Summary Report

Development of Local Supply Chain
A Critical Link for Concentrated Solar Power in India

February 2013

THE WORLD BANK

ESMAP
Energy Sector Management Assistance Program

Contents

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Acknowledgement

This study was prepared by a World Bank team led by Nataliya Kulichenko (Africa Sustainable Development Energy–AFTG1) and Ashish Khanna (South Asia Sustainable Development Energy–SASDE). The World Bank project team consisted of Chandrasekeren Subramaniam (SASDE), Mani Khurana (SASDE), Kanv Garg (SASDE), and Ruchi Soni (Sustainable Energy Unit–SEGEN).

The team is also grateful to the peer reviewers–Chandrasekar Govindarajalu (International Finance Corporation, South Asia) and Roger Coma Cunill (Middle East and North Africa Regional Strategy & Programs–MNARS)–for their insightful inputs. We especially wish to thank Jyoti Shukla (Sector Manager–SASDE) for her constructive guidance and valuable support during the delivery of the report.

The desk study inputs for the study were provided by a consortium of consultants including Ynfiniti Engineering Service, Nixus, Aqua MCG, and National Renewable Energy Centre (CENER). They also interacted with CSP developers and other industry stakeholders to share data and first-hand experiences.

In addition, the team would like to thank the counterparts in the Ministry of New and Renewable Energy (MNRE)–Mr. G.B. Pradhan, Mr. Tarun Kapoor, and Dr. Ashvini Kumar–who provided guidance and technical inputs through the assignment.

This team is grateful for the funding received from Energy Sector Management Assistance Program (ESMAP) for the study.

Preface

Amid the success of Solar Photovoltaic (PV) projects in India, Concentrated Solar Power (CSP) technology also provides a compelling case for support by the government as among solar technologies, CSP is the only techno-economically viable option at present that provides a storage option for dispatchable and dependable solar energy. Furthermore, the conversion of solar to steam is a relatively high-efficiency process versus the conversion efficiency of PV. This process can effectively supplement fossil fuels and renewable fuel, such as biomass, and thus contribute to the overall energy security of the country.

The specific objective of the study is to assess the potential of India's industries to set up a manufacturing base to produce CSP technology components and equipment. The study assesses competitive positioning and the potential of Indian companies in the manufacturing of important CSP components. Various analysis models were prepared for the analysis, and the details have been explained in the elaborated version of the report. The report also proposes an Action Plan to help develop this potential and evaluate the resulting economic benefits. This report includes the following activities:

- Assessment of the competitive position of local industries to support the development of CSP technologies in India
- Evaluation of short, medium, and long-term economic benefits of creation of a local manufacturing base
- Action Plan to stimulate local manufacturing of CSP technology components and equipment

This document is a summary of the larger report. The data analysis and messages presented in the report are based on very limited information presently available in the Indian market. Therefore, it is recommended that the trends and ideas to be given more attention than the data itself.

Conclusions

Indian industry holds immense potential for local manufacturing of sub-components of CSP systems in the country in the short, medium, and long-term. India has inherent competitive advantages that can facilitate the transition to becoming a major provider of CSP technologies. The factors that could contribute to this include highly trained engineering staff, low labor costs, presence of complimentary industries, and a large domestic market. The above aspects can be leveraged by the Indian industry to lower the capital costs for CSP plants, thereby subsequently decreasing the Landed Cost of Electricity (LCOE) and driving the market penetration of solar thermal technologies.

To achieve this potential, existing Indian industries will have to identify and introduce changes to significantly participate in supplying CSP components and systems. Many traditional industries that could take an active part in CSP technology development have been identified as automotive, glass, metal, power and process heat, machine tools and robotics, technical supervising, electronics industry, oil and gas, and chemical industries. Most of them only need a modest effort to adapt their products and manufacturing processes to the demands of the CSP industry. Nonetheless, as competition between CSP players will increase, enlarging the need for Research and Development (R&D) activities to develop cheaper and more efficient components will emerge. Research collaborations between private companies and research laboratories will be an important factor in developing the components and systems that will bring CSP technologies to success.

Cost reductions are also expected from local manufacturing of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures for Parabolic Trough (PT) technology. Developers would find local manufacturing very attractive as well because of value added services, such as the local presence of many Operations and Maintenance (O&M) options, better procurement lead time, and a trained local workforce. The rapid reduction of solar PV prices has made it mandatory for solar thermal technologies to accelerate the cost reduction process for their survival.

