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**"Solar Photovoltaic Technology in India:
An Industrial Outlook "**

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SOLAR PHOTOVOLTAIC TECHNOLOGY IN INDIA : AN INDUSTRIAL OUTLOOK

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Introduction

India is endowed with a vast solar energy potential. Most parts of the country have about 300 sunny days. Average solar radiation incident over one square meter of the land area is recorded in the range of 4-7 kWh per day. The energy scene in India is a complex picture of a variety of sources being used (thermal, hydro, nuclear, renewable) to meet the growing energy needs of the people. The total installed power generation capacity is about 115,000 MW. However, there is a large gap in the demand and supply position. The demand is increasing at the rate of 8-9 percent per year. It is estimated that out of 600,000 villages, about 80,000 villages in the country are still to be electrified, of which about 18,000 villages, situated in remote and difficult areas such as hilly regions, forests, deserts and islands, are not likely to be electrified with the conventional grid as grid extension of these locations may not be possible due to economic, logistic and environmental considerations. It is recognized that decentralized generation, based on photovoltaic technology, offers one of the most promising ways to provide electricity to such villages.

Photovoltaic systems and power plants have already emerged as viable power sources for applications such as lighting, water pumping and telecommunications, and are being increasingly used for meeting electrical energy needs in remote villages, hamlets, hospitals and households. PV systems, if used on a large scale, may cut down the need of extending distribution grid to rural areas. Water pumping is another important application of solar photovoltaic (SPV), which is technically proven and has the potential of replacing diesel-pumping systems, commonly used in unelectrified locations for lifting water from shallow depths. The pumps can also bring the

benefits of irrigation and drinking water supply to backward areas not served by the existing grid and where supplying diesel is also a problem.

The Ministry of Non-Conventional Energy Sources (MNES) is responsible for the overall planning, programme formulation and overseeing the implementation of various activities relating to renewable energy technologies. Recognizing the importance of PV technology in the Indian context, the Ministry has been implementing a comprehensive programme covering R&D, demonstration and utilization, commercialization, industrial development and awareness promotion for more than 25 years. During this period, significant efforts have gone into the development, evaluation and introduction of a large number of applications. Several PV systems and products are now commercially available, and are proving economically viable in several situations. Today, the country has among the world's largest programmes for deployment of decentralized PV systems.

Research and Development

Research and Development (R&D) has been a major component of the Indian PV programme. Initiated as far back as 1976, it initially focused on the development of solar cell technology in the industrial environment. In 1980, a five-year programme for bringing the technology to a stage of commercial production was taken up. The programme also included development and field demonstration of various PV applications. After more than a decade of industry-based technology development, the crystalline silicon solar cell technology reached mature stage. A variety of PV systems had been developed and deployed for demonstration, field testing and evaluation.

Besides leading to the establishment of indigenous manufacturing capability, R&D efforts led to the reduction in costs, improvement in reliability and introduction of newer technologies. Development of amorphous silicon (a-Si) thin film solar cell modules had been supported by the Ministry since early 1980s. During 1985-92, major programme for the development of single junction a-Si solar cell technology was implemented at Bharat Heavy Electricals Limited (BHEL), Bangalore; National Physical Laboratory (NPL), New Delhi and the

Indian Association for the Cultivation of Science (IACS), Kolkata. Single junction a-Si cells of about 12% efficiency were developed at the IACS. A new initiative to develop large area multi junction a-Si solar modules was supported at the IACS, jointly with the Department of Science and Technology (DST). Under this project, 10-11% efficiency small area double junction a-Si cells have been developed. Several items required for fabrication of 30 cm x 30 cm size double junction a-Si thin film modules were locally designed and fabricated, which included multi-chamber plasma deposition and magnetron sputtering systems. A 7% efficiency of the developed modules has been demonstrated. Presently, the IACS is making efforts to improve the process and demonstrate its reproducibility at batch production level. R&D projects on thin film solar cells based on cadmium telluride, copper indium diselenide (CIS) and silicon thin films are also in progress. The Indian Institute of Science (IISc), Bangalore has reported 13.5% efficiency on gallium doped copper indium diselenide solar cells.

