Government of India
Ministry of New and Renewable Energy
(R&D Coord. Group)

"Thrust Areas with Action Plan for RD&D"
For Technology Development
In
New and Renewable Energy

APRIL, 2016

Ministry of New and Renewable Energy
(R&D Coord. Group)

Record of discussion held in "Brainstorming Consultations Meeting on RD&D" on 5th January 2016 in MNRE Conference Hall for review of RD&D Programme and for identifying "Thrust Areas with Action Plan for RD&D in New and Renewable Energy" for support by MNRE.

A "Brainstorming Consultations Meeting" was held on 5th January 2016 in the Conference Hall of MNRE for reviewing of RD&D projects funded by the Ministry of New and Renewable Energy(MNRE) and for identifying "Thrust Areas with Action Plan for RD&D" for support by the MNRE. The meeting was chaired by Sh. Upendra Tripathy, Secretary, MNRE and was attended by invited experts from the field of new and renewable energy, apart from Group/Divisional Heads handling RD&D programmes in the Ministry. The compendium on the status of R&D projects funded by MNRE was distributed to participating experts for their perusal. List of participants is enclosed at Annexure.A copy of the programme is also annexed.

2. Ms. Varsha Joshi, Joint Secretary, MNRE welcomed experts and mentioned that the "Brainstorming Consultations Meeting on RD&D" was needed to discuss the on-going R&D efforts and to bring out action plan with thrust areas for RD&D in new and renewable energy. Shri UpendraTripathy, Secretary, MNRE in his introductory remarks stressed that R&D in new and renewable energy has tremendous potential for technology development and demonstration for large scale deployment for various applications across the country. He also narrated the Indian initiative on launching of the International Solar Alliance (ISA) on 30th November 2015 on the side lines of CoP 21 in Paris. In this context, he mentioned that though the focus on solar has risen during the last two years, efforts should be directed towards development of the entire new and renewable energy sector. Secretary, MNRE strongly emphasised that the focus of R&D should be application oriented. In this regard, he stressed that industries should be involved in the process of R&D. He also mentioned that the MNRE has plans to allocate Rs.100 crore for R&D for 2016-17 and funds will be properly distributed for different areas in new and renewable energy. Dr. B. S. Negi, Director(R&D Coord.), MNRE gave a brief background of the meeting highlighting that around 169 nos. of R&D projects in solar thermal, solar PV, biogas, bio-fuel, hydrogen and fuel cells were sanctioned by MNRE in the 11th Plan Period with total budget of Rs.525 crore, 60% of which was sanctioned for solar projects. He further mentioned that around Rs.419 crore were spent by MNRE on RD&D during the current 12th Plan Period till December 2015. He highlighted the need of focussed R&D and requested experts to bring out clear suggestions for thrust areas for RD&D on the basis of achievements made under RD&D projects funded by MNRE and the global on-going efforts in the direction.

3. The introductory session was followed by presentations by invited experts as per the programme of the meeting. At the end of each presentation, a detailed discussion was held and thrust areas for RD&D were identified. The details of the discussions held and the outcome of the meeting are briefly described as follows;

I. Renewable Energy Resource Assessment

4. A presentation on solar and wind resource assessment being done by NIWE, Chennai was made by Dr. Rajesh Katyal, DDG, NIWE. He showed that the satellite data procured from ISRO is being validated against the ground measured data at NIWE. Dr.Bimal Bhattacharya, Scientist, Space Application Centre(SAC), ISRO made a presentation on satellite based tools for solar and wind resource assessment and validation of satellite data against ground measured data. He also showed that how the satellite data could be used for identification of sites for roof top solar power projects. It was discussed that solar, wind, biomass small hydro resources assessment should be supported vigorously as the same is required for selection of sites for installation renewable energy systems. Dr. B. S. Negi mentioned that under an on-going collaboration activity between SAC and NIWE, SAC is providing training to NIWE for validation of satellite based data against the ground measured data and then comparing the Indian satellite data with that obtained from other source including from NREL, USA.

II. Biogas

5. Dr. S Kale, BARC, Mumbai gave a brief overview of the biogas development and mentioned that the biogas has linkage with both rural and urban development. The wastes which pose grave environmental threat has tremendous potential for methane generation, which could be utilized effectively for cooking, power generation and transport applications. This requires a proper waste management system. He cited examples of such projects installed in Chennai and Coimbatore. He also highlighted the development of Nisarguna biogas plant developed by him and mentioned that the biogas plant has received considerable market across the country. He mentioned that Nisarguna biogas plant needs further development including slurry separation system. Prof. V K Vijay of IIT Delhi, in his presentation, showed that biogas needs to be given more attention as it has tremendous potential for addressing the energy needs both in rural and urban areas. He suggested that there is a strong need for technology development and demonstration for biogas generation as a fuel for cooking, power generation and transport applications. He also showed the laboratory and field results for utilizing biogas as fuel for transport applications. Dr. Sangita Kasture, Joint Director, DoBT mentioned that R&D efforts in the development of biogas technology should focus on reduction in holding time. She also mentioned that validation and cost economics may also be done for proper development of the biogas technology. Prof. H Chankya, IISc, Bangalore mentioned that biogas plants need to be developed and promoted for biogas generation from different feedstock that are available keeping in view the efficiency and cost effectiveness. He mentioned that kitchen waste based biogas plants have tremendous potential. A detailed discussion was held on the R&D needs for technology development and demonstration and standardization of various components for effective and efficient utilization of biogas for various applications. In the case of power generation, it was discussed that efficient engines should be developed.

