Lighting Deprived Rural Communities: Issues, Concerns and Some Suggestions for Improvement

(Mrs.) Vijaya Agarwal
Selection Grade Assistant Professor (Electrical Engineering),
College of Agricultural Engineering, Jawaharlal Nehru Agricultural University,
Jabalpur 482004, INDIA [vijaya.agarwal @ gmail . com]

Prof. Dr. Ing. J. H. Agarwal
Former University Professor & Director - JNAU, G - 83 Krishi Nagar, Adhartal,
Jabalpur 482004, INDIA [jhagarwal @ gmail . com]

Among the developing countries, India has made significant contributions in high-tech areas like software development in information technology, space vehicle launch and satellite communication, food grain production, world-class technical education and manpower training, state-of-the-art R&D in some forefront disciplines; however the progress in providing lighting to rural communities is lagging. Around 60% of rural households stills use oil-based lighting. Grid-connected electricity has not yet reached all villages. Electrical energy shortfall of about 15,000 MW/year makes around 90 - 100 million rural population to live without the use of electricity for lighting; whereas it is a known fact that provision of lighting during evenings and nights helps increase productivity and is directly linked with overall prosperity.

Common methods to produce light for illumination are: i) thermal way by burning oils or open flames from candles, hurricane, and biomass, ii) thermo-luminance way, such as petromax using mantles with rare earth coatings (developed by Albert Graetz in Germany in 1880s), and iii) by electricity (incandescent bulbs, fluorescent and gas discharge lamps, solid-state LEDs). As in near future, there appears no possibility of extending grid-connected electricity to rural areas, the lighting will remain dependent on liquid fuels and decentralized off-grid electricity [4, 5, 6].

Liquid fuel based lighting has many drawbacks, such as: poor light output (< 100 lumens); incomplete combustion emitting CO and CO2; dependence on oil-based fuels and their high cost. These drawbacks lead to ill health. Some efforts were made to design efficient thermo-luminance based light sources. A typical improved petromax version under trade name ‘Noorie’ gave about 1300 lumens (100 W electric bulb equivalent), weighing 1.5 kg, could run on multi-fuels, and more efficient than the earlier versions of commercially available petromax from indigenous outlets [3]. The light output efficiency of the petromax was of the order of 2-3 lm/W as compared to efficiency of 10-15 lm/W of electric bulb and 50-70 lm/W of compact fluorescent lamps.

Various technology options for off-grid, decentralized electricity generations were attempted, they include: gas powered generators, photovoltaic and wind energy based installations, and of late bio-fuel based generation [1]. There is an ample scope for improving the off-grid technology and use of efficient light sources like low-power solid-state white LEDs. However, these need to be experimented and tried to meet the site-specific needs of lighting. There is an urgent need of initiating developmental work to bring some of these systems as acceptable alternative till the grid-connected electricity reaches the rural villages.

Any technology becomes attractive if it becomes economically viable; R&D helps in increasing the efficiency of technology and hence improving its economics – these are true also for the lighting technology for rural areas. Once the technology is available, the cost reduction process and financing mechanism can be undertaken. Unfortunately, until now efforts are lacking.

Specific suggestions are : (1) A technology mission be set up with a mandate to light every rural household (~100-200 lux) by 2010, (2) All projects be under one umbrella, like Ministry of Non-Conventional Energy, (3) Decentralized micro-utilities (~50 kW) be encouraged and subsidies and tax incentives be enacted, and (4) Emerging technologies [2, 6, 7], like biotechnology, nanotechnology, PV-based solid-state lighting be explored.

The Appendix gives supportive updates: A. - improvement in liquid-based lighting, B. - use of LEDs for lighting in Indian villages, C. - cool-beam technology based 4W LED MR16, D. - merits of using LEDs as light source, and E. - research needs for solid-state lighting.

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ABOUT THE AUTHORS

VIJAYA AGARWAL. Presently with the Department of Agricultural Structures & Environmental Engineering, Electrical Engineering Division, at Jawaharlal Nehru Agricultural University, Jabalpur / India; she holds a Postgraduate Degree in Electronics and Telecommunication Engineering. She has undergone advanced courses in Computers, Microprocessors and Electronic Instrumentation. Her areas of interest are: Applications of Electrical, Electronics and Computer Engineering in Agriculture, Rural Electrification and Energy Efficient Systems.