In the short term, India's readiness to manufacture or produce some critical components, such as receiver tubes and mirrors that make up solar thermal plants is questionable, in spite of the huge manufacturing capacity of the country and the skills of its labor force. In some cases, such as in the manufacture of reflecting surfaces, the lack of a natural resource (in this case low-iron sand) poses an impediment to indigenization. In other cases, such as in the manufacture of vacuum tubes, the obstacle to overcome is the lack of a relevant technical know-how that is proprietary technology owned by others. Sometimes, in a fast-growing economy, the high demand for some industrial products might lengthen the delivery time for certain components.

The Jawaharlal Nehru National Solar Mission (JNNSM) Phase-I and state solar policies have catalyzed the growth of the solar sector in the country and contributed to the reduction of prices offered by the project developers. Having achieved significant cost reductions in JNNSM Phase-I, India has the potential to get CSP competitive to solar PV. For this, however, there must be a critical mass of investment, dedicated human resources, and educational efforts. Criticality will be achieved when there is alignment of convergent forces with national and regional policy and the right financial environment.

To keep up this momentum and to achieve further cost reductions for CSP technologies, the government needs to provide clarity on the following:

- Capacity allocation for CSP sector
- Technology demonstration of hybrid CSP projects
- Provision for CSP projects with thermal storage

A review of what cooperation it entails has been presented in this report—the actions the governments and industry need to take to become important players in developing the domestic market and supply of CSP components. The important factors that will enable India to emerge as a competitive base for manufacturing CSP components are as follows:

- Supportive regulatory and fiscal environment to promote indigenization and technology transfers and to create a favorable and viable business environment for all stakeholders involved in CSP projects
- Favorable government policies to create market growth for all stakeholders of CSP projects
- Development of CSP-related R&D capabilities
- Availability of low-cost and adequate financing for CSP component manufacturers

Government, promoters, and industry need to work together to ensure a viable path for CSP development by creating a financial and regulatory environment that supports investment in R&D, establishing financial and political incentives for sustainable development and lowering the effective financial risks for investors while factoring in the positive impacts of renewable energy on the environment, improvements in health, and the natural habitat.

Status and Cost of CSP Projects in India

Present Status of CSP Projects

During the Phase-I Batch-I of the JNNSM, 65 bidders were shortlisted, totaling an installed capacity of 2,811 MW. The Ministry of New and Renewable Energy (MNRE) set a ceiling for total bids at 470 MW. The selection of the bidders was carried out through a reverse auction process against the tariff determined by the Central Electricity Regulatory Commission (CERC) of INR 15.30/kWh. In order to prevent adventurous bidding, the discounts to be offered were linked to additional bank guarantees. The seven successful bidders offered discounts from INR 3.07/kWh to INR 4.82/kWh and were allocated projects at a weighted average price of INR 11.48/kWh.

According to the JNNSM timelines, the developers had to commission the plants by May 2013. The CSP projects in India are currently in the execution phase, and most of the projects have achieved financial closure and are undergoing construction. There are reports that several developers are facing implementation challenges because of the lack of experience. The reasons cited range from issues with financing, inaccurate Direct Normal Irradiance (DNI) dataleading to reengineering the solar collector sizing, and supply chain to the lack of availability of the Heat Transfer Fluid (HTF).

Indian Cost Compared to International Projects

Based on the analysis of project prices offered by the bidders, a comparison between the capital cost of a reference international 50 MW CSP Parabolic Trough plant without storage reveals that cost estimates of a similar plant in the Indian market conditions plant is around INR 560 crores, as compared to an international cost of INR 1,275 crores (around USD 290 million).

Only upon commissioning the projects and assessing the lessons learned, including the reevaluation of estimated costs, would it be possible to determine with a higher degree of accuracy the reasons for the considerably low project prices offered by the bidders. In this respect, it is necessary to emphasize that the bid price of the project doesn't necessarily represent its cost. In markets in which the developers are exploring the ways of early entrance, prices can be intentionally lowered to first secure the contracts and then gain the needed project development and operational experience.