III. Biofuels

6. Dr. D K Tuli, Head, DBT-IOC Centre for Advanced Bioenergy Research, Indian Oil R&D Centre, Faridabad made a detailed presentation on "Developments in Biofuels" covering the international and national efforts being made for technology development in the area of bio-fuels for getting alternate fuels. He showed that though specifications for 10% blend of ethanol in gasoline had been issued but the actual blend achieved last year was only around 2%. He also showed that bio-diesel in the diesel currently being used is almost insignificant, therefore how 20 % blending in transport fuels as per the policy would be achieved by 2017 had to be given adequate thought. He also emphasised that non-availability of feedstock is a major hurdle in the biofuel development. He mentioned that multi-technology approach and multi feed technologies need to be supported for biofuel development. He stressed the need of focussed R&D and also proper monitoring of projects. On the status of R&D projects funded by MNRE, he mentioned that achievements reported under R&D projects should undergo cross validation of the claims made under projects. He suggested that MNRE should develop a mechanism for review and for taking steps such that technology developed under R&D projects could be taken further for commercialization. Dr. Sangita Kasture, Joint Director, DoBT mentioned that DBT has already supported many R&D projects on Cellulosic ethanol and many leads are available hence instead of R&D projects, demonstration projects could be considered for support by MNRE. She also mentioned that gas fermentation is one of the important areas and the process involves biotechnological interventions and bio reactor design, development hence related R&D projects are being supported by DBT. She suggested that once the technology is ready at lab scale, MNRE may consider for demonstration/pilot projects. Dr. Arvind Lalli, Head, DBT-ICT Centre for Energy Bio-sciences, Institute of Chemical Engineering, Mumbai, who could not come to attend the meeting, through email informed that algal oil grown with marine water has considerable potential for producing renewable biofuels. He suggested that only projects which target cost reduction and large scale use should be funded.

IV. Biomass Gasification & Biomass Cookstove

7. Prof. S. Dasappa, IISc, Bangalore made a detailed presentation on biomass gasification, and showed that multi-fuel gasification technology developed by IISc, Banglore, has considerable potential for MW scale grid connected power generation. He mentioned that draft standard and specifications for biomass gasifier was prepared under a project funded by MNRE. He showed that gasification technology needs to be given more attention for both power generation and hydrogen production. Prof. Upadhayay mentioned that for hydrogen generation, emphasis on gas purification and separation is essential and suggested that MNRE should keep this aspect into consideration while considering proposals on hydrogen production. In the case of biomass cookstoves, it was considered that the testing process should be rigorous to ensure the quality of cookstoves in terms of efficiency and emission reduction.

V. Solar Photovoltaics

8. Dr.Vikram Kumar, former Director, NPL, and currently Emeritus Professor, CARE, IIT Delhi made a detailed presentation on SPV development covering the status of technology development and deployment at both global and national levels. In his presentation, he showed that crystalline silicon based solar cells has about 90 % global market and the remaining 10% is of thin films solar cells. Prof. Kumar also showed that single junction solar cells have achieved efficiency of 25% at lab scale, and 20% at the commercial scale at international level. He mentioned that at the module level the efficiencies are 2 to 3% lower than the individual solar cell efficiency. In the context of India, he mentioned that though JNNSM has given thrust on solar cells research in India, there is a strong need to fund R&D in the area in association with industry. He cited the contributions made by research groups working in NPL, IIT Bombay, IACS, Kolkatta, BESU, Kolkatta and BHELon the development and fabrication of 15-18% efficiency solar cells. Prof. Vikram Kumar emphasised that in the foreseeable future silicon will remain dominant technology and therefore MNRE should support the existing research centres to improve the Si-PV efficiency and also ways of reducing the material and processing costs. He also suggested that R&D in development of thin films solar cells,DSSC, Perovskites Hybrid solar cells should also to be supported for long term solutions. He highlighted that module efficiency and reliability and development of inverts are the key areas requiring technology development.

9. Prof. A K Barua, BESU, Kolkata, while appreciating MNRE's decision for scaling up solar power to 100GW mentioned that RD&D on all aspects of SPV technology should be supported in association with industry with focus on the development of indigenous capacity for material development, components and production technology. In this context, he mentioned that consortium needs to be formed for development of different technologies. Prof. Barua strongly suggested that the target of efficiency for silicon solar cells should be 25% by 2022. Prof. Vasi of IIT Bombay while sharing the experience of NCPRE project funded by MNRE at IIT Bombay mentioned that 18 % efficiency had been achieved and the goal is to achieve 22% efficiency by 2022. He mentioned that though silicon is abundantly available the production cost of cell is very high. He mentioned that R&D efforts on development of new materials such as Pervoskites solar cells should also be supported for long terms solutions. Dr. A K saxena, AGM, BHEL mentioned that making Si material from sand, indigenously is one of the most important thrust areas. He also suggested that test labs should have facilities for testing input material such as Si wafers, EVA, Tedlar, pastes, etc. to help industries for manufacturing these components. Dr. P. K. Singh, Chief Scientist, NPL mentioned that measurements at solar cell level needs to be given adequate attention as an uncertainty in device efficiency may lead to ambiguity in the product value assessment both in technical and financial terms. He suggested that a national standard for calibration of photovoltaic devices has immense requirement. Dr. B. Bhargava, DG, ONGC R&D Centre mentioned that R&D should also be focussed on development of materials for module package and production indigenously to reduce the space needs. A detailed discussion was held and thrust areas for RD&D in SPV.