Presently, the R&D efforts in India are focused on further improvements in the material technology and efficiencies of crystalline silicon cell and modules, development of thin-film technology, development of new systems and improvements in designing of Balance of Systems.

The programme also took cognizance of the need to establish national standards for various SPV products and their components. National standards are now available for the SPV modules and related items. The MNES has drawn up specifications for solar lanterns, home lighting systems, streetlights and water pumping systems for use in various programmes. Some of the user organizations, such as the Department of Telecommunications and Ministry of Railways have come out with their own specifications and standards.

Commercialisation Of PV Products

It is realized that there is a large potential for the commercialization of several PV products if suitable financing arrangements are made available to individuals and commercial users and appropriate marketing efforts are made by the PV manufacturers. In order to promote the development of the market of PV products, the MNES

has supported soft loan schemes through Indian Renewable Energy Development Agency (IREDA) established in 1987. Under these schemes soft loan assistance is available to individuals as well as commercial organizations for the purchase of solar photovoltaic systems. Financial intermediaries, PV manufacturers, product distributors, cooperative societies, NGOs etc. are also free to access the loans. Loans from IREDA are also provided to manufacture silicon wafers and solar cells under an interest subsidy scheme launched by the Ministry in 1999. Recently, the Ministry has announced another scheme to provide soft loan at 5% to the users through IREDA and some of the commercial banks.

In order to accelerate commercialization of PV products in India, IREDA is implementing projects supported by the World Bank and KfW, and has sanctioned projects of an aggregate capacity of more than 3 MW. Separately, as a private sector initiative, the IFC and GEF have also supported a US\$ 15 million project on "Photovoltaic Market Transformation Initiative" (PVMTI) in India. This project was initiated to attract private investments in photovoltaic projects, to develop and sustain new markets.

To reach out the consumers, in recent years, many companies have started offering PV systems under loan and lease financing arrangements. The Ministry has already been supporting the opening of 'Aditya Solar Shops' in different parts of the country to sell and service all solar products. So far, 48 solar shops have been established. Government subsidy on the PV products is also available through these shops.

The expanding market for photovoltaic applications has led to growth of the domestic PV industry. The present domestic production is based on crystalline silicon solar cells. During the last decade, many private companies have started commercial production and a number of joint ventures have been established. Export of PV products to other countries is also increasing. There are 9 manufacturers of solar cells and 15 active manufacturers of PV modules in regular production. About 60 companies manufacture PV systems, and most of these are small businesses. During the financial year 2004-05, about 32 MWp of solar cells and 45 MWp of modules were produced.

It may be noted that about 105 MWp of PV products have been exported so far to USA, Germany, Japan, Australia, several countries in the African continent and many Asian countries. Another important feature of the industrial development in this sector is the domestic manufacture of key materials and equipment required for processing of solar cells and modules. Some testing equipment is also made in the country. Several international projects have been taken up in India through bilateral cooperation, especially with USA and Germany. India has also set up projects in other countries like Cuba, Senegal, Syria, Mali and Kenya. A PV module production line has been set up in Syria.

Solar PV Utilization

The major areas for Solar Photovoltaics utilization are:

- Domestic Sector
- Agriculture Sector
- Commercial Sector
- Power Sector

While evaluating the economics, it can be seen that the initial cost is very high and by constructing the increasing power tariff rates, inefficiency in the transmission system, the Photovoltaic may appear to be economical option in the long run.

With the recent advancement in technology and greater awareness among the public coupled with suitable policy measures and offering various hybrid systems, this may be made more commercially viable.

In India, many Photovoltaic demonstration programmes have been taken up initially to review the performance of the systems before taking up large-scale commercialization project. Basically, there are 4 types of market exists for utilizing Photovoltaic systems.