Similarly, almost twice the cost of the international CSP plant could be attributed to factors such as, premium pricing for recovery of sunk technology costs, execution of the projects through the full Engineer-Procure-Construct (EPC) method, longer project preparation cycle time, higher costs of obtaining permits and clearances, and higher wage costs.

Easing CSP Project Development through Localization

Since costs—and hence, the financial closure—and supply chain are cited as major reasons, it is critical to examine the possibility of cost reduction and better access of components in JNNSM Phase-II, and beyond, through localization. The current import policy, concessional customs duties, and exemption from excise duty for CSP components, result in imported components in being almost at par with domestically manufactured components. By contrast, even if there is an assumption that these components can be manufactured locally, the issue is whether that would result in a significant reduction in costs or not.

The key components, such as mirrors, heat collector element (HCE), HTF, and solar steam generators, constitute only 25 percent of the cost of a CSP project. The other critical equipment, presently being imported, is the steam turbine generator, which adds another 10 percent to the project cost. This 35 percent import value is for the PT technology. In the case of the tower or Compact Linear Fresnel Reflector (CLFR) technology, the only component that may need to be imported is the flat mirror and steam turbine, which will translate to about 20 percent of the project cost. The manufacture of low-iron, glass-based mirrors involves emptying the furnace of the earlier charge and replacing it with a new charge of low-iron sand. Emptying the furnace and achieving the quality needed for solar application takes about 10 days. Because the volumes are low, the mirror manufacturers typically schedule the manufacturing twice a year. Unless there is sufficient volume, the mirror manufacturers may find it more cost-effective to import the mirrors than to manufacture them locally.

Based on the analysis, assuming that local manufacturing would result at best in a 25 percent reduction of certain equipment costs, this would translate into a reduction of 5–9 percent of the project cost. Therefore in the next round of CSP solicitation, the project bid prices for CSP projects are likely to come down to about INR 9 crores/MW and INR 8.5 crores/MW for CLFR and PT technology, respectively, which is very competitive as compared to global CSP costs[1].

[1] *Based on limited data availability.*

Potential of Local CSP Supply Chain Development

Competitive Position of Local Industries

To perform an assessment of the competitive position of industries in India to support the development of CSP technologies, a detailed analysis of the local industrial capabilities was carried out for different critical components of CSP. The analysis included an assessment of the requirements of components, current industrial capacity in India, expected impacts on cost reduction as a result of local manufacturing, relative market growth, and market dynamics. Further, CSP component-wise local manufacturing capability in India and corresponding recommended actions were also analyzed. The results are presented in Table 1.

TABLE 1: Assessment of Local Manufacturing Potential in India

Component or Material	Present Local Manufacturing Capability	Recommended Actions
Receiver (Parabolic Trough)	Low	Promote R&D for metal glass seal, and solar selective and antireflective coatings Promote collaboration with global players
Receiver (Power Tower System)	Low	Promote R&D for receivers able to work under high solar flux, for volumetric receivers using atmospheric air as HTF, and for durable pressurized air receivers
Mirror (Parabolic Trough)	Medium	Explore sources of low-iron sand Lower customs for bending equipment and low-iron sand
Mirror (Power Tower System)	Medium/high	Lower customs for low-iron sand Explore sources of low-iron sand
Drive/tracking (Parabolic Trough)	Medium	Promote R&D for solar sensor and controller technology Promote collaboration with global players
Drive/tracking (Power Tower System)	Low	Promote R&D for solar sensor and controller technology Promote collaboration with global players
HTF (synthetic oil and molten salts)	Medium	Lower customs for oil and salts Promote R&D in materials having high heat density and stability Promote R&D in thermochemical and electrochemical storage
Turbines	Medium/high	Establish technical and quality standards for CSP turbines

To realize the CSP potential in India, existing Indian industries must identify the opportunities and react proactively to participate significantly in supplying CSP components and systems. Many traditional industries that could take an active part in CSP technology development are automotive, glass, metal, power and process heat, machine tools and robotics, technical supervising, electronics industry, oil and gas, and chemical industries. Many of them only need a modest effort to adapt their manufacturing processes to the demands of the CSP industry. Nonetheless, the competition between CSP players will increase in the future, enlarging the need for R&D activities between private companies and research laboratories to develop cheaper and more efficient components.