VI. Solar Thermal

10. Prof. S. Srinivasa Murthy, IISc., Bangalore made a detailed presentation on solar thermal technology covering the developments in the area at both national and global levels. In his presentation, he showed the R&D efforts being made in the area of solar thermal power generation, solar heat for industrial processes, cooling and dehumidification applications, solar water heating, solar cooking, desalination, hybridization and polygeneration, and establishment of performance standards and testing. In the area of concentrated solar power technologies, he showed that though all the three types of technologies, namely, parabolic trough, central tower receivers and parabolic dish are proven technologies, they need to be optimized with reflector materials suitable for Indian conditions and to be integrated with reliable storage systems. Prof. Murthy suggested that light weight reflectors supported by optimized supporting structure are needed for utilising these technologies in cost effecting manner. He also mentioned that hybridization and polygeneration offer attractive options for solar thermal power generation technologies. He mentioned that development and deployment of evacuated tube collectors, compounded parabolic collectors (CPC) and efficient low cost flat plate collectors need to be promoted for domestic/commercial hot water and industrial process heat applications. Prof. Murthy suggested that the technology development coupled with standardization of all solar thermal technologies is critically required for expanding the market for various applications in the country. He also showed that for large-scale power generation applications utilising solar concentrating technologies, R&D should be supported utilizing high temperature power cycle such as Brayton cycle. The presentation of Prof. Murthy followed a detailed discussion on the progress of the R&D Projects funded by MNRE. It was noted that projects funded by MNRE in solar thermal power generation particularly utilizing parabolic trough and central tower technology have not provided the performance evaluation data. It was discussed that research and development in Solar Thermal Power Generation need to be supported with development of hybrid mode with other RE sources, and also in retrofit mode with conventional power plants to achieve improved energy efficiencies and lower carbon footprints.

VII Power Control Systems and Energy Storage

11. Prof. S.C. Srivastava, IIT, Kanpur made a presentation on 'Grid Integration of renewable sources: control and operation issues'. He highlighted the issues concerning technical challenges due to intermittent generation of power dependent on season, weather and other parameters relating to power balancing, voltage and frequency control, integration to power management. For wind integration, he highlighted the importance of integration to power management with wind speed prediction as accurate forecasting tool. Prof. Srivastava mentioned that power control systems and integration to power management is critically required in wind and solar power projects. He suggested that development of micro-grid for integration of various renewable energy sources with storage offers considerable potential for renewable energy utilisation. This will require proper designing of micro-grid and power balancing. Sh. S.K. Sangal, former, Executive Director, CEL ,

currently Sr. Consultant NISE, suggested that higher weighted average efficiency (i.e. at peak and partial loads) inverters need to be developed for low capacity solar power plants for off-grid applications as well as solar roof top programme. He also suggested that high efficiency inverters (with MPPT) should be developed for Solar Pump application.

12. Prof. Sampat of IISc, Bangalore made a presentation on energy storage R&D. In his presentation, he covered the various types of battery developed till date and the work carried out by their group at IISc, Bangalore. He suggested the need for research and development in the areas of batteries and super capacitors, metal air systems and organic systems. Dr. V V Giridhar, Sr Principal Scientist, CECRI(CSIR), Chennai shared the development efforts at CECRI on the automation of Li-ion battery fabrication through the TAPSUN program and on the development of both 18650 cells and pouch cells. Dr. Giridhar mentioned that CECRI has done considerable work in many areas of different types of battery system over the past several years. However, the present focus is on Pb-acid batteries, alkaline batteries (Ni-Fe, Fe-air, Ni-Metal hydride), Li- based batteries (Li-ion, Li-air, Li-S), redox flow batteries (Zn/Bromine, soluble Pb) and electrochemical capacitors (electrical double layer and pseudo capacitors, Pb-C battery-super capacitor hybrid). He also shared experience on demonstrated a 250 kW Zn/Br2 redox flow battery system in collaboration with IITM at their venue last year and demonstration on the fabrication of 18650 cells and pouch cells of 650 mAh capacity in the newly constructed Li-ion battery fabrication facility at its Madras Unit, Chennai. He suggested that MNRE should support projects on battery research and super capacitors as they are required to carry out the solar/any other renewable energy storage through batteries. A detailed discussion was held and it was considered that R&D in energy storage systems should be taken up for demonstration.