She has about 40 publications to her credit. She has chaired sessions and delivered keynote / invited lectures in several National and International Conferences.

Mrs. Agarwal has been the President of the Engineering Sciences Section, Indian Science Congress during 1993-94. She served as a Member of the National Executive Committee and the National Council of the Indian Science Congress for several terms. She is also actively associated with the Indian Women Scientists' Association and contributing in their scientific activities. Countries visited : USA, Canada, Austria.

J. H. AGARWAL. Former University Professor and Director (Instrumentation), Jawaharlal Nehru Agricultural University, Jabalpur / India, Dr. Agarwal is associated with several

Ministries / Departments of Government of India as Expert Member on technical committees and is active in professional societies like Institution of Electronics and Telecommunication Engineers, Institution of Engineers (India), Indian Science Congress, Computer Society of India.

He is a pioneer in the field of applications of Electronics, Microprocessors, Computers and Information Technology in Agriculture. As early as in 1970s, associated as an Expert with the Electronics Commission of India and the Scientific Advisory Committee to the Cabinet, Govt. of India, he introduced the Applications of Electronics and allied technologies in Agriculture in India. Thereafter, he has been guiding a large number of programmes under the ICAR, CSIR, DST, DOE, and several Universities. During 1985 to 1995, Dr. Agarwal headed a prestigious project of UNDP and Govt. of India on "Applications of Microprocessors and Computers in Agriculture". Under the Project and deputed by the UNDP and GOI, he visited several countries (USA, UK, Australia, Germany, Japan, China, etc.) on technical missions.

Dr. Agarwal actively participated in many national and international conferences. In 2005, on invitation of AvH, DAAD and TUI, he attended the 11th International Congress on 'Germanistik', at Paris / France, from 26 Aug – 03 Sept 05; the 50th International Scientific Colloquium on 'Micro and Nano Technologies', at Ilmenau / Germany, from 19 – 23 Sept 05; and the 7th International Conference on 'Lighting Engineering - Lux jr. 2005', at Doernfeld / Germany, from 23 – 25 Sept 05.

He has been a Member of National Executive Committee of CSI and served as the Chairman of CSI Division III on Scientific Applications of Computers and Information Technology. He served on the National Council of Institution of Electronics and Telecommunication Engineers as its Vice President, and the DOEACC Society of Ministry of Communications and Information Technology, Govt. of India as a Member on its Governing Body. The Institution of Engineers (India) awarded him 'Certificate of Merit' for his three research papers published in the journals of the Institution.

(Educational Background : Graduate Studies, 1954-58, BE (Hons) – Electronics & Telecommunications, Engineering, Govt. Engineering College, Jabalpur/India; Post-graduate Studies, 1958-59, M.Tech – Electronic Devices, IIT Bombay/India; PhD (Dr. Ing.), 1959-63, Technical University, Ilmenau/Germany. *Advanced Short Course* : Solid-State Electronics, Roorkee University, 1969; German Language, Leipzig University, 1959 & TU Ilmenau/Germany, 1961-63; Solar Photovoltaics, CSIR Bhavnagar, 1978 & SOGESTA Italy, 1982; Analytical Instrumentation, Germany & Switzerland, 1981, IARI New Delhi, 1991; Computers & Management, ASCI Hyderabad/India, 1971; Microprocessors, Bhopal/India, 1985; etc.).

Appendix – Supportive Updates

A. Improvement in liquid-based lighting

[*Source*: Based on the work conducted at Nimbkar Agricultural Research Institute, Phaltan, Maharashtra, India < www.nariphaltan.org >].

The presently used thermo-luminescent (TL) mantles in pressurized kerosene and gas lanterns have not changed since developed in Germany in 1880's. They are basically a mixture of 99% thorium oxide and 1% cerium oxide (called thoria mixture). However with the present level of materials technology and use of nanotechnology it should be possible to develop new materials for TL mantles which will use less of radioactive thoria mixture and also increase the efficiency. Research is also needed in developing better substrate for mantles. Presently the mantles are made of silk cloth and after firing them a very thin ash substrate remains which is very fragile. Consequently, the mantles have to be replaced frequently which increases the running cost of such lanterns. There is thus a need to develop stronger and more durable materials such as those based on ceramics and carbon-carbon composites. With such mantles the liquid based lighting can become very rugged besides being efficient.

