

Institutional Report

Gujarat Energy Research and Management Institute

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Introduction

The Gujarat Energy Research & Management Institute (GERMI) is a centre of excellence in industry learning and was set up to, i) develop human resource to cater to the petroleum and allied energy sectors, ii) improve knowledge base of policy makers and technologists and iii) provide a competitive edge to leaders to compete in the global arena. GERMI is a registered Society under the Societies Registration Act, 1860 and a Trust under the Bombay Public Trust Act, 1950. It is recognized by the Department of Scientific and Industrial Research (DSIR), Government of India, as Scientific and Industrial

Research Organization (SIRO). The institute is also a Schedule-I environment Auditor recognized by the Gujarat Pollution Control Board (GPCB) and Energy Auditor Consultant recognized by the Gujarat Energy Development Agency (GEDA). Recognition is also by the Government of India as 'Scientific Research Association' under section 35 (1) (ii) of the Income Tax Act, 1961. It is an autonomous and non-profit organization, promoted by Gujarat State Petroleum Corporation (GSPC) Ltd., Gujarat, Govt. of Gujarat undertaking. GERMI has a vision that young professionals in energy sector ought to have an access to the opportunities for being more competent,

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efficient, highly knowledgeable and courageous to innovate and experiment in the global arena and societal concern of a citizen will inspire productive and efficient use of energy with wider perceptions of clean environment and awareness of futuristic scenario.

GERMI has the mission to provide facilities and opportunities for creation of knowledge, develop blue print of futuristic technologies and new business opportunities, and to commit itself for societal good in all walks of human endeavor at macro as well as at grass-root levels. One of the main objectives of the institute is to contribute to knowledge and assist need-based transformations of various dimensions of efficiency enhancement in extraction and use of energy with appropriate innovation and adaptation of various processes. It also helps to realize the scalable developments of newer technologies. GREMI's mandates include, (i) Higher Education, (ii) Research and Development and (iii) Consultancy and Training. GERMI has initiated higher education by creating Pandit Deendayal Petroleum University (PDPU). The University addresses to the need for trained human resource in Science, Technology, Management and Humanities. GERMI has also initiated Indian Institute of Information Technology, IIIT-Vadodara under Private-Public- Partnership mode along with Tata Consultancy Services and Gujarat State Fertilizers and Chemicals limited to promote computer science and IT sector.

Research and Development activities through Gujarat Research Innovation and Incubation Center (GRIIC) are being carried out. This R&D Center comprises Petroleum Research, Solar Energy Research and Environment and Energy Efficiency Research.

Initiatives by the institution have resulted in significant outputs. For example, scientific, technological, management and training leadership in the field of energy and environment has now reached the national level. Typical examples include, management of the 5 MW Photovoltaic Rooftop Programme at Gandhinagar, ii) development of an institutional mechanism for optimization of solar energy for safe climate and iii) integration of alternative energy systems.

Initiatives in petroleum sector are under way

with major multi-lateral, multi-institutional co-operation. Another standing example is the mega project taken up in the environment sector deals with chemical substitution and compliance with funding from the United Nations Environment Programme (UNEP).

New initiative in the petroleum and renewable energy sectors imply a major growth for GERMI that aims to be a "Centre of Excellence" to develop human resource assets in areas non-renewable and renewable energy resources and in mitigation of associated environmental impacts. Simultaneously, in-house and collaborative research is being strengthened. GERMI has created state of the art laboratory facilities related to all the three research wings.

Petroleum Research

This has two major activities, laboratory studies and the Data Interpretation Centre (DIC)

Petroleum Research – Lab Studies

Petroleum Research has the objective of development of increasingly efficient and well adapted technologies, exploration, production and performance prediction and development of techniques to improve the recovery for hydrocarbon resource. Current research programmes includes the conventional and non-conventional hydrocarbon resources and development of synthetic combustion fuel for energy security and at the same time addressing the environmental concerns.

As part of students' internship programme, a vast area of Cambay basin has been studied to create a database for anomalous behavior of microbial and heavy metal assemblage in the surface and sub-surface soil zones of the region. This will be extended to all the sedimentary basins including the mining areas under Gujarat Mineral Development Corporation. Memorandums of Understanding have been signed with IIT-Mumbai, PDPU-Gandhinagar and National Institute of Magneto biology and this joint venture research has been variously funded.

In order to enhance the techno-scientific approach GERMI develops research projects and provides consultancy on hydrocarbon exploration and production industries by taking surface indicators as basic tool along with seismic data interpretation.

R&D Projects Completed

- Integration of surface geochemical and 3D seismic data for evaluation of hydrocarbon Potential in onland block of KG Basin

The study aims at integrated approach using geo-microbial, adsorbed soil gas and 3D seismic studies to understand the mechanism of hydrocarbon seepage and to evaluate the hydrocarbon potential in a block falling in Onshore KG Basin. Here we correlated the geochemical anomalies with microbial anomalies. It reveals that, adsorbed propane indicate that the anomalies follow the natural model depicting 'Halo' pattern. Integrated anomaly plots between adsorbed light hydrocarbons and bacterial anomalies, demonstrate that light hydrocarbon distribution showed low signal resulting in a halo anomaly and the bacterial activity to hydrocarbon concentration exhibited an apical anomaly. Integration of the geo-microbial and adsorbed soil gas data with 3D seismic data shows that the geochemical anomalies were observed in the vicinity of the major fault and these may be due to the feeble gases which have generated from high gamma-high resistivity shale section and have migrated along this fault and deposited in the shallow regions.

- Integration of adsorbed soil gas and trace metal anomalies with 3D seismic data for evaluation of hydrocarbon prospectivity in Cambay basin

The concentrations of trace elements have been used as indirect proxy for detection of hydrocarbon microseepage. The long-term seepage of hydrocarbons creates near surface oxidation reduction zone that favors the development of a diverse array of chemical and mineralogical changes. Under the reducing environment, the solubility of trace element increases and due to hydrodynamic flow, these metals move towards the oxidizing zone. This study compares the trace element concentrations with adsorbed soil gaseous hydrocarbons and explains the trace elements concentrations pertaining to the hydrocarbon micro seepages. Total 81 numbers of soil samples were collected from the depth range of 1-2.5 meters below the ground level from Southern part of the Cambay Basin.

The trace metals such as Chromium (Cr), Copper (Cu), Arsenic (As), Selenium (Se) and

Antimony (Sb) in the soil samples were analyzed using Atomic Absorption Spectrometer. The analytical results show the varying range of concentrations as Cr (0 to 76ppm), Cu (59 to 168ppm), as (63 to 155ppm), Se (72 to 182ppm) and Sb (6 to 19ppm). The analyses of adsorbed soil gases show the presence of high concentrations of methane (CH₄) ranged between 2 to 290 ppb, and sum of concentrations of ΣC_{2+} ranged between 7 to 118 ppb. The increased concentrations of trace metals, suggest a soil chemical change to a reducing environment, presumably due to the influence of hydrocarbon microseepage.