- Government markets
- Government driven markets
- Private market through leasing route
- Director sales - open market

In many cases, the Photovoltaic Systems were installed in various Government departments under different programmes to establish the credible

performance of the systems. The number of applications in different sectors are growing fast and with the advancement in technology and reliability of the system, it has been felt that private markets can be tapped with appropriate precautionary measures on standardization, Quality Control and suitable incentive structure.

In the country as on December 31, 2005 approx. 191 MW (12,02,000 system) of Solar Photovoltaic systems were deployed for different applications.

This includes an export of 105 MW with capacity of Photovoltaic products, the sector-wise deployment of Photovoltaic modules is given below :

Sector-wise use of PV Modules Aggregate capacity 191 MW (12,02,000 systems)

Lantern	Home Light	Street Light	Pump	Power Plant	Telecom	Others	Exports
6.4 MW	12.4 MW	3.95 MW	10.35 MW	5.05 MW	17.0 MW	30.85 MW	105 MW

The above includes mostly Govt. and industrial markets but the direct sales are not accounted due to lack of reliable data.

In order to go for self-sustainability in Photovoltaic production, the manufacturing base in India has been strengthened gradually over a period of time. The production of Photovoltaic modules and cells in the country have been increased from 13 MW to 77 MW in last 8 years as indicated below :

Year	1996-97	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05
Solar Cell	5.2 MW	8.3 MW	6.6 MW	9.5 MW	14 MW	20 MW	22 MW	25 MW	32 MW
PV Module	8.2 MW	11 MW	9.5 MW	11 MW	17 MW	20 MW	23 MW	36 MW	45 MW

IREDA has extended financial support to nearly 20 manufacturing units for production of different types of Solar Photovoltaic systems and components in the last 10 years. The number of manufactures for modules, cells and other PV components are given below:

Status Of Number Of Pv Manufactures/Suppliers

Solar Cells	09 (40 MW capacity)
PV Modules	15 (75 MW capacity)
PV Systems	60 approx.

Though majority of basic raw material is being imported for manufacturing of Solar Photovoltaic cells, the dependence on other components have been reduced by creating total infrastructure. This has ultimately resulted in reduction of the end product cost and also availability of products for end users. While encouraging the manufacturing units, sufficient care has been taken for development of new technologies in order to be competent in the world Photovoltaic markets.

During 1993-94, IREDA started implementing SPV Market Development Programme under commercialization mode based on the experience gained in the previous years. Under the Market Development Programme, IREDA has supported nearly 149 projects with a total estimated loan sanctions of Rs. 1,377 millions. The estimated energy conservation due to power generation from Photovoltaic sources under the commercialization mode is approximately 9.1 million units.

Major PV Programmes

IREDA has implemented two major PV programmes under commercialization namely:

- SPV Market Development Programme under World Bank LOC
- Solar Photovoltaic Pumping Programme for Agriculture and related uses.

In both the programmes, the main objective is the participation of end user in purchasing of the system and to provide loan to the user. The implementation of the programmes have been planned in such a way that gradual awareness has been created among the end users and simultaneously the products were made available by enhancing the manufacturing capacity in India. The financial assistance have been provided through innovative models so that the users could procure the

system from the local suppliers at an affordable cost in easy installments.

In case of pumping programmes the financing companies and manufacturers/system suppliers could act as intermediary between IREDA and users, to leverage high initial cost of the product and offer the same at reasonable price to consumer.

Promotional Activities

IREDA has taken various steps to create greater awareness on Solar Photovoltaic applications through print media, electronic media, seminars, business meets, exhibitions etc. Though it is very difficult to spread the message in a vast country like India. In short time, IREDA has taken initiative by conducting business meets i.e. 150 nos. in all the States in the last few years.

Apart from the same, various video films have been prepared and separate manuals, product leaflets etc. are printed and distributed to the potential clients, market developers, consultants, business development associates etc. to popularize these programmes.

