarovar	377	Gujarat
Loktak	286	Manipur
Wular	261	Jammu & Kashmir
Kolleru	246	Andhra Pradesh
Gobind Sagar	169	Himachal Pradesh

- **Estimation of water saving using floatovoltaics and Floatovoltaics power plant rating:**
  - Assuming that if 20% of reservoir surface area used for installation of floatovoltaics without affecting the environment.
  - Based on data that is available because of installations of floatovoltaics in other countries, a conservative estimate of 40 MWp capacity FSPV is taken per sq. km.
  - Assuming if 1200 million litres of water per year per sq. km is saved due to reduction of evaporation loss.

1. **Srisailam Dam**

   Reservoir surface area = 616.42 km^2

   Installed capacity = 1670 MW

   Proposed area coverage for FSPV = 616.42 * 0.20 = 123.28 km^2

   Proposed FSPV rating = 123.28 * 40 = 4931.2 MW

   Saving of water per year = 123.28 * 1200 = 147936 million litres

2. **Indira Sagar Dam**

   Reservoir surface area = 913.48 km^2

   Installed capacity = 1000 MW

   Proposed area coverage for FSPV = 913.48 * 0.20 = 182.69 km^2

   Proposed FSPV rating = 182.69 * 40 = 7307.6 MW

   Saving of water per year = 182.69 * 1200 = 219228 million litres

3. **Tungabhadra Dam**

   Reservoir surface area = 378.13 km^2

   Installed capacity = 127 MW

   Proposed area coverage for FSPV = 378.13 * 0.20 = 75.62 km2

   Proposed FSPV rating = 75.62 * 40 = 3025.04 MW

   Saving of water per year = 75.62 * 1200 = 90744 million litres

4. **Rihand Dam**

   Reservoir surface area = 468 km2

   Installed capacity = 300 MW

Proposed area coverage for FSPV = 468 * 0.20 = 93.6 km2

Proposed FSPV rating = 93.6 * 40 = 3744 MW

Saving of water per year = 93.6 * 1200 = 112320 million litres

5. **Rengali Dam**

Reservoir surface area = 378 km2

Installed capacity = 50 MW

Proposed area coverage for FSPV = 378 * 0.20 = 75.6 km2

Proposed FSPV rating = 75.6 * 40 = 3024 MW

Saving of water per year = 75.6 * 1200 = 90720 million litres

Observations: Taking an example of setting up floatovoltaics systems on 5 reservoirs it is observed that potential of 22.03 GWp power generation and 660948 million litres of water can be saved per year. Thus it is believed that there is huge potential of power generation in India through floatovoltaics.

5.3 Calculate the feasibility/economics of implementing a floatovoltaic project in India:

Current Projects:

1. **Kyocera TCL solar LLC**

   The project has a capacity of 13.7 MW and is being built under JV of Kyocera Corporation and Century Tokyo Leasing Corporation. The construction of dam is taking place on Yamakura Dam reservoir, Japan.

   Cost calculation:

   Planned capacity: 13.7 MW or 13700 kW

   No. of PV modules: 51,000

   Area covered: 180,000 metre square

   Yearly generation: 16,170 MWh

   No. of households supplied: 4,970 (3,254.4 kWh/ household)

   Solar module rating: 270 watt/ module

   Cost of pv cells: $1.5/ watt

   Cost per module: 270 * 1.5 = $405

   Cost of total installation = 405 * 51000 = $20655000

   Total project cost = 20655000 * 1.3 = $26851500

   Cost/ MW or kW = 26851500/ 13.7 = $1959963/ MW or $1959/ kW ~ US$1960/ kW

   Cost per unit area = US$300/ metre square = Rs. 21,000/ metre square

   Generation/unit area = 76 watt/ metre square

   For 1 kW = 14 metre square

   Total installation cost: US$1960/KW

   *costs calculated here do not include leasing cost as they are subject to lease agreement

2. **Balbina dam reservoir**

   Brazil is constructing 350 MW floating solar powerplant in Amazon, which will be sold at Rs. 4705.22/MWh.