- Geochemical analysis of lignite and shale samples of GMDC operated lignite coal mines

This study aimed to characterize the Tadakeshwar coals. The area under study through chemical composition utilizing the parameters through proximate and ultimate analyses. The analytical evaluation of properties such as moisture, volatile matter, fixed carbon, and ash forms the proximate analysis. The moisture content in the coal samples ranges between 7.25 and 22.17 wt%. The fixed carbon content varies from 41.62 to 62.15 wt%, the ash content ranges between 7.74 and 29.10 wt%, volatile matter ranges between 37.85 and 57.69 wt%. The statistical analysis of the results show the average concentration of fixed carbon as 50.63 wt%, ash content as 17.10 wt%, moisture as 12.64 wt%, and volatile matter as 54.39 wt%. The concentration of carbon content ranges between 42.65 and 72.52 wt%, The oxygen content ranges between 20.02 and 42.16 wt%, the hydrogen ranges between 1.80 and 7.77 wt%, sulphur ranges between 0.84 and 6.31 wt% and nitrogen ranges between 0.08 and 0.90 wt%. The statistical analysis of the results show the average concentration of carbon as 58.55 wt%, hydrogen 5.11 wt%, nitrogen as 0.51, sulphur as 3.67, and oxygen as 28.81 wt%. The analytical results suggest the existing coal with varying thickness spread all over the region is of lignite rank.

Sponsored Projects

- Laboratory scale development of synthetic combustion fuel using algae as a Resource supported by Department of Climate change, Gujarat.

The objectives of the project are-

- Isolation, screening and evaluation of naturally occurring photosynthetic microalgae strains that exhibit high growth rate and high oil content
 - Optimization of nutritional and physiological parameters for the enhancement of biofuel production along with CO₂ sequestration by selected strain
 - Comparison of technologies for biofuel production
 - Development of novel plant for the commercial scale biofuel production using optimized parameters and analysis of its impact on economy and environment
- (b) Laboratory scale development of technology for Algal Fuel production supported by Gujarat Council for Science and Technology

This project aims to develop a technology for the commercial scale biofuel production using optimized parameters and analysis of different kinds of algae by isolation of Algal stains, cultivation of specified algae, extraction of Algal oil and conversion of Algal oil to biodiesel (Fig. 1).

Petroleum Research-Data Interpretation Center (DIC)

The center has expertise in geophysical and geological data interpretation such as seismic attributes, complicated fault block interpretation, well-seismic correlation, post and pre-stack inversion, texture



Fig. 1: Extraction of Algal biofuel using Soxhlet extraction method

attribute analysis and TOC mapping. A focus on adopting new techniques from various disciplines, with potential for the advancement of technology related to oil and gas industry for multidisciplinary studies for enhancing the understanding of the hydrocarbon plays.

The center has carried out several R&D and sponsored projects on Geological and Geophysical (G&G) data analysis for hydrocarbon exploration and mentored 49 students and trained 78 geoscientists in seismic data interpretation. For applied R&D for exploration, GERMI also engages domain experts, post-doctoral fellows' geo-scientists and programmers in computational geophysics. The center has 5 multi core work stations with 55 TB storage and is managed by a group. The infrastructure also develops graphic intensive interactive interpretation and processing applications, high compute intensive seismic depth imaging using Message Passing Interface (MPI) and Computer Unified Device Architecture (CUDA) parallelization technologies on workstations, harnessing the power of multi-core CPUs and GPUs.

(a) Software Development

The seismic software development group is one of its kind in India and targets the vast gap in development of seismic software that will be commercially marketed. **Following areas are targeted:**

- Development of seismic data processing softwares in a user friendly environment.
- Development of Seismic Imaging softwares namely Reverse Time Migration algorithm through high performance computing.
- Apart from development of routine software modules for interpretation, the group is focusing on the development of niche products relevant to Indian hydrocarbon industry.

Research Areas of DIC group

1. Enhancement of Seismic signatures and development of new attributes
2. Development of new technology and Custom solutions as plugins
3. Data conditioning for Fault and Fracture extraction
4. Integration of multiple domain data sets for interpretation

5. Quantitative interpretation of pre stack data including prestack inversion
6. Seismic velocity modeling for plausible depth estimations
7. Seismic Imaging using High Performance Computing
8. Mapping of TOC through Cores, Logs and Seismic
9. Strengthening the efforts of open source G&G interpretation software like openTect
10. Development of indigenous interpretative Seismic processing software

Research and Development in G&G data Analysis activities include to create new workflows for seismic data interpretation, to use advancement in Digital Signal/Image processing for seismic attribute computation, to provide R&D support to Indian E&P companies in G&G data analysis and to develop methods for mapping TOC through core, logs and seismic data.

Evaluation of Exploration & Production Blocks activity include to provide techno-commercial consultancy to clients for evaluation of exploratory Blocks for acquisition to provide comprehensive acquisition strategy to clients for acquiring small and medium fields, to assist and provide advisory to acreage holders in managing PSCs and implementation of MWP, seismic API project management and execution, seismic Data acquisition (2D & 3D), provides acquisition project consultancy including Optimization of equipment and technologies, modeling based survey designing, optimization of field parameters, planning of experimental work, QC of 2D & 3D seismic data acquisition and to provide comprehensive, industry accepted QHSE solutions

Seismic Data Processing (2D & 3D) activity include comprehensive consultancy for finalization of specifications, for processing and preparation of tender documents for processing and assist clients in finalization of processing contracts, provides seismic data processing project consultancy including optimization of processing sequence, model based processing, analysis of experimental processing work, and optimization of processing parameters monitoring quality control of production processing of 2D, 3D

seismic data, Processing of 2D and 3D seismic data (PSTM and PSDM), processing for Coal characterization for CBM exploration etc.

The group is also capable of well log data processing and interpretation. It provides comprehensive consultancy for well log data analysis. The team has highly professional Petro-physicists having more than 30 years of quality experience in well log data acquisition, processing and analysis. It also provide core analysis and production log analysis.

The group has accomplished many projects in Geology and Geophysics. For example, it has developed workflows for post stack data enhancement and fault and fracture analysis, channels and thin sand delineation, TOC prediction through core data, well logs and Seismic correlation, multi attribute analysis & ANN for log property mapping, texture attributes, Poisson impedance for reservoir characterization, coal characterization. Improving stack quality and identification of coal seams using state of the art processing and interpretation technologies along with channel partners.

The group has completed many consultancy projects. For example, pilot project on evaluation of G&G data of a NELP block of M/S Mercator Pvt. Ltd, G&G data analysis for hydrocarbon exploration for M/S Sintex Oil and Gas Limited etc.

Training and Development on Petroleum Exploration

The group has an indigenous training and research organization whose vision is to provide, world-class continuing education facility for human capacity building for the Indian petroleum industry. It is now proposing to collaborate with the national and international exploration and production training services, to form a consortium of international trainers. For this purpose it can source locally and also around the world the most competent and experienced; earning consultants in the technical, non-technical and management disciplines. The group personnel are of renowned explorationists involved in E&P business in India and abroad having more than 30 years of professional experience. Its key objective is to develop a facility that is conducive for the impartation of knowledge & skills for enhancing competency, productivity and professionalism in both the upstream

and downstream stream sector of the petroleum industry.

The Data Interpretation Center has designed workshops for young geophysicists, petro - physicists, geologists and reservoir engineers to enrich their knowledge in seismic data interpretation, tool physics and formation evaluation. During the period from March 2013-April 2015 it has conducted 3 trainings related to G&G data analysis. It was attended by about 78 geoscientists from oil industry (Oil and Natural Gas Corporation Limited (ONGC), Indian Oil Corporation Limited (IOCL), Bharat Petro Resource Limited (BPRL), Gujarat State Petroleum Corporation (GSPC) Selan Exploration Technology Ltd., Central Mine Planning and Design Institute (CMPDI), Jindal, Indian Institute of Technologies and various other Institutions).