For liquid fuel based lighting to progress it is necessary that alternative to kerosene is developed. Thus the liquid fuel should be produced from locally available biomass resources and made available at affordable rates in rural areas. Liquid fuels that can be manufactured from biomass sources are ethanol, pyrolysis oil and non-edible oils from tree borne seeds. Ethanol and non-edible oils have been used for cooking and lighting for quite some time. However extensive R&D is required in pyrolysis oil. This medium calorific value fuel can be produced by fast pyrolysis of biomass at ~ 500-600^{0}C.

Another new technology, which is coming up in U.S., is that of thermal depolymerization of any type of agricultural and animal waste. In this process, waste materials like municipal, kitchen or process industry wastes can be converted under high pressure (around 40 atmospheres) and medium temperatures (500-900^{0}C) into light crude oil. This technology can transform the waste material in rural areas into value added oil thereby generating wealth and useful energy.

B. Use of LEDs for lighting in Indian villages

[*Source*: Chopra, A. Low-cost lamps brighten the future of rural India. *The Christian Science Monitor*, 03 Jan. 2006].

"*Life does not halt anymore when darkness falls*" says Ganpat Jadhav of village Khadakwadi, India (Chopra, 2006). Life in this humble village without electricity would come to a grinding halt after sunset. Inside his mud-and-clay house, Jadhav's three children used to study in the dim, smoky glow of a kerosene lamp; and when their monthly fuel quota of four litres dried up in just a fortnight, they had to strain their eyes using the light from a cooking fire. That all changed with the installation of low-cost, energy-efficient lamps that are powered entirely by the sun. The innovative lights were installed by a NGO (non-governmental organization).

Some 100,000 Indian villages do not yet have electricity. The NGO used LEDs. After a $ 55 installation cost, solar energy lights the lamp free of charge. LED lighting is a technology whose low cost could allow the rural poor to leapfrog into the 21st century. As many as 1.5 billion people - nearly 80 million in India alone - light their houses using kerosene as the primary lighting media. The fuel is dangerous, and despite being subsidized consumes nearly 4% of a typical rural Indian household's budget. A report by a NGO group states that indoor air pollution from such lighting media results in 1.6 million deaths worldwide every year. The LED lamps produce nearly 200 times more useful light than a kerosene lamp and almost 50 times the amount of useful light of a conventional electric bulb.

C. Cool-beam technology based 4W LED MR16

[*Source*: Canada LEDS, Mississauga, Ontario, Canada].

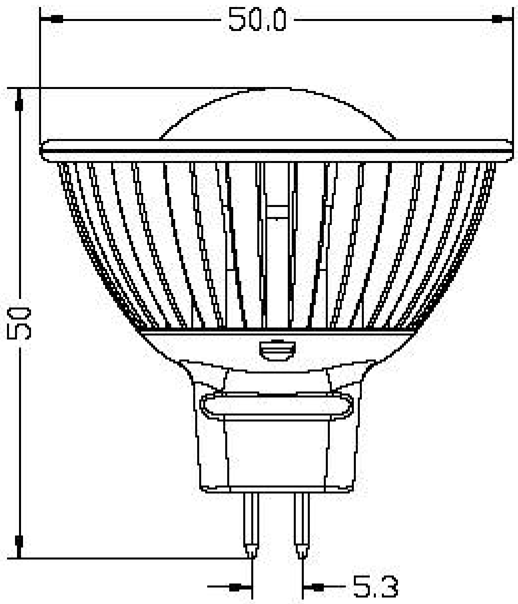
Features:

- Light source – 4W LED
- Source life – more than 40,000 hours
- Low heat, no UV or IR radiation

Specifications:

Operating voltage	12V DC.
Power consumption	4.5 W.
Optics	optical grade glass lens, 30 mm lens diameter, beam angle 60 / 120 degree.
Housing	molded aluminum with chrome finish.
Weight	60 gm.
Operating conditions	minus 20 to plus 40 deg C, 0 – 95% non-condensing humidity.
Make	Canada LEDS, Mississauga, Ontario, Canada.