Financing Mechanism

Unlike other renewable energy sources, solar energy is peculiar in nature and due to its thin and wide spread availability, it is highly accessible to the end user but on the other side the initial cost of the product is high compared to other similar energy products. Moreover, these products/systems are similar to consumer durables and can be installed conveniently in the remote places as an alternative to grid supply or become supplementary to the conventional sources wherever quality grid power is not available. Though the initial cost seems to be high, the economics would be favourable by considering with power generation through environment cost, cost of conventional fuels suppliers, high transmission, losses etc. In order to make it more cost effective/attractive for common user, MNES/IREDA have formulated various innovative financing mechanisms while commercializing the technologies so that the end user could afford to purchase the equipment.

IREDA developed the following financing models to provide loans to the end user through intermediaries:

- Corporate model - leasing/hire purchase mechanism
- Co-operative model - rental/leasing mechanism
- NGO model - leasing/hire purchase/rental
- Direct sales through dealers.

Under the PV market development programme - World Bank line of credit, 85 projects have been supported leading to nearly creation of 2.1 MWs of solar power generation by different systems namely solar lanterns, solar home lighting systems, small grid interactive power plant, stand alone power plants, Photovoltaic high grid systems etc.

The type of products and the numbers financed under the market development programme are given in the table:

No. of Units procured	Total
Solar Lanterns	39000
Solar Home Lighting Systems	3602
Solar Street Lighting Systems	1016
Grid Interactive Solar Power Plant	344
Garden Lighting Systems	349
Solar Water Pumping Systems	86
Stand alone Solar Power Plant	8
Others	33
Total	44438

Some of the financing models implemented by IREDA in commercialization of Solar Photovoltaics in India are given in the Annexure.

From the experience, it can be seen that affordable financing at the grass root level to the end user for procurement of Photovoltaic products can also play a major role in commercialization process. However, there is no single financing model applicable universally under market development programme for effective marketing of PV products.

It was to be designed depending upon the economic activity of the local consumers, present power supply position through conventional route, need for renewable

energy, cost of other alternative sources for power and also repayment capacity of the end user.

Spv Pumping Programme

Under solar pumping programme, India being an agrarian country, much thrust is given to agricultural sector and to relieve the farmers from dependence on limited conventional grid supply, a separate programme has been launched by the Ministry, implemented by IREDA, for popularizing the solar PV pumping systems for agricultural and related uses.

This programme is unique in the world implemented by IREDA for the last 10 years wherein nearly 5500 solar pumping systems have been installed in different parts of the country for different agricultural related uses such as horticulture, animal husbandry, poultry farming, high value crops, orchards, silviculture, fish culture, salt farming, drinking water etc.

The pumping systems are given to the farmers on near commercial mode which can work on solar energy with zero dependence on conventional power supply and thus eliminating the usage of diesel generator sets leading to pollution free/clean environment. It has not only improved the confidence level of the end users on solar energy application but also given a boost to the industry to develop manufacturing base and infrastructure and to create after sales service network through the country.

This programme will be continued further and can take new heights, given an opportunity for development of different SPV Pump models to suit the end user requirement.

Village Electrification

The number of remote villages which cannot be electrified through extension of the conventional grid was earlier estimated to be 18,000 but now it has been revised to 24,418 remote villages.

A remote village is deemed to be electrified if atleast 10% of the households are provided with lighting facilities. For electrification of remote villages and hamlets, the MNES provides technical guidelines and financial assistance for meeting upto 90% of the project

costs and for their comprehensive maintenance for periods upto 10 years.

To ensure sustainability of the project, revenue generation from beneficiaries is made mandatory through collection of user charges upfront and/or on annual/monthly basis.

Under the program, 1744 remote villages and 572 remote hamlets have been electrified as on 31st December 2004 and projects were under implementation in 1,350 remote villages and 724 hamlets. .

Technical backup/Infrastructure

As a part of building the infrastructure, IREDA has taken up the task of organizing training programmes to create technical manpower base in the country to cope up with after sales service needs for the products to be deployed in different rural areas of the country. IREDA has created a good technical manpower base of nearly 900 engineers and technicians, trained under Solar PV Training programme which is one of the largest programmes in the world with the help of internationally renowned training experts such as Siemens, USA and their Indian counterparts.