Expected CSP Indigenization

Based on extensive discussions with CSP players, the possibility for indigenization for CSP components in India is summarized in the timeline in Table 2.

TABLE 2: Possible Indigenization of CSP Components in India

Component	Short-term (1–3 years)	Medium-term (4–7 years)	Long-term (8–12 years)
Solar Field			
Site development	Local	Local	Local
Foundations andpylons	Local	Local	Local
Mirrors PT and PD[2]	Import	Import	Local
Mirrors CR and LF	Import	Local	Local
Frame and support structure	Local	Local	Local
Receiver tubes PT and LF	Import	Import	Local
Receivers for CR and PD	Import	Local	Local
HTF synthetic oil	Import	Import	Local
Drive and track PT and LF	Local	Local	Local
Drive and track CR and PD	Import	Import	Local
Power Block			
Solar steam generator	Local	Local	Local
Turbine	Import	Local	Local
Cooling system	Local	Local	Local
BOP	Local	Local	Local

Local | Import

Conclusion

Solar Field:

Mirror: Partial Manufacturing is possible in Phase-I with full indigenization in Phase-II.

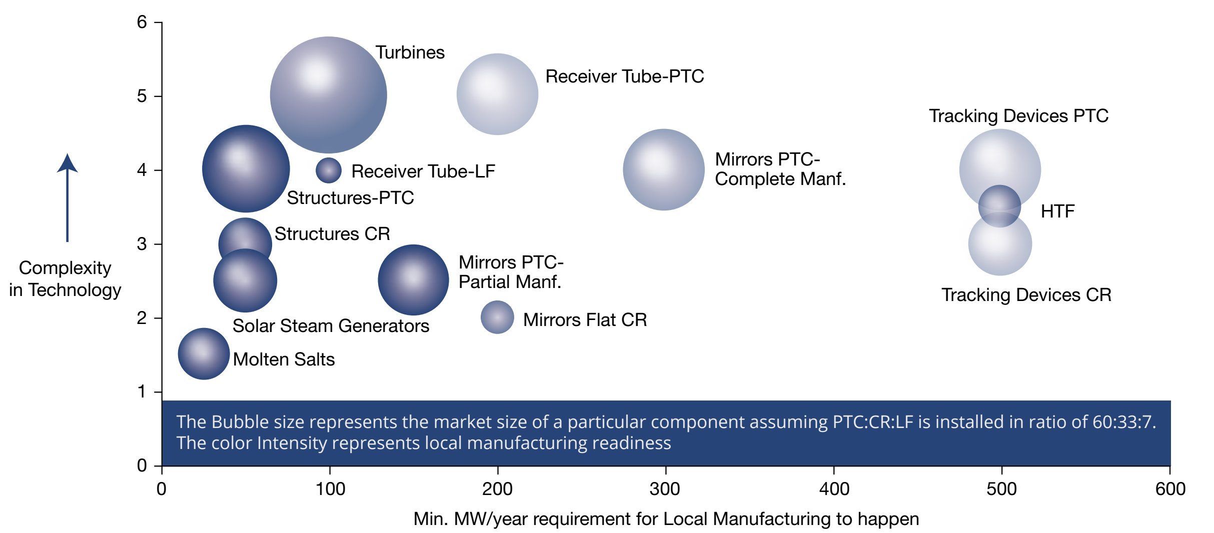
Receiver Tubes, HTF. Drive & Track Mechanism: Indigenization is estimated by Phase-III.

Power Block:

Turbines: Indigenization may happen in Phase-I itself, but is expected to get stablized by Phase-II.

It is interesting to note that, as depicted in the figure below, local manufacturing for all CSP-specific components will require less than 500 MW/year of demand. For manufacturing of receiver tubes (PT) and

FIGURE 1: Minimum Demand Requirement



[2] *The technology for mirror manufacturing would be available at these phases provided that low-iron sand is available in India. Otherwise low-iron sand would have to be imported.*

tracking devices to happen in India, significant R&D is required within India or through a joint venture or licensing agreement with international players.