VII Hydrogen and Fuel Cells

13. Prof. S. N Upadhaya, BHU presented an "Over view of hydrogen production technologies and applications". He showed that globally almost 90% hydrogen is produced through steam reforming of natural gas or light oil fraction with steam at high temperature. In USA, around 95 % of hydrogen is produced through steam reforming, which is associated with greenhouse gas emission and local pollution. He showed the various routes and technologies being pursued both nationally and globally for hydrogen production, and also presented cost and energy efficiency data for a few selected hydrogen producing technologies. CH4-Steam reforming was shown to be the most cost competitive and energy efficient process, whereas water electrolysis and biomass gasification route as the most expensive and less efficient technologies. Prof. Upadhyay suggested that focussed R&D projects need to be supported for hydrogen production through biomass gasification, bio-hydrogen, thermo-chemical splitting and thermolysis of water. He also suggested that R&D should be pursued in partnership with industries in material development, reactors/fuel cells, and hydrogen storage vessels. He suggested that Centres of Excellence may be set up with focused R&D for long terms goals. In storage, he suggested the indigenous technology for storage of hydrogen needs to be

encouraged on priority basis. This will promote the use of hydrogen available from chlor-alkali industries as surplus (estimated to be around 6600 tons annually) as well as from fertilizer units and refineries. He suggested that in view of the falling prices of petroleum products at the global level, the MNRE may think of approaching fertilizer (urea) making units and refineries to produce more hydrogen than their needs and divert the surplus for immediate use in the hydrogen driven vehicles and stationary hydrogen based stand-alone power units to meet the projected growth in the demand of hydrogen for energetic uses. For making this a success, the hydrogen storage and transportation require immediate attention. Prof. O N Srivasatav, BHU mentioned that technology and material for storage at -20^{o}C had been developed by BHU and further R&D is needed to scale up storage at commercial level. A detailed discussion was held on R&D needs in the area of hydrogen energy for transport and stationary power applications.

14. Dr. H S Maiti, former Director, CSIR-CGCRI, Kolkota made a detailed presentation on "Fuel cell technology developments". He showed how the fuel cell development has taken place in India giving examples of use of fuel cells, and suggested proper monitoring for development of efficient and cost effective fuel cells for stationary applications. In this context, he suggested that MNRE should support focused R&D for technology development and demonstration in collaboration with industry with rigorous monitoring. He also suggested that a consortium approach need to be adopted for fuel cell technology development for large scale use of fuel cells. The presentation was followed by a detailed discussion. Prof. Upadhayay, BHU mentioned that it would be appropriate to link R&D efforts in the fuel cell area with that in the area of electrolyser development, as several component and material needs are similar. Dr. Giridhar, Senior Principal Scientist, CECRI(CSIR), Chennai also shared R&D experience in fuel cell at CECRI. He mentioned that CECRI has demonstrated 1 kW LTPEMFC stack for 4G applications of RIL, Mumbai and is in the process of upgrading the same to 3 kW system. Earlier, the institute demonstrated a 5kW HT-PEMFC stack for vehicular applications at CECRI, Madras Unit, Chennai.

III Wind

15. Dr.Katyal, DDG, NIWE made a detailed presentation on the wind power development in India. He showed that though the wind machines and related components are being developed by leading international wind industries, there is a strong need of indigenous design and development of MW scale wind turbines and related components. Indigenous manufacture will bring down the cost drastically. He suggested that RD&D projects in wind hybrid systems need to be supported for improved energy supply. He highlighted that proper power control systems also need to be developed for improved power supply from wind machines.

IX Small Hydro Power

16. Dr.Arun Kumar, AHEC, IIT Roorkee, made a presentation on small hydro power(SHP) projects development in India and showed that technology

development is needed to produce the power at competitive price. He showed that at present the cost of SHP is Rs.9crore/MW. He mentioned that development of design tools/techniques for recourse assessment and performance prediction and also performance evaluation are needed for proper designing and development of SHP systems. It was discussed that standardization is needed for effective development of SHP.

X. Geothermal

17. Dr. T. Harinarayana, Director, GERMI, Ahmadabad, made a brief presentation on the geothermal potential. He showed that there are 4 locations of high field geothermal areas and more than 100 locations of medium field geothermal fields. He mentioned that technology is available to generate power with a temperature as low as 70-80^0 C of hot fluids and 20-25^{0}C of cold fluid. He showed that there is scope for using geothermal energy for space heating and power generation. He was requested to prepare a technology demonstration project proposal for consideration by MNRE.

Concluding Session

18. In the concluding session, chaired by the Secretary, MNRE a detailed discussion was held on the progress of R&D projects and need for further RD&D in new and renewable energy. Experts suggested that the projects should be periodically monitored by MNRE so that proper and timely action is taken for implementation. They also suggested that the achievements under R&D projects should be validated by standard institutions having testing and evaluation expertise and facilities. The thrust areas identified in the meeting were discussed for technology development and demonstration for large scale use of new and renewable energy for various applications across the country. It was considered that RD&D in the thrust areas may be vigorously pursued with proper monitoring and adequate funds may be earmarked for the same. Secretary, MNRE requested all experts to provide further inputs/suggestions for consolidating thrust areas for RD&D, which will be considered by MNRE. Accordingly, on the basis of discussions held and further inputs received from experts, who participated in the brainstorming consultations meeting and also who were invited but could not attend the meeting, the following thrust areas for RD&D with Action Plan in various areas of new and renewable energy were identified;

Solar Thermal

- Development and optimization of low cost reflectors, efficient and cost effective receiver systems and coatings for Solar Thermal Power Generation Technologies
- High efficiency novel storage- technologies to cover wide temperature and capacity ranges, materials, systems and integration with CSP technologies.
- High efficiency CO_2 Brayton cycles (100kW-1MW)
  Super critical CO_2 Brayton cycle: > 50% cycle efficiency even at 500^{o}C receiver temperature.