Special Concessions

In order to promote the systems in the rural areas and far reach out areas special concessions such as reduction in promoters contribution, interest rates, waiver of commitment fees, inspection charges etc., have been introduced, to encourage the entrepreneurs setting up projects in these areas.

Procurement And Quality Control

Various measures have been taken up to improve the quality of products and also to create awareness among public on performance of PV Systems to build up their confidence level. IREDA has prepared the performance specification for different PV products/systems and the same have been adopted, while procuring the systems by different corporate bodies, NGO's etc. under market development programme. In addition to the same testing of PV modules and products through reputed laboratories

and test centers have been taken up during procurement of the systems to ensure the quality and longer life etc.

Barriers And Issues

The important barriers in commercialization of Solar PV in India can be categorized as:

Policy Issues

- Lack of
 - Appropriate policy support
 - Level playing ground in fiscal & financial incentives
 - Appropriate legislative mechanisms
 - Proper institutional and implementation arrangements

Product And Technical Issues

- Lack of
 - Presentable and Packaged quality products
 - Proper product & performance specifications
 - Adequate service/maintenance personnel
 - Proper system integration

Financial Issues

- Lack of
 - Motivation of financial institutions
 - Adequate awareness in financial institutions
 - Consumer financing routes/options
 - Financing through various sectors

Commercial Issues

- Non availability of good brand name
- Inadequate warranty/guarantee
- Lack of
 - Publicity by the manufacturers
 - Dealership network
 - Demonstration efforts

Strategy And Action Plan

The following strategy and action plan proposed for promotion of PV under commercial mode:

- a) Encouraging establishment of energy servicing companies in different regions and different parts of the country
- b) To motivate the rural banks to act as intermediary for micro financing
- c) Involvement of co-operatives and NGO's in promotion of Solar PV in rural areas
- d) Greater participation of corporate bodies to act as intermediary for leasing/hire purchase of PV systems to large number of consumers
- e) Effective promotional activities through financial intermediary/business development associates by conducting business meets, seminars and advertising in different magazines etc.
- f) Rationalization of fiscal incentives to bring down cost of PV products in the long run
- g) To offer attractive soft loans to the consumers.

Future Demand And Growth

It is expected that large scale utilization of PV in different sectors can take place in the next five years and the physical targets for different products are indicated below. Moreover, it is planned to electrify the very remote villages (which are not likely to be electrified through conventional system in next 10 years) through renewable energy and Solar PV can be play major role in this process.

Solar Photovoltaics and Village Electrification

(10th Five Year Production)

Units	Physical target	Outlay
Solar Lanterns	16 MW	Rs. 1120 million.
Solar Home Systems	16 MW	Rs. 1940 million.
Solar Pumps	18 MW	Rs.1668 million.
Solar Generators	7.5 MW	Rs. 61 million.
Village Electrification	20 MW	Rs. 7200 million.
Power Plants & Other Systems	3 MW	Rs. 452 million.

Total Budget Outlay: Rs. 1433.56 million.