Solar Energy Research Wing

The Solar energy research Wing supports the fundamental and applied research ranging from solar cell material and device designs to plant performance analysis. The Wing also provides technical and advisory services to government as well as industries for deploying solar and related renewable energy initiatives. The wing has a successful track record in setting up rooftop and megawatt-scale photovoltaic power plants, smart and micro-grids, social projects such as solar streetlights, as well as structuring public private transactions to ensure sustainability. This rich experience also culminates into very successful and comprehensive professional and vocational training programmes.

Sponsored Research Projects

- (a) Design, development and demonstration of micro-grid system for optimization and control of multiple sources of power supply.

Efficient integration and optimization of renewable energy sources and energy storage to existing distribution network (at CMPDI, Ranchi) to maximize renewable energy utilization, enhance energy-related user experience and reduce to overall carbon footprint

Status of project: All of the installations including 190 kW rooftop solar and micro-grid components

such as voltage stabilizers, battery bank, automatic demand response equipment and control software are commissioned. Installation of integration equipment, i.e. auto-changeover panel, is also completed.

- (b) Global Technology Watch Group (Sub-Group 4: Renewable Energy Policy and Business Model)

The Global Technology Watch Group - Renewable Energy (GTWG-RE) aims to provide a robust assessment of the global renewable energy technology development landscape that will assist the NMSKCC in developing a domestic knowledge network, enhancing institutional capabilities for strengthening the negotiating position, and advising the government on technology strategy. This is an ongoing process which will progressively continue during its term. GERMI has developed a repository of information and analysis regarding the solar energy sector at central as well as state-level

- (c) Development of 'Best Practices Manual' for implementation of state-level rooftop solar photovoltaic programmes for India

Development of a manual for administrative stakeholders including state governments, distribution companies, state nodal agencies, electrical inspectors and financial institutions. The chapters of the manual describe rooftop solar business models, policy, regulations, technicalities, implementation processes and appraisal considerations. The manual is nearing completion.

Fundamental Research and Development

- (a) Development of graphene for photovoltaic applications

Graphene is a single atomic layer of graphite and it is a 'wonder material' due to its exceptional mechanical strength, high electric conductivity and high optical transparency. Use of Graphene in commercial solar cells is being explored. Crystalline (and polycrystalline) silicon is considered as the complementary material (i.e. for forming the hetero junction), due to its proven techno-commercial viability, material maturity

and its ability to achieve high efficiencies (approaching its thermodynamic efficiency limits). GERMI, Graphene is investigated for its potential as (i) an absorber layer, (ii) substrate/superstrate, (iii) current-spreading layer, and (iv) anti-reflection coating.

High quality graphene film is fabricated using mechanical exfoliation of highly-oriented pyrolytic graphite. The graphene films on glass substrates are characterized using field-emission scanning electron microscopy, atomic force microscopy, Raman spectroscopy, UV-vis spectroscopy and Fourier transform infrared spectroscopy. A very high intensity ratio of $2D$ to G -band (≈ 1.67) and narrow $2D$ -band full-width at half maximum ($\approx 40 \text{ cm}^{-1}$) correspond to the bi-layer graphene formation. The bi-layer graphene/ p -GaN/ n -InGaN/ n -GaN/GaN/ $s\text{Al}_2\text{O}_3$ system is studied theoretically using TCAD Silvaco software, in which the properties of exfoliated bi-layer graphene are used as transparent and conductive film, and the device exhibits an efficiency of 15.24% compared to 13.63% for ITO/ p -GaN/ n -InGaN/ n -GaN/GaN/ Al_2O_3 system (Behura *et al.*, 2014).

(b) Indium Gallium Nitride (InGaN) Solar cells

This work has been carried under GERMI-CSIR Central Electronics Engineering Research Institute, Pilani, Rajasthan collaboration. The III-Nitrides (consisting of Aluminium Nitride, Gallium Nitride, Indium Nitride and its alloys) is a novel semiconductor material system that has the potential of achieving over 50% photovoltaic conversion efficiencies. However, there are several technological challenges in achieving high quality semiconductor material as well as low-resistance contacts. Additionally, following items are being investigated. For example, design, fabrication, characterization and optimization of wide-band gap InGaN solar cells, accurate modelling and simulation of InGaN solar cells through investigating material and device datasets.

(c) p -GaN/ i -In x Ga $1-x$ N/ n -GaN solar cell with indium compositional grading:

The effect of indium compositional grading on

the performance of p -GaN/ i -In x Ga $1-x$ N/ n -GaN/ p -GaN/ i -In x Ga $1-x$ N/ n -GaNsolar cell has been investigated using TCAD Silvaco. An enhancement in efficiency of almost two times is found and this may be due to the increase in short circuit current density and open circuit voltage. This can be imputed to high carrier collection due to the reduction of band offset at the interface and high band bending in intrinsic layer. The optimized GaN/In x Ga $1-x$ N/GaN/In x Ga $1-x$ N solar cell with indium composition grading from 0 to 0.11, results fill factor of 77 %, short circuit current density of 0.99 mA/cm² and open circuit voltage of 2.21 V under AM1.5G illumination.

Applied Research and Development

(a) Solar Thermal Energy Generation Potential in Gujarat and Tamil Nadu States, India

Government of India has come out with an ambitious target of 100 GW of using solar energy alone by the year 2022. To reach this target, innovative ideas are required to use the solar energy more effectively. For solar electricity generation, mainly two types of technologies are presently in use, namely, solar PV and solar thermal. More research is required on economic aspects to make the solar thermal competitive to solar PV. Towards this direction, in our present study we have simulated a solar thermal power plant using Parabolic Trough Collector (PTC) technology and normalized with 1 MW solar thermal power plant at Gurgaon near New Delhi. Through simulation, we have extended our study and computed the electricity generation possible at different locations of India. For this purpose with $1^\circ \times 1^\circ$ spacing, computations have been carried out at 296 locations. The work is further extended for more detailed study at two representative states, namely, Gujarat and Tamil Nadu. In these two states, closer data points with $0.25^\circ \times 0.25^\circ$ spacing have been considered at 273 locations for Gujarat and 197 locations for Tamil Nadu. Our results indicate a large potential of electricity generation using solar thermal energy in southern states of India, namely, Tamil Nadu, Karnataka, Kerala, southern and western part of Andhra Pradesh

and eastern part of Maharashtra. Good potential has also been observed in eastern parts of Gujarat and parts of Madhya Pradesh and eastern part of Rajasthan. The annual potential ranges from 1800 MWh to as much as 2600 MWh. Major parts of northern states, for example Uttar Pradesh, Bihar, West Bengal, Punjab, Jammu and Kashmir have medium range potential. Here, the annual potential ranges from 1000 to 1500 MWh. Poor range of potential is observed towards eastern parts of India and north eastern states. Here, the electricity generation potential ranges from 600 to 1200 MWh. Our results (Fig. 2) are useful to solar thermal developer and decision managers (Reddy and Harinarayana, 2015).