- Hybridization of solar thermal power technologies with other RE sources for (non-grid) power generation
- Development of solar thermal technologies/systems including evacuated tube/CPC collectors for cooking, water heating, cooling, drying, desalination and industrial processes
- Hybridization and polygeneration

Action Plan/Strategy

- Establishment of performance standards and testing
- Centres of excellence/Consortium based approach in specific areas mentioned above in specific areas
- HYBRIDIZATION and RETRO-FITTING with Coal Based Thermal Power Plants. This can improve the efficiency, increase the capacity and reduce the CO2 emissions.

Solar Photovoltaics

- Improving Si PV efficiency and reducing the material and processing cost.
- Making Si material from sand
- Strengthening Research Groups for research in new areas such as PERC cells, dark silicon cells, Si nano-wire cells, passivated interface cells, micromorph cells etc.
- Second generation (thin film) for improving their efficiency and stability.
- Third generation cells including organic semiconductor PV, DSSC, perovskite based cells as long term solution to the energy scenario.
- Improving modules quality and reliability in cost effective manner.
- Development of standard designs for supporting structures to mount SPV systems for application on different widths and types of canals and reservoirs/lakes.
- Assessment of water saving in reduced evaporation and performance enhancement of SPV systems installed over water bodies.
- Materials and fabrication Technology for solar cells and modules
- Production Technology for solar cells and modules.
- Balance of Systems to draw power from PV array
- Inverters and converters and storage systems
- Power Conditioning Units(PCU) with high weighted average efficiency inverters(with MPPT) and Charge Controllers for off-grid solar power plants. Power Conditioning Units(PCU) with high weighted average efficiency inverters(with MPPT) for low capacity solar power plants for grid connected(Grid Exporter) configuration
- High Efficiency BLDC Motors (with MPPT) for solar pump configurations. High Efficiency inverters (with MPPT) for solar pump applications
- Development of Materials and Fabrication Technologies for solar cells and Modules
- Measurement facilities for calibration solar cell efficiency

Action Plan/ Strategy

- Technology demonstration should be scaled up for applications in various sectors like Telecom. Railways, Defense, Space, etc.
- In all RD&D efforts, industry which are at present producing modules from cells and wafers to be associated.
- The target of efficiency for silicon solar cells should be 25% by 2022
- The R & D/academic organizations working in the area of crystalline silicon solar cell should be directly linked to the Indian Industries, which are at present producing modules from cells and wafers. In addition, the Indian Installers of PV Systems with c-Si modules should be part of this consortium. The association with academic and R and D organizations will help the Industries in upgrading their product and help in solving technical problems,
- Setting up test labs for testing input material such as Si wafers, EVA, Tedlar, pastes etc. to help industries.

Biogas

- Development, demonstration and evaluation of existing and new designs of biogas plants for biogas generation utilizing different feedstock for cooking, power generation and transport applications.
- Development of efficient and cost effective slurry handling system
- Standardization of multiple designs of biogas plants – all sizes, all feedstock based. Performance testing utilizing standardized gas flow meters for measurement of biogas generated.
- Technology development for reduction in HRT
- Performance validation and cost economics before approval.
- New enzymes/ consortium of bacterial development of fast biomethnation processes
- Development in new materials of biogas plants for cost reduction.
- Standardization biogas slurry based bio-fertilizer, value addition and marketing network development.
- Bio-manure upgradation (incorporation of micronutrients into the slurry for land application).
- Development and standardization of scrubbers for biogas purification and gas flow meters.
- Development of efficient 100% biogas engine for power generation.

Action Plan/Strategy

- Development of centralized biogas generation plants with distribution through piping.
- Development of business model for biogas fertilizer plants should be taken up. Strategy should be developed for large scale biogas plants, i.e., sewage treatment plants, sugar industry effluent, goushalas etc.
- Mechanism and regulation should be developed to segregate the municipal

- solids wastes and Polluter–Pays principle should be made mandatory to stop the burning of crop and industry derived biomass source.
- City dairies are to be mandated to treat their waste and produce biogas.
- Technology development and demonstration and standardization of Bio CNG.Bio Gas scale up projects. Only those projects which have reduced HRT ~ 1-2 days and which can give BIO-CNG at ~ 25 Rs/Kg must be scaled up
- Command area for biomass waste collection and utilization in urban and rural areas needs to be promoted.
- Promoting Bio–CNG marketing mechanism with standardization and control systems.

Biofuel

- Cellulosic ethanol pilot demonstration plants in range of 2-10 Tons per day
- Enzyme scale up projects at 250-500 lits (4 Crores). Presently there are no scale up facilities in country for enzymes which are required in cellulosic ethanol technology.
- Biomass availability studies- real time. This study is essential as many technologies are being planned based on agricultural wastes.
- MSW / Waste to bio-energy projects demo scale . After verification of claims of the developed technologies, these projects need funding.
- Waste gas fermentation for ethanol/ bio diesel. Gas fermentation is new area which is presently not pursued in country however waste industrial gases can be converted to ethanol/ bio diesel and China has set up few plants in steel industry.
- Agro waste to distillates by catalytic hyro-pyrolysis
- Semi-Commercial plants on Pyrolysis/gasification
- LCA , GHG and economic studies as these will be essential to classify fuels as environmentally sustainable.
- Technology for algal oil production as renewable biofuels.