   Capacity: 350 MW or 350,000 kW

Electricity sale price: US$0.073/ kWh or US$73/ MWh

3. Cost of land based solar in India

Installation cost = Rs. 1, 40,000/ kW (without subsidy) = $2000/kW

Barren land cost = 3, 50,000/ acre = 87 rupees/ metre square

For 180,000 metre square = Rs. 15660000

For 1 kW land= 87*14 = 1,218 rupees

Install cost = ~Rs.1,40,000/ kW

OR

Figure.5

Rising cost of land for solar power

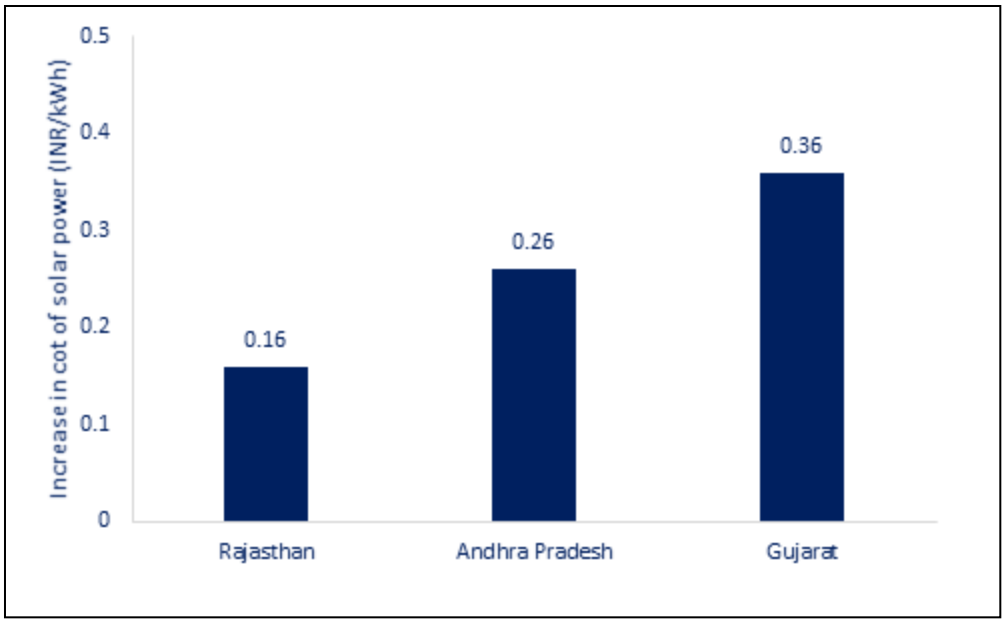


Table 3

Comparison of cost of land rental for different states

	Andhra Pradesh	Rajasthan	Gujarat
One Time Charges			
Development Charges	INR 4.3 m/MW	INR 2.014m/MW	INR 8.52m/MW
Processing Fee		INR 1m/project	INR 0.5m/project
Land allotment charges		INR 609,000/MW	
Solar park and development fund	1% of the project cost	1% of the project cost	1% of the project cost
Annual charges			
Solar Park O&M charges	INR 250,000/MW with an annual escalation of 6%	INR 100,000 with an annual escalation of 10%	
Land Lease rent	INR 5,000/MW	INR 30,484/MW fixed for first two years thereafter an escalation of 5% per annum	
Others		INR 100,000	

*Service tax and stamp duty extra as applicable

Land charges per MW = Rs.38, 54,198

Land charges per kW = 3,854 rupees = $55 per kW

+ 1% project cost = $30/ kW

Total cost per unit = 2000+55+30

Total installation cost= US$2,085/KW

Chapter 6:- Conclusion

- The main advantages, challenges of floatovoltaics and drivers to solar energy in India found to be:
    - Installation of floatovoltaics over water reservoirs can increase electricity production as they are mounted on water so panels will remain cool.(Advantage)
    - Floatovoltaics are mounted on water so there is risk of corrosion of components. Humidity and water are present which can cause faster corrosion of components.(Challenge)
    - 30% subsidy on project cost for off-grid photovoltaics.(Driver)

- From calculations of floatovoltaics systems on 5 reservoirs it is observed that potential of 22.03 GWp power generation and 660948 million litres of water can be saved per year. There is huge potential of power generation in India through floatovoltaics.
- Installation cost = ((US$2,085/kW + annual charges + less efficiency + increasing charges on land) vs (US$1,960/kW for floating - more efficiency - draught relief - alternate use of land).

Chapter 7:- Bibliography

- Floating solar power generation developed in Kolkata
  Link: http://economictimes.indiatimes.com/industry/energy/power/kolkatas-college-develops-solar-power-generation-system-on-waterbodies/articleshow/33472736.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
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- National Register of Dams
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