Physical dimensions (in mm):



D. Merits of using LEDs as light source

- Low cost.
- Converts 85-90% of electricity directly into light, whereas incandescent bulbs covert about 10-15% of electricity into light.
- Greatly reduced energy costs.
- Works on low voltage 3-12 volts.

- No pollution, no UV radiation.
- Unbreakable, shock resistant.
- No heat radiation.
- Low operation and maintenance costs.
- Long life, 30,000 to 100,000 hours;
  incandescent bulb life is 8,000 to 10,000 hours.
- No filament to burn out.
- Potential to replace all existing forms of lighting.

E. Research Needs for Solid-State Lighting

[*Source* : *a.* McGehee, M. Organic and polymeric photovoltaic cells. In: A. Dodabalapur (Chair) and C. Dimitrakopoulos (Co-Chair), Final Report on technological challenges for flexible light-weight low-cost and scalable organic electronics and photonics, National Science Foundation Workshop, Arlington, U.S., 16-17 Jan. 2003; *b.* Sun, Z., Chen, T., Zhang, Z.J., Wang, L.L., Ni, S., Cao, Z.Y., Chen, Y.W., Guo, P.S., Sun, Y. and Tay, B.K. From nanostructured thin films to photonic devices - development and commercialization. *IEEE Conference on Emerging Technologies – Nanoelectronics,* 10-13 Jan. 2006, pp. 29-32 http://ieeexplore.ieee.org/xpl/tocresult.jsp?isnumber=33794 ; *c.* U.S. Department of Energy, the Basic Research Needs Workshop Series, BES Workshop on Solid State Lighting (SSL), 22-24 May 2006 http://www.sc.doe.gov/bes/reports/abstracts.html#SSL].

Lighting uses an enormous amount of energy. In 2001, in United States of America (U.S.), 22% of the nation's electricity, equivalent to 8% of the nation's total energy, was used for artificial lighting. The cost of this energy was roughly $ 50 billion per year or approximately $ 200 per year per person. Around 130 million tons of carbon emitted into the atmosphere, this was about 7% of all the carbon emitted in the U.S. in the year.

About 1.5 billion light bulbs are sold each year in the U.S., each one converting the precious energy resources mostly into waste heat, pollution, and greenhouse gases. There is an ample scope for reducing the energy cost and the environmental degradation by improving the light sources. If a 50%-efficient technology were to exist and be extensively adopted, it would reduce energy consumption in the U.S. by about 620 billion kilowatt-hours per year by the year 2025 and eliminate the need for about 70 nuclear plants, each generating a billion Watts of power. Solid-state lighting (SSL), the direct conversion of electricity to visible white light, has the potential to be just such an energy-efficient lighting technology.

The current values (as Oct 2006) for the 'luminous efficacy' (the total luminous flux emitted by a light source divided by the total power input to the source through its driver, expressed in lm/W) of some of the light sources are – for incandescent bulbs: 10-18 lm/W, for compact fluorescent lamps (CFL): 35-60 lm/W, for cool white LED 5000K: 45-59 lm/W, for warm white LED 3300K: 22-37 lm/W; whereas the long-term research and development goal calls for white-light LEDs producing *around 160 lm/W in cost-effective, market-ready systems,* by 2025.

Priority research directions and roadmap set to overcome the roadblocks in the current SSL technologies are: search for ultra-high-efficiency light-emitting materials and nanostructures for inorganic LEDs (materials such as the Group III nitrides, oxides, and novel oxychalcogenides) and for organic LEDs (materials such as carbon-based molecular, polymeric, or dendrimeric compounds); the cross-cutting research directions such as light extraction from solids, hybrid organic-inorganic and unconventional materials and light-matter interactions; conversion efficiency of organic photovoltaic cells to be raised by a factor of 3, from current 3.5% to 8-12%, bringing the efficiency into the range needed for large-scale commercialization.

(*Disclaimer*: No preference to any particular firm by the authors; figures and few briefs adopted from the product literature / websites for academic interest).

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