(b) Solar PV Energy Generation Map of Karnataka, India

Four solar PV power plants in Karnataka state are fully operational installed by Karnataka Power Corporation Limited (KPCL). They are located at Kolar, Belgaum and Raichur with 3 MW capacity each and at Mandya with 5 MW capacity. In the present study, using ground mounted weather station data solar power generation has been estimated and compared with actual generation for two consecutive years

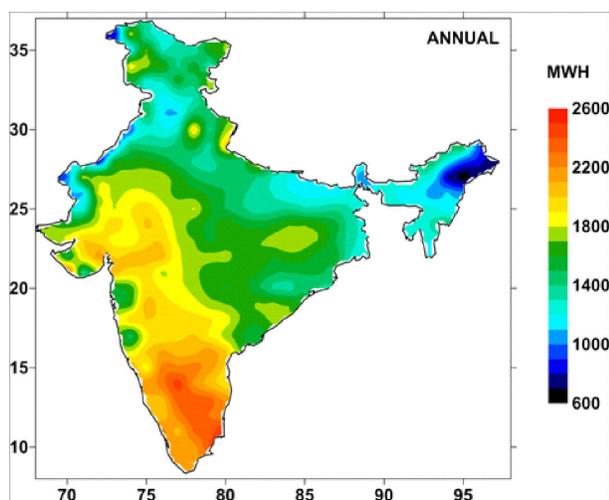


Fig. 2: Solar thermal energy generation potential map for India using PTC technology. Considering 1 MW power plant at different locations. The solar thermal potential ranges from 600 MWh/annum in parts of north eastern region to about 2600 MWh/annum in parts of south India (Reddy and Harinarayana, 2015)

of 2012 and 2013 for one location initially, namely 3 MW Kolar Solar PV Plant. The procedure is repeated for rest of the plants. The simulated results have been corrected with ground mounted weather data. After such corrections, the simulated results have been compared with the actual energy generation of the four plants. Results showed a close match with a small deviation of about 5%. The model then applied throughout the state for every 0.25 degree station intervals in a grid manner. The annual energy generation obtained for the state varies from 1.53 to 1.73 MUs/MW. Central and south eastern part of the state are found to yield significantly higher solar power generation as compared to the northern part and south western part of Karnataka. Interestingly, north western part of Kodagu district has shown the least potential of 1.53 MUs/MW as compared to other parts. This can be attributed mainly due to low irradiation and high temperature condition at this location. The energy generated map from our study will be useful and helpful for both solar developers and decision makers of Karnataka state (Gajjar *et al.*, 2015).

(c) Theoretical Study of Wind Turbine Model with a New Concept on Swept Area

Commercially available wind-turbines are optimized to operate at certain wind velocity, known as rated wind velocity. For other values of wind velocity, it has different output which is lower than the rated output of the wind plant. Wind mill can be designed to provide maximum power output at different wind velocities through modification of swept area to match with the wind speed available at the moment. These results in increased utilization of generation capacity of wind mill compared to its commercially designed counterpart. A theoretical simulation has been done to prove a new concept about swept area of wind turbine blade which results in a significant increase in the power output through the year. Simulation results of power extracted through normal wind blade design and new concept are studied and compared. Study establishes that there can be a significant gain in the power output with the new concept (Sagarkumar *et al.*, 2015).

(d) Solar PV Energy Generation Potential Estimation in India and Gujarat, Andhra, Telangana States

It is a well-established fact that solar energy proved to be the most sought after source for energy generation. Although, solar energy potential maps of India have been prepared based on solar irradiation maps in the earlier studies, the present research study has been carried out with a focused attention directly on solar energy generation considering various parameters. In this work it is shown that solar energy generation does not depend on solar radiation alone at a location. Instead, there are various other factors that influence the energy generation. Some of them are ambient temperature, wind velocity and other parameters like weather and topographic conditions. In this study the locations with high and low solar energy generation potential in India have been identified through systematic analysis by computing the solar energy parameters at every grid point ($1^\circ \times 1^\circ$). The work has been extended with more detailed study for Gujarat, Andhra Pradesh and the newly formed Telangana states. The data points considered for the states are $0.25^\circ \times 0.25^\circ$ having resulted in adding more number of locations. Our results indicate that the total annual energy generation in India varies from 510,000 KWH to 800,000 KWH per acre of land (Fig. 3). The least energy generation location pertains to the eastern parts of Arunachal Pradesh and eastern part of Assam and the highest annual solar energy generation has been identified in the eastern parts of Jammu & Kashmir and eastern part of Uttarakhand (Harinarayana and Kashyap, 2014).

(e) Increasing the Efficiency of Grid Tied Micro Wind Turbines in Low Wind Speed Regimes

Major problem with grid tied micro wind turbine is synchronization and wind variability. Due to this problem the stability of available grid gets reduced. The stability can be achieved by output power control of the turbine. Major countries like India, the annual mean wind speed is not high. The rated wind speed of turbine remain around 11 m/s and cut in is around 3.5 m/s. Due to this problem we aimed to develop a

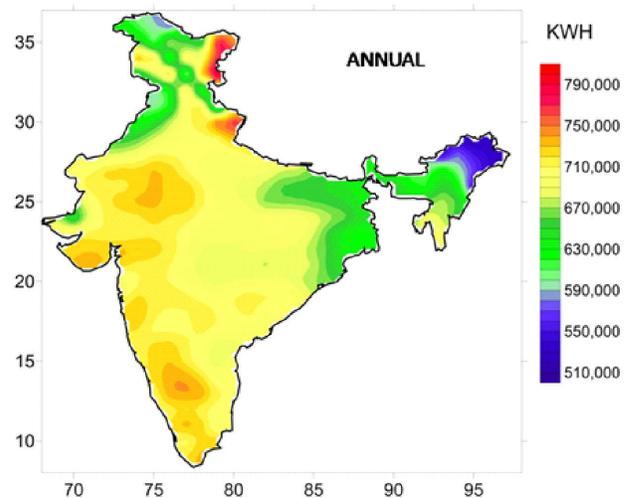


Fig. 3: Annual solar energy generation potential map for India estimated from the study. Blue colour shows the low energy generation and Red indicates the high energy generation (Harinarayana and Kashyap 2014)

sustainable wind energy system that can provide stable power supply even at the locations of low wind speed of 2 - 4 m/s. To address this issue, a momentary impulse or external torque to the rotor by external motor is one of the good options to maintain the momentum of blades and thus provide stability for sufficient time. Various theoretical calculations and experiments are conducted on the above method. This would increase the output power and also the efficiency of wind turbine. We show that Return-On-Investment will be high as compared with other grid connected turbines. Our proposed concept in the present study, if implemented properly, can help the installation of number of wind turbines even at domestic level. It also makes the consumers energy independent and promotes the use of wind as a source of energy and may enter as a rooftop energy supply system similar to solar (Tiwari and Harinarayana, 2014).

(f) Aircraft Disaster Management in Gujarat Using Geographic Information System

Among various disasters, aircraft disaster is considered to be one of the deadliest disasters. Search and Rescue (SAR) operations play a vital role at the time of disaster. Reducing the search area, decreasing the reach time and following the optimal route to reach the crash

site are some of the important factors to enable the SAR team to save more lives in the accident area. Using the laws of projectile motion combined with the force due to air drag we can approximately predict the possible area of crash of the aircraft in order to find the wreckage and the approximate time of the plane to reach the ground. Additionally, Geographic Information System (GIS) helps to identify the area of the wreckage, generates a probability map with probable location of the crash, suggest the optimal route to reach the crash site and help to assist the ground crew – for example, district administration, hospitals, police, NGO's etc in the vicinity of the crash site. The scope of the present study is aimed at an aeroplane under cruising experience failure due to structural or engine malfunction. We apply differential equation and formulae to analyze the situation in four different hypothetical cases considering the Gujarat state, India and suggest ways and means for SAR operations (Manoj Siddhardha and Harinarayana, 2014).