Action Plan/Strategy

- Cellulosic ethanol pilot, Demo plants in range of 2-10 Tons per day—will need large funding of ~15-20 crores in collaboration with industry.
- The basic technology of the project proponents should be vetted by experts before funding ensuring commercialization of the technology.
- DBT already has several R&D projects on cellulosic ethanol and many leads are available hence instead of R&D projects only demonstration projects could be considered in this area for support by MNRE.

Hydrogen Energy

- Hydrogen production from various feedstock in association with industry
- Technology for storage of hydrogen

Fuel Cell

- High Temperature Proton Exchange Membrane Fuel Cell with combined cycle
- Low Temperature Proton Exchange Membrane Fuel Cell
- Planar Solid Oxide Fuel Cell
- Phosphoric Acid Fuel Cell (for civilian applications only)
- Direct Methyl/ Ethyl Alcohol Fuel Cell
- Molten Carbonate Fuel Cell
- Bio-Fuel Cell

Action Plan/Strategy

- R&D should be pursued in partnership with industries in material development, reactors/fuel cells, storage vessels.
- Centres of Excellence may be set up with focused R&D for long terms gaols.
- The indigenous technology for storage of hydrogen needs to be encouraged on priority basis.
- Focussed R&D projects need to be supported for hydrogen production through biomass gasification, bio-hydrogen, thermo-chemical splitting and thermolysis of water.
- In all areas of RD&D, industry must be associated with projects for technology development and demonstration ensuring commercial applications.

Control and Operation Issues with Integration of Renewable Energy Sources (RES)

- **Development of Low Cost High Efficiency Converters and Associated Controls for Integration of Solar And Wind Generation Plants** :
    - New Topology, Maximum Power Point Tracking, Power Quality Control, Grid Synchronization, Voltage and Frequency Control, Active and Reactive Power Support, Online Health Monitoring and Accelerated Life Testing.
- **Development of Controls for Power Management of RES Sources**
    - Grid Connected and Islanded Operation, Standalone Operation with Storage, Smart/Net Metering
- **Microgrid Development**
    - Microgrid Architecture Design- AC vs DC, Converter Topology and Controls for integration of various RESs and Energy Storage systems, Fast and Adaptive Protection, Island Detection and Management scheme. Pilot Microgrid Test Bed for R&D.
- **System Wide Power Management and Controls**
    - Wind, Solar irradiation, load forecasting, power balancing Ancillary Services, SCADA/EMS with Renewable Management, Synchrophasor Technology for Dynamic Monitoring and Control, Wide Area Control, Offshore wind farm integration, Flexible AC Transmission System (FACTS) Controllers.

Action Plan

Centre of Excellence in Grid related Research for RES Integration

Energy Storage

- Batteries and Supercapacitors
    - Lithium ion batteries
    - Solid state batteries
    - Hybrid capacitors
    - Redox flow batteries
- Metal-Air systems
    - Zinc-air rechargeable batteries
    - Lithium-air rechargeable batteries (futuristic)
    - Iron-air batteries (futuristic)
    - Aluminium –air batteries (futuristic)
- Organic systems
    - Organic, green, environmentally friendly electrode materials for all organic batteries
- Pb-acid batteries, alkaline batteries (Ni-Fe, Fe-air, Ni-Metal hydride), Li-based batteries (Li-ion, Li-air, Li-S), redox flow batteries (Zn/Bromine, soluble Pb) and electrochemical capacitors (electrical double layer and pseudo capacitors, Pb-C battery-super capacitor hybrid).
- Small Capacity Pumped Storage systems

Action Plan/Strategy

- Consortium for RD&D for technology development and demonstration between the institutions and industries.
- Fabrication and Demonstration of 2-3 Ah Li-ion cells and battery pack of 30 Ah for energy storage applications to sources from wind/solar with a cycle life of 3000 cycles.
- Fabrication and Demonstration of 2-3 Ah Li-ion cells and battery pack of 60 Ah for energy storage applications to sources from wind/solar with a cycle life of 5000 cycles.

VII. Wind

- Wind Resource Assessment and forecasting
- Wind Turbine System Design(wind turbine rotor, mechanical structures / materials, electrical components)
- Wind Energy Integration**(w**ind power plant capabilities/Grid planning and operation)
- Offshore Technology (resource, off-shore structures, turbine design and simulation understanding the external climate and wake effect).

Action Plan/Strategy

- Proper resource assessment including satellite based data

- Standards for wind turbines and related systems/components

VIII SHP

- **Small Hydro Turbines and generators**
  - Development of ultra-low (below 3 m) head turbines
  - Development of permanent magnet generators for small capacity
- **hydropower systems**
  - Development of flowing water kinetic energy based systems
  - Development of IT based performance monitoring of SHP systems
  - Development of Small Capacity Pumped Storage systems

Action Plan/Strategy

- Development of software for resource assessment for site identification including use of modern techniques like RS and GIS.
- Standardization of SHP turbines and systems including automation for pwer plants

Renewable Energy Resource Assessment

- Technique Development for high-resolution solar and wind / wave energy forecasting using model, satellite and in situ data
- Roof-top solar energy modelling using satellite-based 3D-city model
- Exploratory research investigation on Bio, Geothermal and Small-Hydro energy resource assessment with Satellite data
- the validation exercise of satellite-driven energy outputs with NIWE will continue as benchmarking activity.