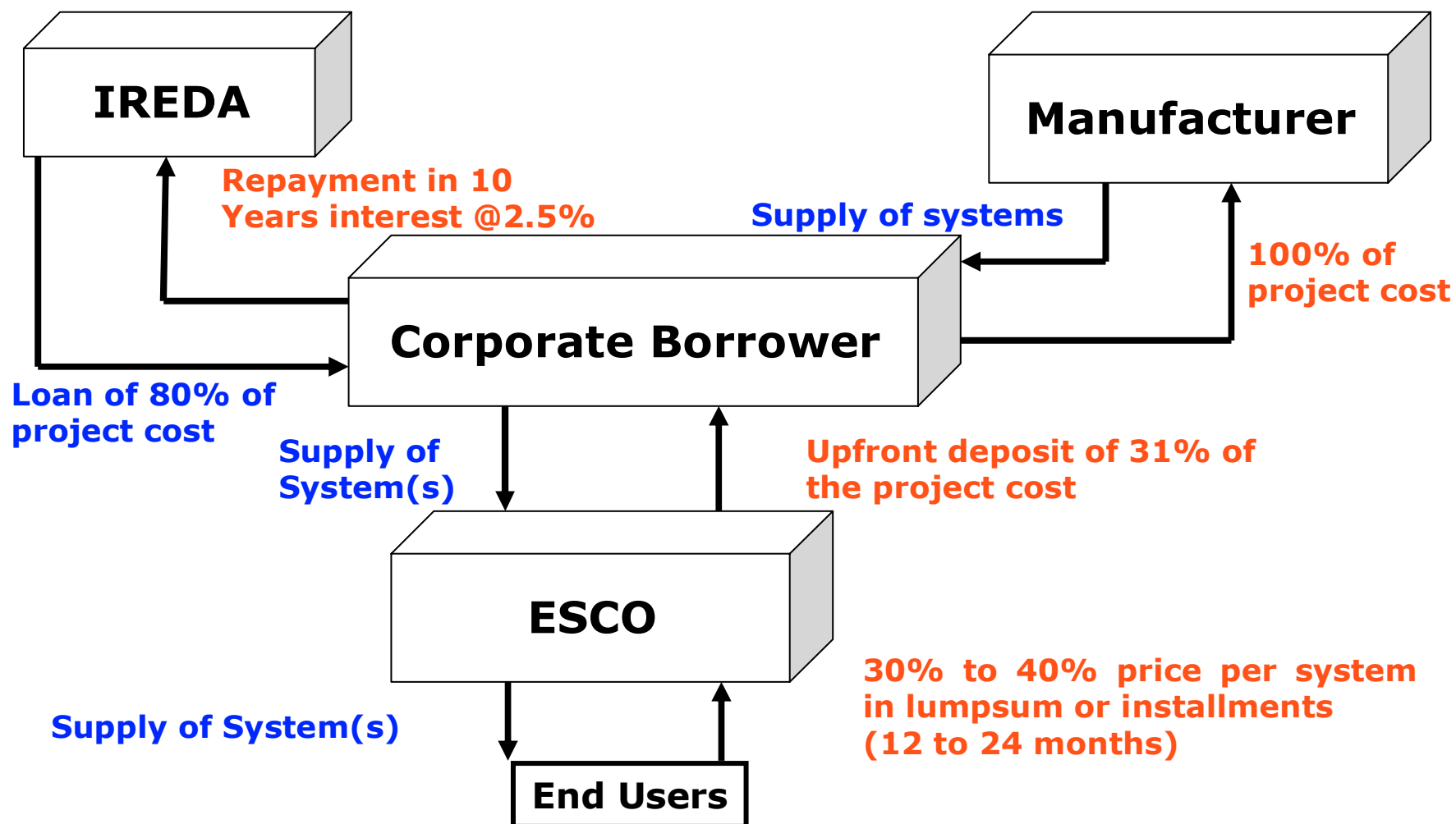
Conclusion

The PV Market Development Programme and commercialization process taken up by IREDA/MNES is one of the largest programme in the world and the experiment gives rich experience for further development. Moreover, commercialization is a continuous process and require to overcome various barriers/obstacles for greater popularization/penetration of photovoltaics in the domestic and commercial sector. There is no unique solution available for effective marketing and it requires greater participation and active involvement of government, private sector enterprises, financial institutions. Moreover, continuous upgradation of technology is essential for cost effective solution. In order to make the programme more sustainable and provide consumer satisfaction/confidence build up, micro financing with proper product distribution/service network are essential parameters.