(g) Solar Energy Generation Using Agriculture Cultivated Lands

Generation of electricity using solar PV is picking up in India in a big way in recent years. It needs a clear direction such that it can optimally be utilized and the benefits, without being concentrated in a few locations, can reach the majority of poor population as well. Indian farmers, for the last few decades are affected in terms of availability of electrical power. The present study suggests the use of fertile and cultivated land with about 5 m elevated structure with solar panels. It creates shade on the crops. In the present study, the shade effect on the crops below the structure has been examined systematically through modeling studies. Different solar panel design configurations are suggested such that the crops or plants below, on the ground surface, can also be grown without any reduction in their yield. The effect of the elevated structure on the neighboring lands is also examined. It is shown that the present concept can easily be implemented in India, perhaps in the world, at all the locations such that power can be generated using farmer's own

land for his own benefit, perhaps with some profit to him. The present concept, if implemented, also reduces the huge cost involved in establishing the network of transmission and distribution lines (Harinarayana and Vasavi, 2013).

(h) Development of Geotourism in Kutch Region, Gujarat, India: An Innovative Approach

Geotourism in Kutch has an exemplary potential of being designated as a site for perfect establishment of a National Geopark. The paper is aimed to describe the geological significance of the sites with basic concept of creation of geoparks and promote geotourism. The financial, infrastructural aspects, deliverables to the society are presented primarily focusing on the local economic and sustainable development of Kutch. The need for development of infrastructure for geotourism is urgently required as the rare geological heritage of Kutch region is eroding and being destroyed due to manmade activities (Swarna *et al.*, 2013).

Patents and Flagship Programs

A few patents are also filed related to energy savings. For example, thermal cooling device for portable electronic equipments, a system for cooling and heating of indoor space using geothermal energy and solar energy and energy efficient pressure cooker.

1) **GERMI innovation on “Smart Pressure Cooker” vide registration no. 268695 on 1st of August, 2015**

The new pressure cooker helps energy efficient cooking and thereby minimizing LPG consumption. The test results confirmed around 40% savings of LPG while compared with energy consumption by normal pressure cooker for cooking same amount of food stuff. Smart controller helps reducing energy loss and thereby when implemented with smart controller, it can further reduce LPG consumption by 20% reducing overall LPG consumption by a massive 60%. The product shall cost additional INR 2000 compared to a normal 5 liter pressure cooker. Assuming only 40% of saving on LPG, LPG cylinder price at INR 900 and consumption of 6

cylinders of LPG a year, the product offers attractive savings of INR 2000, thereby offering return in one year time.

2) **GERMI innovation in designing a product for Thermal Cooling Device for Portable Electronic Equipments (registration No. 266563)**

The product does not require any energy but makes any product keep it's surface will make the product to cool naturally. Although it has been prepared for the laptops and other devices, it has many more applications to cool a location in a natural way without using any energy.

In applied research GERMI's flagship project is related to micro-grid project at Central Mine Planning and Design Institute (CMPDI) Ranchi (Fig. 4). This project will aim to minimize the campus to minimize the carbon footprint of the campus, while improving the quality and availability of power and install and optimally utilize multiple renewable energy sources and energy storage systems while also ensuring their economic viability, and utilize demand-

side management (DSM)/automated demand response (DR) to balance the variability of renewables and minimize diesel consumption.

In the implementation of the project a study of existing energy baseline including the energy supply patterns from grid and generators, consumption patterns, wiring within the campus and existing strategies of load prioritization are completed. This was followed by identification of possible micro-grid strategies using the available generation, storage, control and communication technologies; model various optimization strategies are prepared in terms of financial viability and minimization of fossil-based energy consumption. Optimal specifications for monitoring equipment for baseline determination, rooftop solar and wind energy generating systems aggregating to 200 kWp, battery bank with management system, switchgear for mechanized switching with remote communication capabilities, micro-grid controller to control and communicate with various power supply, generation and consumption point are being designed.

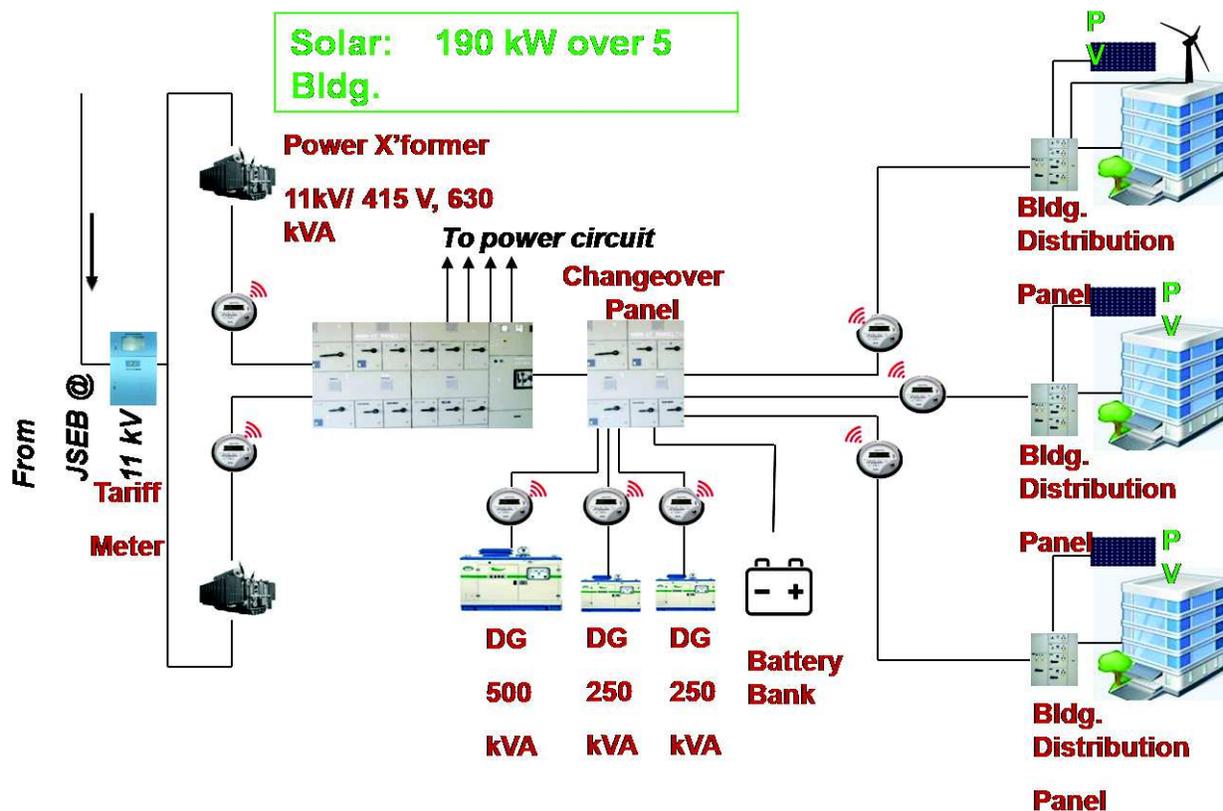


Fig. 4: Micro-Grid at CMPDI

The 5 Mw Gandhinagar (Solar) Photovoltaic Rooftop Programme

Prior to 2012, rooftop solar projects were implemented through direct government funding and it was widely observed that the performance of such systems was not at their technical best. Hence due to cost and performance issues, it was obvious that this model would not work for widespread rooftop solar deployment. Therefore GERMI was assigned the task of implementing the 5 MW Gandhinagar (Solar) Photovoltaic Rooftop Programme by the Energy and Petrochemicals Department, Government of Gujarat. GERMI revised the entire methodology of rooftop solar programmes and establish the widespread practice/philosophy of distributed solar and renewable energy generation and demonstrated the technical feasibility of large volume of scattered energy injection into the distribution grid. The program is now functional and has paved way for large-volume rooftop programmes by leveraging public investments, and public participation.