Action Plan

- Resource assessment should be vigorously pursued and reviewed for its accuracy.
- Validation of satellite data against ground measured data and also comparing the same with that obtained from foreign source including from NREL and then developing a model for resource assessment across the country.

Suggestions/comments may please be sent at the following address:

Dr. B.S.Negi
Adviser/Scientist-G(R&D Coord and Biogas Power)
Ministry of New and Renewable Energy
Government of India
14-Block, C.G.O. Complex , New Delhi - 110003
Telefax: 24368581
Email: negi@nic.in

"Brainstorming Consultations Meeting on RD & D"

for Review and Preparing
"Action Plan with Thrust Areas for RD & D in New and Renewable Energy"

On 5th January 2016

Venue: MNRE Conference Hall

Programme Schedule

10:00 -10:10	**Introductory Remarks: Sh. Upendra Tripathy, Secretary, MNRE**
Review and Discussions for Preparing Action Plan with Thrust Areas for RD&D	
Session – I Resource Assessment	
10:10:10:20 10:20- 10:30	"Renewable Energy Resource Assessment-An Overview" with Talking Points for Discussion. Jointly by Dr. Bimal Kumar Bhattacharya, SAC, ISRO, Ahmedabad and Dr. Rajesh Katyal, DDG, National Institute of Wind Energy(NIWE), Chennai. 10 min. Discussion: 10 min
Session II Bioenergy Technologies	
10:30-10:40	"Biogas Technology Developments-An Overview" with Talking Points for Discussion. by Dr. S. P. Kale, Associate Director, BARC, Mumbai. 10 min.
10:40- 11:00	Discussion: 20 min.
11:00-11:10	"Technology Developments in Biogas Generation for use as Fuel for Transport Applications-An Overview" with Talking Points for Discussion. by Prof. V. K. Vijay, IIT Delhi. 10 min.
11:10-11:20	Discussion 10 Min.
11:20-11:30	"Biomass energy Technology Developments-An Overview" with Talking Points for Discussion By Prof. S. Dasappa, IISc, Banglore 10 min.
11:30-11:40	Discussion: 10 Min.
11:40-11:50	"Technology Developments in Biofuel for Alternate Fuel- An Overview" with Talking Points for Discussion.
11:50-12:00	Dr D K Tuli, DBT Centre, Indian Oil, R&D Centre, Faridabad 10 min. Discussion: 10 Min.
Session III Solar Energy Technologies	
12:00- 12:10	"Developments in Solar Photovoltaic Technologies - An overview" with Talking Points for Discussion. by Prof. Vikram Kumar, Former Director, National Physical Laboratory, currently Emeritus Professor, CARE, IIT Delhi. 10 min.

12:10-12:40	Discussion: 30 min.
12:40-12:50	"Development in Solar Thermal Technologies - An overview" with Talking Points for Discussion by Prof. S Srinivasa Murthy, Emeritus Professor IIT Madras 10 min.
12:50-13:20	Discussion: 30 min.
13:20-14:00	**Lunch**
Session IV	**Power Control System and Energy Storage**
14:10-14:20	"Power Control System-Balance of System for Grid Connectivity for Renewable Energy-An Overview" with Talking Points for Discussion. by Prof. S C Srivastava, IIT Kanpur, Kanpur. 10 min.
	Discussion 20 min.
14:20-14:40 14:40-14:50	"Technology Developments in Energy Storage for Renewable Energy Applications-An Overview" with Talking Points for Discussion. by Prof. S Sampath, IISc Bangalore 10 min.
14:50-15:10	Discussion 20 min.
Session- V	**Hydrogen and Fuel Cells**
15:10-15:20	"Hydrogen Research & Development for Alternate Fuel-An Overview" with Talking Points for Discussion. Prof. S N Upadhyay, Dept. of Chemical Engg., IIT(BHU) 10 min.
15:20-15:40	Discussion 20 min.
15:40-15:50	"Fuel Cell Technology Development for Alternate Fuel" with Talking Points for Discussion. Dr. H.S. Maiti, Former Director, CGCRI, Kolkata. 10 min.
15:50—16:00	Discussion 10 min.
Session-VI	**Wind, SHP, Geothermal**
16:00-16:10	"Wind Power Development-An Overview" with Talking Points for Discussion…… by Dr. Rajesh Katyal, DDG, NIWE 10 min.
16:10 -16:20	Discussion 10 min.
16:20-16:30	"SHP Development- An Overview" with Talking Points for Discussion
16:30-16:40	by Prof. Arun Kumar, IIT Roorkee 10 min.
16:40-16:50	Discussion 10 min.
16:50-17:00	"Geothermal Technology Developments-An Overview " with Talking Points for Discussion. by Dr. T. Harinarayana, Director, GERMI, Ahmedabad 10 min.
	Discussion 10 min.
17:00-17:30 Concluding Session Recommendations of Action Plan with Thrust Area Under the chairmanship of Shri Upendra Tripathy, Secretary, MNRE	