Potential Cost Reduction through Local CSP Manufacturing

Under JNNSM Phase-I, a significant reduction of tariffs has been achieved because of the implementation of a reversed auction bidding mechanism, combined with the approach taken by the solar project developers, which is a combination of both locally manufactured and imported components. For example, the developers went in for domestic structural, civil, and mechanical items, while limiting the imports to important components, such as mirrors, receiver tubes, HTF, and solar steam and turbine generators. In the future, further cost reductions could be expected from the local manufacture of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures (PT). Local manufacturing has additional benefits, such as developing an indigenous O&M industry supported by local subcontractors, better procurement lead time, and trained local manpower. This study analyzes the potential cost reduction, considering the potential involvement of international players in local manufacturing activities in India. Interactions with players in the CSP field have resulted in the following results for cost reductions (in percent) possible from indigenization in manufacturing and design.

TABLE 3: Cost Reduction through Localization

Component	Reduced logistics	Local manufacturing	IP in local design	Total[3]
Mirrors, parabolic	5	3	10–20	18–28
Mirrors, flat	3	3	Not Applicable	6
Tracking devices drive mechanism	2–5	3	25–30	30–38
Receiver tube—PTC	2	3	20–25	25–30
HTF pumps	3	8–10	Not Applicable	11–13
Turbines	2	5–10	10–15	17–27
Structure—PTC	3	4–7	20–30	27–40
Solar steam generator	2	3–5	15–20	20–27

A significant cost reduction is expected from the local manufacture of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures (PTC). Developers can also find local manufacturing very attractive because of valueadded services, such as the local presence of many O&M options, better procurement lead times, and a trained local work force.

Potential Socio-economic Benefits of Indigenization

With appropriate incentives, some countries have reached a very high rate of local manufacturing for CSP components. For example, the Spanish Association of the Solar Thermal Electricity Industry claims that between 75 percent and 80 percent of the components used in the Spanish CSP plants come from

3 *Cost reductions because of technological breakthroughs, higher volumes in domestic and International markets, and learning curve gains would have effects over and above the figures shown here.*

local manufacturing or are developed with domestic technology. The Spanish industry benefited from incentives, enabling the development of manufacturing plants, combined with other mechanisms focusing on job creation, and promoting the development of innovative companies.

The report analyzed the domestic economic benefits from local CSP development in India. The results are aggregated by average share of local manufacturing in India, economic impact on Gross Domestic Product (GDP), labor impact (that is, job creation), and foreign trade impact. A summary of the results is depicted in Table 4.

TABLE 4: Summary of Socio-economic Benefits Analyzed

Scenario	Installed capacity	Export market demand in 2022	Local share in manufacturing	Cost reduction[4]	Jobs created
Scenario A (pessimistic)	2,000 MW	0 MW	76%	13%	19,000
Scenario B (moderate)	6,000 MW	0 MW	83%	16%	58,000
Scenario C (optimistic)	10,000 MW	2,000 MW	90%	20%	96,000

The projections indicate that the potential cost reductions in CSP's solar field components are large, which would be led by the savings resulting from local manufacturing, lower customs duties for equipment and raw or processed material, and the lower cost of logistics and labor. For other components, cost reductions could materialize because the increase in market size and the passage of time would result in economies of scale. In cases where the critical minimum market size is not reached, cost reductions resulting from local manufacturing have been suitably scaled down. A total reduction of approximately 10 percent has been projected for components taking into account the learning curves by 2022 if volume growth is ensured (optimistic scenario). This has been reduced to 3 percent in the other extreme where the volume growth is small (pessimistic scenario). A moderate scenario has also been projected.

Effects on direct and indirect economic values are calculated in absolute numbers for each scenario. In addition to local manufacturing of components and construction of the plant, it is also assumed that EPC and O&M will contribute to the economic impact of CSP plants. The economic impact is strongly related to the market demand for CSP technologies.

Foreign trade, in terms of generated exports, is estimated only for CSP solar field and thermal conversion specific components. It is assumed that there will be no additional exports for conventional elements, such as power blocks and electrical conversion blocks resulting from the projected growth of the solar thermal industry. Consideration has also been given to the expected learning curve and the lead time for stabilization that will be required for the manufacture of components in India. Minimum market demand for manufacturing also plays an important role because this factor will be decisive for determining proper timing to start production in India. For this reason, in scenarios A and B, exports are not considered because with two technologies competing for the market—PT and central receiver—the demand will be just adequate to justify full-fledged production of some components for each technology, but not sufficient to start exports. In this report, exports have been considered mainly for the currently commercially mature PT technology. Assuming growth in exports from 400 MW per year in 2022 to 900 MW per year in 2030, the export market is estimated to be about INR 5,000 crores in 2022, INR 8,000 crores in 2025, and INR 11,500 crores in 2030, respectively.