20 MW advisory and Project Management Consultancy Under National Solar Mission

Gujarat State Electricity Corporation Limited (GSECL) decided to develop a solar Photo voltaic (PV) project under the Jawaharlal Nehru National Solar Mission (JNNSM). GERMI advised GSECL on its bidding strategy for Batch-2, Phase-1 of the JNNSM. Analysis cost of ongoing projects and equipment the economics of the program based on various techno-commercial parameters, GERMI recommended a viability gap funding (VGF) for GSECL to be quoted. The bidding results indicated GSECL's bid as a most mature bid resulting into the award of project. Consequently, GERMI was awarded the Project Management Consultancy (PMC).two 10 MW project each of GESCL and Gujarat Power Corporation Limited (GPCL).

Professional Training in Solar Energy

Solar Energy group at GERMI regularly conducts Solar Power Professional Workshops high and mid-level engineering/management professionals wishing to orient their employees to companies without prior solar experience. Trainers range from in-house subject experts to technology leaders from industries. We have already trained 400+ professionals through

these intensive 6-day programmes. The various modules in this programme are directly help participants to gain basic knowledge of components of a photovoltaic power plant (photovoltaic modules, inverters, charge controllers, batteries, switchyard, Supervisory Control and Data Acquisition (SCADA) mount in structures). It also explains them Photovoltaic system types, design philosophy, principles, examples and calculations, project management, economics and financial aspects, policies on solar energy, Renewable Energy Certificate (REC) and carbon credits through material with worked-out examples, data sheets, discussions, etc. Also imparted is hands-on experience with site survey tools, weather measurements and installation of photovoltaic system. Comprehensive learning of industry-standard photovoltaic system designing software is also included in the programme. Additionally, site visit to megawatt-scale and rooftop photovoltaic power plants and manufacturing units.

Solar Vocational Training

GERMI assists in the development of a skilled workforce for the solar industry through a widespread vocational training of trainers and as institutions.

National Certification Programme

The National Certification Programme for Rooftop Solar PV Installer is a platform to develop and promote solar vocational capabilities in training and educational institutions by standardizing curriculum and content, training the trainers, assisting in setting up training infrastructure, monitoring training quality and certifying the successful technicians. The Government of India has set an ambitious target of 100 gigawatts of solar capacity in the country by the year 2022, out of which 40 gigawatts are to be installed on rooftops. As on July 2015, the total installed solar capacity in India was just over 4.1 gigawatts, while under 99 megawatts (i.e. 0.099 gigawatts) were installed on rooftops. Rooftop solar systems offer tremendous advantages such as lower transmission and distribution losses, lower investment amounts, lesser number of clearances, public participation and higher employment and entrepreneurship opportunities. One of the most critical component of aggressive rooftop solar deployment is the availability of highly skilled and qualified installers. It is estimated that India will need approximately 10 Lakh solar technicians by 2022 to meet its targets.

Energy Efficient Air Conditioning System Using Geothermal Cooling-Solar Heating in Gujarat, India

It is well known that a unit of electrical energy saved is equal to more than two units produced. One way of economizing the power is utilization of energy efficient systems at all locations. In this study, the air conditioning system was analyzed and an innovative way for energy saving was suggested. We used natural low temperature of shallow sub surface (1-3 m) of the earth—geothermal cooling system. Given that majority of the households and the apartment complexes in India have two tanks for water storage. One is the underground water sump and the other is the overhead water tank we used these two water tanks for space cooling during summer and also for heating during winter using a simple idea of transferring the low temperature from underground water sump to the room in the house using water as a mode of heat transport.

In India for most of the year, the air temperature is high and demands space cooling with only a few months of severe winters. For heating the space, we suggest to use the well known solar water heater and

an effective heat exchanger was developed through computation, modeling schemes and laboratory experiments. In geothermal cooling, the ambient air temperature of 35°C-40°C in the room was brought down to 26°C without much (how much) consumption of electricity. Analogously, the room temperature at night (13°C) during winter in Ahmedabad was increased to 27°C through circulation of water from solar water heater in the heat exchanger. The schematic diagram of the concept used in the study is shown in Fig. 5.

Innovations in Solar and Renewable Energy

GERMI is currently investigating degradation of solar PV modules and development of innovative structures for canal top solar power plants, evaluation of solar PV modules of different technology etc. in the field of solar energy. Forecasting of solar and wind energy, development of virtual power plants and smart wind generators are being examined. Work on demonstration of industrial and residential heat applications process running on solar thermal energy and thereby helping commercialization of the solar thermal technology in cooking, air – conditioning, heating, and drying applications in residential and

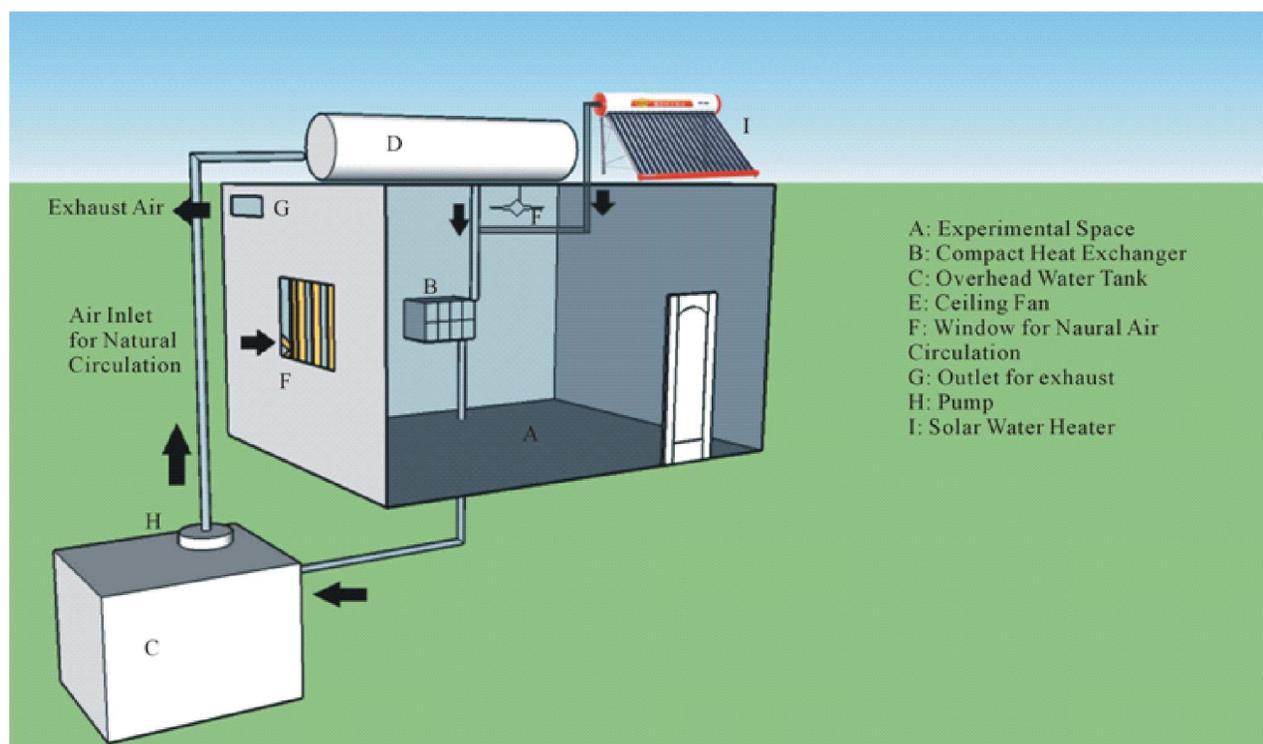


Fig. 5: Schematic diagram showing the concept used in the study. Here underground cooled water is pumped to the overhead tank (Sneha Shahare and Harinarayana, 2016)