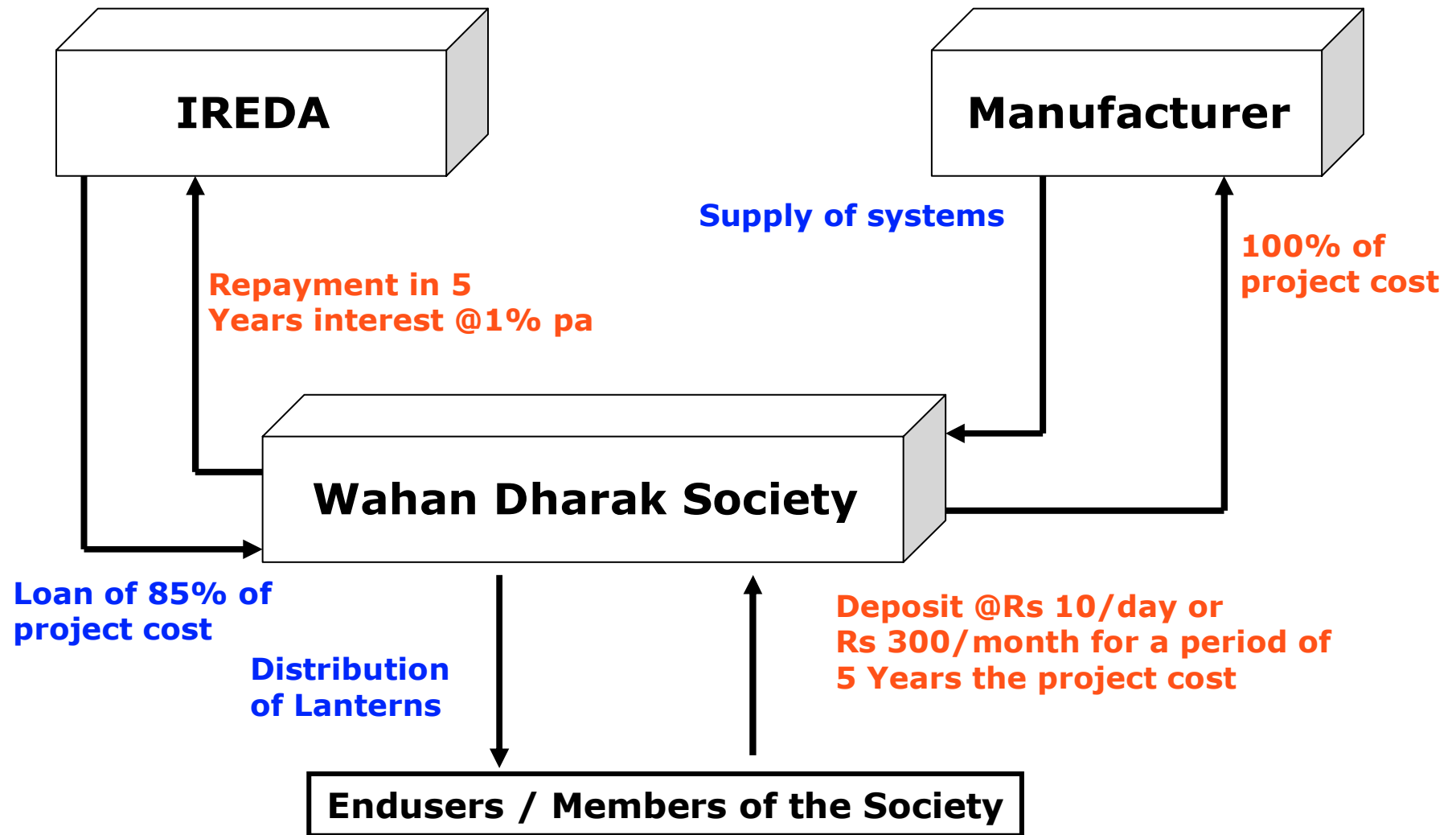
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.....Product and Fund Flow through Intermediaries