List of Participants

SI. No	Name with Designation	Name of organization with email address
1.	Sh. Upendra Tripathy, Secretary,	MNRE
2.	Ms. Varsha Joshi, Joint Secretary	MNRE
3.	Dr. O. S. Sastry, Director General	National Institute of Solar Energy(NISE), MNRE, Gurgaon, Haryana
4.	Dr. B. S. Negi, Director (R&D)	MNRE
5.	Prof. Vikram Kumar, Emeritus Professor	Centre for Applied Research in Electronics(CARE), IIT Delhi, New Delhi-110016 Email: Vikram Kumar vkmr47@gmail.com
6.	Prof. A K Barua, Emeritus Professor	Indian Institute of Engineering Science and Technology(IIEST), Shibur, West Bengal Ashok Barua <baruaasok@gmail.com>,
7.	Prof. S. Srinivasa Murthy, Emeritus Professor	IISc, Bangalore-560012 Email: Srinivasa Murthy S <ssmurthy@iitm.ac.in>
8.	Prof. S. N .Upadhyay	IIT (BHU) Varanasi Email: Prof S N Upadhyay <snupadhyay.che@itbhu.ac.in>
9.	Prof. O. N. Srivastava	Hydrogen Energy Center, BHU, Varanasi
10.	Dr. P. K. Singh, Chief Scientist	National Physical Laboratory(NPL), CSIR, New Delhi
11.	Prof. S. C. Srivastava	Deptt. of Electrical Engg., IIT Kanpur Email: ssc@iitk.ac.in
12.	Prof. Bhim Singh, Prof. & Head	Electrical Energy Deptt, IIT Delhi, New Delhi -110016 Email. bsing@eeiitd.ac.in
13.	Prof. S. C. Mullick, Retd. Professor,	Centre for Energy Studies IIT, Delhi, New Delhi-110016 Subhas_ cmullick@gmail.com
14.	Prof. Juzer Vasi Emeritus Fellow	IIT Bombay, Mumbai vasi@ee.iitb.ac.in
15.	Dr D. K. Tuli, Head	DBT Centre, IOC R&D Centre, Faridabad Email. tulidk@gmail.com
16.	Prof. H. S. Maiti Ex- Director CGCRI	CGCRI, Kolkata Hsmaiti2009@gmail.com

17.	Prof. V. K. Vijay	IIT Delhi, New Delhi-110016 vkvijay@rdatiitd.in
18.	Prof. T. Harinarayana Director GERMI	GERMI, Ahmedabad, Gujarat harinarayana@germi.re.in
19.	Porf. H. P. Garg, Sr. Consultant	NISE, Gwalpahari hpgarg01@rediffmail.com
20.	Mr. V.V. Giridhar Sr. Principal Scientist	CECRI, Madras unit CECRI-Madras Complex, Chennai
21.	Dr. A.K. Saxena, General Manager	BHEL, Gurgaon aksaxena@bhel.in
22.	Mr. Sudip Bhattacharya Sr. Consultant (PV)	NISE, Gurgaon Sudip_75@mail.com
23.	Prof. Arun Kumar,	AHEC,IIT Roorkee aheciitr.ak@hotmail.com
24.	Dr. B.K. Bhattacharya Scientist "G",	Space Application Centre(SAC), ISRO, Ahmedabad bkbhattacharya@sac.isro.gov.in
25.	Prof. S. Dasappa	IISc., Bangalore dasappa@cgpl.iisc.ernet.in
26.	Prof. H.N. Chanakya	CiSTUP , IISc., Bangalore chanakya@astra.iisc.ernet.in
27.	Dr. B. Bhargava, Director General	ONGC Energy Center, New Delhi bhargavabh@gmail.com
28.	Dr. Sangita Kasture Joint Director	Department of Biotechnology, Ministry of Science and Technology, New Delhi Sangita.kasture@nic.in
29.	Dr. (Mrs.) Parveen Dhamija Director	MNRE, pdhamija@NIC.IN
30.	Dr. Yogender Kumar Yadav Director General	National Institute of Bioenergy(NIBE), MNRE Kapurthala director@nire.ses.in
31.	Dr. MR Nouni, Director	MNRE, mrnouni@nic.in
32.	Mr. VK Jain, Director	MNRE, varunk@nic.in
33.	Mr. S.K. Singh, Director	National Institute of Soar Energy(NISE), Gurgaon, Haryana sk.singh.mnre@nic.in
34.	Dr. Rajesh Katyal, DDG	National Institute of Wind Energy(NIWE), MNRE, Chennai Email: katyal.niwe@nic.in
35.	DR. P. C. Pant, Director	MNRE
36.	Mr. I.P. Singh, Director	MNRE
37	Mr.Girish Kumar, Director	MNRE, **gkumar.mnre@nic.in**
38.	Mr. Anil Kumar, Scientist "C"	MNRE
39.	Mr. S. R. Meena, Scientist "C"	Biofuels Division, MNRE
40.	Ms. Preetika Singh	Tata Power peetika.singh@tatapower.com