commercial segment. For example, in conventional power segment, drying of lignite through flue gas exhaust or by use of solar thermal concentrators is very important applied work and the group has established feasibility of the same for one of the lignite based power plant in Gujarat.

GERMI Innovations in Renewable Energy Research

Activities

These activities of innovation are being undertaken with support from experts from industries and academia and also providing opportunity to develop scientific acumen in the young graduates / undergraduates through summer internship program (SIP) of GERMI.

Demonstration of New Technologies

The group executes couple of demonstration projects in the field of solar thermal energy, wave energy, geothermal energy etc which are at different stages of development. Noteworthy amongst these are geothermal technology, wave energy technology, innovative coating of solar PV modules and automatic cleaning of solar PV plant through robots, magnetic fly-wheel development for dispatching reliable supply of wind energy etc.

Creating Knowledge Centres across the Country

The group has started first O&M training program in the country. It has also offered wind energy workshop. It has played a major role in framing and execution of elective course in Renewable Energy for NTPC School of Business (NSB) at New Delhi. The group is also engaged in creating knowledge centers at different institutes in India to create skilled man-power to address the need of industry, research and development, policy makers etc.

Solar App

A Solar APP is developed and made it available to all freely to the smart phone users. The link is available using Google Play. It provides digital values of solar energy in any location using google map. This application is based on ten years of data collected from satellite through NASA. Right now, the application calculates the amount of solar generation

for an acre of land.

This application also features email links so that the developer can receive feedback for future improvements. Besides solar power generation, GERMI is also conducting research on other renewable energy sources.

Sponsored Projects

- (a) Solar PV Module Degradation Study & Performance Evaluation of GTPS 1 MW Multi-Technology SPV Plant & 1 MW Canal Top SPV Project at Sanand

Scope of Project is to test solar PV modules to identify degradation in the solar PV modules from Canal Top SPV and different solar PV module technologies under operation at GTPS 1 MW power plant and to study and analyze performance of both these power plants.

- (b) Demonstration of Solar Powered Smart Village at Shapar, Junagadh, Gujarat. Scope of Project is to install 500 kW solar PV plant with demand/supply control to cater to village electricity supply. The project is successfully completed and is now under operation at village Shapar, District: Junagadh, Gujarat for more than one year now. The project has lot of replication potential as urban micro-grids/smart grids.

- (c) Enhancement of Livelihood Opportunities through Solar Applications for 161 Villages under Integrated Coastal Zone Management Program in Gujarat

Scope of Project is to study village requirement and suggest appropriate solar/other renewable energy applications/solutions with focus on enhancement of livelihood activities in 161 villages in Gujarat. Various tasks in the project are bid process execution support, supervision and quality control, training and creation of sustainable model for long term operation of the installed systems.

- (d) Demonstration of 150 TR solar thermal AC

The Scope of Project is to select and identify most suitable solar thermal technology, to select and identify most suitable VAM technology, to install 150 TR AC operating through dual fuel

mode i.e. solar thermal and grid, to assess performance of the system and to provide replicable business/execution model for future replication of the project under smart city initiatives. Achievement/Merits of the Project is successful demonstration of the project shall result into replicable projects, shall establish reliability of the technology and shall give a big boost to replace fossil electricity for space heating/cooling applications.

(e) Feasibility Study of Drying of Lignite through Flue Gas Exhaust/Solar Thermal Energy

The Scope of Project is to study technical feasibility of concept of drying of lignite and to suggest different sources like energy from flue gas exhaust or from solar thermal energy for drying of lignite. Achievement/Merits of the Project are that drying of lignite can enhance plant efficiency. Apart from drying, our study revealed several other possibilities like desalination of water, electricity generation from flue gas heat recovery, cleaning of flue gas etc.

(f) Development of Hydrophobic Coating for Solar PV Modules (Incubation Activity)

Scope of Project is to test the hydrophobic coating under STC and under field condition and to assess the claims (expected benefits) of the technology. Achievement /Merits of the Project is that Government of Gujarat has initiated solar PV plant on Ash – dykes, the plant suffers heavy loss in electrical output due to ash powder getting deposited on the module surface. Successful demonstration of the technology helps in reducing soiling losses and offer ease of cleaning to the operator with savings of water for cleaning.

(g) Development of Automatic Cleaning Robot for Solar PV Modules (Incubation Activity)

Scope of Project is to test the automatic cleaning robot and evaluate the technology in terms of cost – benefit analysis under field condition and to assess the claims (expected benefits) of the technology

Achievement/Merits of the Project are as follows. With advancement of solar parks and very large scale solar PV plants, cleaning is

becoming a headache. Automatic cleaning may offer very fast cleaning system and hence, number of cleaning cycles can be increased/ operation time may be reduced which may result into saving of energy. Savings in water consumption for cleaning of modules are expected to be 1/4th only.

(h) Solar Powered Drinking Water at Village Pavda, Gujarat (Incubation activity)

Scope of Project is to select solar powered drinking water system for village, to supervise quality of the plant, to assess performance of the plant and to prepare appropriate village business models for future replication of the technology. Achievement /Merits of the Project is that Government of Gujarat has initiated roof – top solar for villagers. The development is required in order to satisfy the need for power and water for the villagers.

(i) Development of Innovative Solar Structures for Canal Top Plant

Scope of Project is to design structures which are cost effective and suitable for canal top plants, to fabricate and tests the structures in the field and evaluated its performance. Achievement/Merits of the Project is that Government of Gujarat has initiated canal roof – top solar PV project with an intention to save on land cost by utilizing space above canal. It is found that biggest bottleneck shall be cost of solar structures. The new types of structures, which are different in design, can offer cheaper structures for canal top solar PV plant.

Environment and Energy Efficiency Research Wing

The Environment and Energy Efficiency Research Wing (E & EERW) of GERMI conducts fundamental and applied research on issues of national and international importance related to science, technology and management pertaining to environmental pollution, energy efficiency, bio-energy and optimization of conversions of waste-to-energy. This research wing primarily focuses on research and services to solve the practical problems faced by the industries and enables the integration of innovative need-based technologies and other holistic interventions.

This research wing is also working on environmental pollution and energy efficiency, renewable energy and optimization of conversion of waste to energy. The nature of this wing's research will be in response to emerging environmental challenges faced by Gujarat and the country at large, aligned with India's priorities, commitments and stand with respect to multilateral environmental agreements. The research wing has established the environmental software lab with 13 softwares for authentic prediction of environmental impacts.