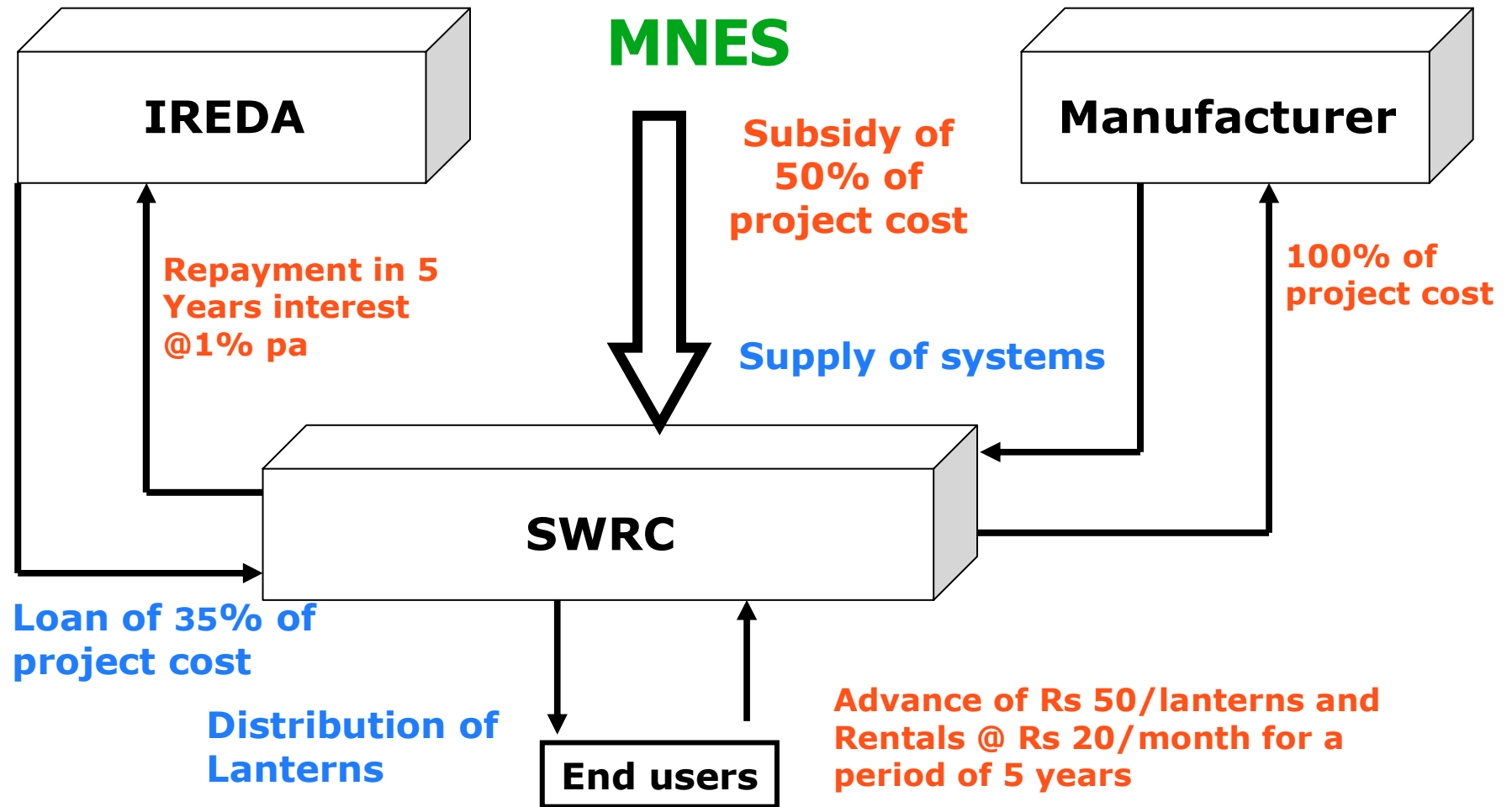
PV SECTOR - CORPORATE INTERMEDIARY



CO-OPERATIVE SOCIETY - WAHAN DHARAK



SWRC - NON GOVERNMENTAL ORGANISATION



....SOLAR PV SECTOR

FINANCE COMPANY