[4] *Based on limited data availability.*

The Way Forward: Action Plan to Stimulate Local Manufacturing of CSP Components in India

As part of the study, two workshops were conducted that brought together representatives from the industry and government. It discussed industry expectations to kick-start the market development of CSP projects and plant components in India. These discussions are reflected in the report. Because timing is one of the most common sources of failure, the suggested Action Plan for the Government of India and industries should be carefully timed. To address the industry expectations, the report suggests a comprehensive Action Plan in Table 5 below.

TABLE 5: Proposed Action Plan

Section	Action Plan	Supportive responsibility	Y1	Y2	Y3	Y4	Y5
Long-term policy framework for CSP development	Regular allocation for CSP power projects	MNRE					
	Regulatory support and tariff mechanism for solar thermal hybrid projects	MNRE and CERC					
	Renewable Energy Certificate mechanism for solar thermal energy generation	CERC					
Planning for payment security	Adequate payment security mechanism (using the coal cess funds)	MOF or MNRE					
Low-cost financing	Enabling of low-cost financing for CSP from banks and separate exposure limits for CSP projects	MOF					
Financial planning of subsidies and incentives	Time-bound and milestone-based CCD and zero excise duties for materials and components used for manufacturing of solar systems and development of projects	MOF					
	Fiscal incentives for sponsored research and in-house R&D expenditure	MOF					
Mechanism for promotion of R&D and innovation	Setting up of demonstration plants using hybrids and storage	MNRE					
	Development and maintenance of a public repository of knowledge	MNRE					
	Development of quality and specification standards	MNRE					
	Establishment of an R&D framework on a PPP basis	MNRE					
	Development of solar energy courses	MNRE					
	Sponsored research projects in educational institutions	MNRE					

An immediate positive outcome may not be realistic if it depends on an activity whose implementation may take years.The responsibilities are assigned within the current operating institutional framework of the central and state governments. The second and third phases of the JNNSM should provide clarity in the allocation of capacity for CSP versus other solar technologies for the foreseeable future.

A policy that requires a large domestic input in parts and systems where the domestic capacity to produce those parts and systems is non-existent may unduly delay market penetration or may require adhoc adjustments to show early wins. A policy that completely shields investors from risk may generate complacency and inefficiencies. Any of these possibilities may slow rather than promote market penetration.

To offset the high capital costs representing a large fraction of the LCOE in CSP plants, the government should focus its effort on establishing an adequate payment security mechanism coupled with low-cost financing for CSP. From the technology perspective, hybrid technologies—such as biomass and coal, including generation of pure steam and heating, ventilation, and air conditioning (HVAC)—need to be made eligible to receive government incentives (in proportion to their solar components), along with those facilities that employ only solar technical options. Accelerated depreciation benefits and/or investment tax credit policy needs to be sustained for the long term. This also has to be accompanied by tax holidays and zero excise duties for components produced locally. For those components that are currently available in the Indian market, market growth should be promoted in order to reduce costs.

Future investments in development of local manufacturing units (especially for specialized equipment) will depend heavily on several factors:

- Successful implementation of CSP projects from Phase-I developers
- Demonstration of new CSP possibilities using public support
- Firm government commitment for the development of CSP plants
- R&D assistance from Indian institutions or through joint ventures or licensing arrangements with international companies
- Easy availability of financing options

The study, ‘Development of Local Supply Chain: A Critical Link for Concentrated Solar Power in India’, is a diagnostic of the India’s local manufacturing potential to supply components and related engineering and operation and maintenance services for CSP projects. The study looks at the domestic manufacturing capability for CSP projects to support solar power development in India and realized the resulting economic benefits. It also shows that developing indigenous value chains could lower the overall project costs and spur industrial growth and R&D capacity in the long term.

The study is part of a series of publications on the topic. The earlier publication was focused on the Middle East and North Africa (MENA) region. These studies are published to communicate the World Bank’s views on pressing issues and stimulate policy and public discussions.

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. Its mission is to help low- and middle-income countries increase know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth.

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