Objectives and Targets

- The basic objective is to serve as a Center of Excellence in research and development of Environmental Technologies.
- To offer short & long term academic programs to develop skilled work force.
- To provide expert consultancy services related to Environmental Pollution control.
- The Research Wing aims to generate insights that lead to integrated benefits for multiple stakeholder groups, including industry, policy and decision makers in the government, bi-and-multilateral institutions and communities.
- The Research Wing recognizes the fact that environmental impacts are cross-cutting and can emerge from the extraction of energy from various sources, and use in industrial, domestic and other applications.
- The research wing will focus on dissemination of information on Energy Efficiency practices, devices and technologies as it believes that "Energy saved is energy produced".

Areas of Research and Services

Fundamental and applied research related to environmental technologies for water and waste water treatment, air pollution, municipal and hazardous solid waste management and reuse - recycling of water. Other research areas are - conversion of waste to energy, monitoring, control and mapping of gaseous emissions-ambient and source, contaminated site remediation and preventive practices for petroleum sectors, mitigation and adaptation measures in areas impacted due to climate change related to petroleum sectors.

Additionally, scientific and technological aspects of energy efficiency in homes, buildings and manufacturing including energy audit and carbon credits. It is a resource center providing comprehensive information to Industries on energy efficient practices, devices and techniques to conceptualize the policy interventions for effective environmental management at state and central government level. The group also conducting short and middle term online/training programs leading to certificate or diploma.

The group offers various services to the industry in environmental audit and energy efficiency audit. Different audit parameters that can be handled by the institute are-

A. Environmental Audit

- a) Schedule I Environmental Auditor – Recognized by GPCB
- b) GERMI can audit 15 industries – 4 industries for the year 2014
- c) GPCB will provide 15 – 20 industries to be audited for the year 2015
- d) Other certification like Adequacy of EMS and possible research projects from GPCB

B. Energy Efficiency Audit

Recognized by GEDA as energy auditor that provides walk through audit. Additionally, the group is conducting awareness program for final year electrical engineering students, conducting awareness programs for industries through industrial association and completed walk through audit for 4 industries.

The group has so far completed the following Projects. - Determination of hydraulic carrying capacity and Quality modeling of creek passing through Surat – Surat Municipal Corporation and SO₂ - H₂S control system for Rubber reclamation by Resilin Ruber Tech Ltd – Surat and adequacy of Pandesara CETP, Pandesara. Additionally, the following projects are on-going.

- a) Environmental Impact Assessment for the Development of Ranmal Lake for Jamnagar city – Jamnagar Municipal Corporation,

- b) Gopal Glass: Determination of Sulfur balance for using Petcoke as fuel
- c) Design verification for Coal based Gasifiers located at Morbi as per the guidelines of Hon'ble High Court of Gujarat – 65 Industrial Units
- d) Waste – to – Energy: MSW to Power generation through Gasification – Innovative Eco Care Pvt. Ltd., Ahmedabad

The group has established the Environmental Software Laboratory. This is one of its kind. Based on the various softwares, Consultancy services to the field consultants and the authorities, development of the new software based on Indian conditions, modifications and/ or extensions of the software for impact predictions, hands on training of the Environmental Software for Capacity Building, developing the R & D projects for funding by pollution control authorities, ministry of environment forest and climate change, DST and other Government Organizations have been taken up. The various software available for use are -AERMOD, ALOHA, CUSTIC, CAMEO, DESCAR, V Leach, Limits curve, Qual 2E, High way pollution, WR Plot, Hydraulics, Mobile 6, Noise pollution and HSSM.

Fundamental Research topics by the group are waste to energy based on conversion of organics to fuels: In this topic three types are being studied.

- 1) Biogas Route: Development of pH based Biphasic Anarobic Migrating Blanket Reactor for Biogas generation
- 2) MSW to Energy: Gasification Route
- 3) Biogas or Syngas to Dimethyl Ether (DME) – a diesel substitute

In addition to above, developing 'Graphene' as adsorbent for Wastewater treatment and chloride corrections for determination of COD have also taken up.

In applied research, design for SO₂ control systems for rubber reclaim industries has been taken up. As the concept is new a patent is expected on this topic.

ACADEMICS

In order to promote, the academic sector with young human resource, E-courses have been initiated by the group. They are- design of wastewater treatment units with III modules.

- Module I: Design of Wastewater Treatment Units- Physical & Chemical
- Module II: Design of Wastewater Treatment Units – Biological
- Module III: Design of Wastewater Treatment Units - Advanced

Additionally, a project on development of OHS Manual for GSPC group companies has been taken up.

The group has received various recognitions. They are :

- Schedule I Environmental Auditor – Gujarat Pollution Control Board
- Energy Audit Consultant – GEDA. In this regard, it is pertinent to say that GERMI is one of the Seven Institutes identified by GPCB & Hon'ble High Court of Gujarat for Morbi Project

In order to increase R&D activities, various MoUs have been signed. They are :

- MoU with Wisdom Edutech Internation (WEI) with focus on Marketing of E–Courses
- MoU with SEED with focus on Waste-to-Energy: Plasma Gasification
- MoU with Gujarat Pollution Control Board as a Knowledge partner
- MoU with Microvision Enviro Projects Pvt. Ltd. as a Technology Partner

Training and Development Centre

The Training & Development Centre was envisioned in a backdrop of a substantial gap between the demand and supply for targeted and effective training courses in the emerging energy sector. Hence, a strong case for a world-class training centre in terms of knowledge base, training structure and infrastructure facilities was realized. Programmes at the Centre are structured to reflect the most relevant needs of the industry. Each programme seeks to focus on new developments and latest trends in technical and managerial practices in specific areas.

The Objectives of the industrial training programme are :

Impart value-added skills in professionals to assess qualitative and quantitative parameters, articulate, position and help integrate relevant interventions for improved decision-making through appropriate tools, technologies, policies, plans, programmes and projects, ensure compliance with performance standards and benchmarks for continual improvements, forecast and adopt optimization pathways. More than 1100 people are trained by GERMI. A total of 32 training programs in Solar Photovoltaic, Oil and Gas and Energy and Environment (21 nos. of Solar courses, 8 nos. of Oil & Gas courses and 3 nos. of Energy and Environment courses are conducted).

Some of the principal areas are:

- Total energy value chain including process up gradation,
- SWOT of locally adapted energy systems,
- Indicators, remediation and preventive management.

These are aligned with the essentials of energy production, extraction and use including impacts management at the local, national, regional and global levels. These are aimed at comprehensive human and institution development to sustain progress.

The Training and Development Centre takes up the following training module framework in order to ensure a comprehensive learning forum.

- Public/Open Courses
- Customized In-house Training Courses
- Integrated Certified Programmes
- Accredited Certified Programmes

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- Statutory Training Programmes
- International Programmes on Energy Management and Education

Infrastructure and Training Resources

- State-of-the-art training facilities with technical equipments and simulators for technical and operational courses.
- Updated library with access to books on technology and online journals.
- Fully equipped computer centres with PC's, laptops and internet facilities.
- Air conditioned rooms and auditoriums with seating capacity of 150 participants.
- State-of-the-art audio-visual and teleconferencing equipment.

The centre boasts of a highly qualified and experienced training faculty who has domain expertise in the areas of their respective training modules. As a matter of policy, the centre is responsible to develop faculty from experts available within the country.

Training methods include lectures, cases, seminars, group discussions, business games, role plays, simulations, exercises, hands-on experiments, structured and unstructured group work with field visits, and tests.

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