light up the world foundation

Solid State Lighting
In the Developing World

"*The only people who think that the provision of electricity is not a priority in poverty alleviation are those who have never been without it.* ***In fact, there is no single change in living conditions which is more beneficial than the arrival of electricity – yet 1.7 billion people on our planet are without it.*** *Renewable technologies, in particular offer huge opportunities to reduce that figure. We have to think small as well as big. For many millions in Africa, linkage to a grid will be a possibility but local generation using the most appropriate available technologies is equally important…Access to energy underpins the three pillars of sustainable development: economic growth, social development, and environmental protection."* *Extract from Tech Museum, Technology Benefiting Humanity, Fall 2002 - United Kingdom Energy Minister, Brian Wilson. "Energy has a crucial role in poverty battle Wilson tells Africa Energy Forum", Hermes Database, (Dept. of Trade and Industry, July 1, 2001).*

www.lutw.org

The Founder of Light Up The World Dave Irvine-Halliday in Pico Power Nepal's lab in Kathmandu. 2002 Rolex / Xavier Lecoultre

Light Up The World Introduction

Light Up The World Foundation (LUTW) is the world leader in utilizing solid state lighting (SSL) technologies and processes to enhance the quality of life of the poor in the developing world. LUTW Foundation brings affordable lighting to developing countries using a micro-enterprise model that fosters economic development. LUTW installs efficient white LED lighting with low power consumption, in a safe reliable manner using batteries that can be recharged by solar panels or other renewable energy power generating means.

LUTW and its partners in cooperation with foreign governments will bring light to lives of millions of people. The cost effective solution provides many benefits including enhanced learning opportunities for children and women. Reduction in emissions by not burning environmentally hazardous fuel, through replacing present systems with LUTW Lighting Solutions provides both tangible and intangible benefits for years to come.

History

In 1997, at a colleague's invitation, electrical engineer Dave Irvine-Halliday spent his sabbatical leave from Canada's University of Calgary in Nepal, helping the University of Tribhuvan in Kathmandu launch its electrical engineering degree.

With time to spare, the Scottish-born Canadian fulfilled his ambition to trek the Himalayas' famous Annapurna Circuit. Near a schoolhouse in a small Nepalese village, a sign entreated passing foreigners to stop and teach local children. Peering into the unlit classroom, Irvine-Halliday thought: "Gosh, it's dark in there!" Then, inexplicably: "I wonder if I can help them?" The question has already changed his life, and is likely to transform millions more lives.

When he left Nepal in 1997, Irvine-Halliday wondered how he could light houses in villages remote from power networks. Only 200,000 of Nepal's 3.4 million households have a reliable power supply. With household incomes averaging US$200 a year, low cost and reliability would be paramount. So he set out to devise a lighting system that could be installed "on a pico budget, and use pico energy". (In mathematics, the Latin prefix "pico" means a trillionth.)

Once he got back to the University of Calgary, where he works in the Department of Electrical and Computer Engineering, Irvine-Halliday had a flash of insight. Why light an entire home, when light was required only in certain areas?

Like many in the photonics community, Irvine-Halliday saw solid-state lighting as the future. Tiny, light-emitting diodes (LEDs) fabricated from layers of silicon and seeded with atoms of phosphorus, or germanium, arsenic and other rare-earth elements, exploit the quirky laws of quantum physics to transform electrons directly into photons of light, without heat. A cheap plastic reflector focuses the light into a conical beam that can be narrow and very bright, or wide and diffuse.

Technical advances have greatly improved the quality and reliability of LEDs since they were invented in the 1960s, making them much brighter and more efficient. The late 1990s brought high-brightness LEDs that could shine continuously for 100,000 hours, or 30 to 40 years in normal service. But because they emitted light only at pure wavelengths or colours - blues, greens, yellows, oranges or reds - they were unsuitable for domestic lighting. In 1997, Irvine-Halliday needed something that did not yet exist: a highbrightness LED that emitted at all visible wavelengths to produce white light.

In 1998, after a fruitless year trying to develop a white LED, he was browsing the World Wide Web when he discovered that a Japanese company, Nichia, had solved the problem by adding a phosphorus-doped layer to its blue LED. It changed some of the blue photons to amber, and the synergy yielded white light.

In pitch-darkness in his Calgary University photonics laboratory, Irvine-Halliday and his technician John Shelley switched on one of Nichia's 0.1-watt, white LEDs. The moment is seared into Irvine-Halliday’s memory. “Good God, John!” he exclaimed. “A child could read by the light of a single diode!” Irvine-Halliday began developing a multi-diode lamp to light homes in Nepal, and simple generators to power it. Thus was born his Light Up the World Foundation. In 1999 he, wife Jenny and son Gregor installed demonstration systems in several Nepalese villages and to date Light Up The World has spread to 12 different countries.

LUTW Today

In 2003, LUTW now has the support of a strong Board of Directors and large group of volunteers who help to coordinate lamping projects and broker industrial partnerships around the world. Presently, Steve MacArthur of CSE Imaging in Calgary is responsible for the design and fabrication of the current LUTW 1 watt luxeon lamp. Stanford University along with several industrial partners are collaborating with LUTW to develop other WLED lamps for the developing world market.

Countries With LED Lights

We now have our WLED Lamps in such countries as, Guatemala, Nicaragua, Haiti, Dominican Republic, Peru, Bolivia, Brazil, Chile, Uganda, Angola, Cameroon, Afghanistan and large lighting projects in Nepal, the Philippines, India, and Sri Lanka. By the fall of 2003 our lamps will be in South Africa, Uganda, Tanzania, Tibet, and China.

Muni Raj (left) of Pico Power Nepal with LED lamps that his firm sells at socially responsible, affordable prices. 2002 Rolex / Xavier

Social Entrepreneurship & Human Development

Micro enterprise development is a fundamental component of LUTW's philosophy and approach. Conventional project delivery combined with a local business start-up meets the twin demands of reaching a very poor segment of the population while simultaneously reinforcing entrepreneurship as one of the most effective and sustainable forms of local development. LUTW purchases the assembled equipment and services from a local business start-up for most area projects. LUTW installs equipment at no cost to the very poor but does require a high degree of initiative and mobilization among the community organizations to be a candidate.

A LUTW assisted business start-up ensures that installation, maintenance and support services continue to replicate after our initial projects have seeded the technology.

Establishing Micro enterprise - Pico Power Nepal

In Nepal Dr.Irvine-Halliday found a young woman along with her father to operate and own "Pico Power Nepal" - a small company he privately financed. This was in keeping with two of his long-held beliefs: to encourage both women and entrepreneurship. Pico Power Nepal now employs two full-time technicians and is the first of many independent micro-enterprises LUTW hopes to help establish in the following years.

Forging Industrial and Humanitarian Partnerships

As a humanitarian organization whose public works and advocacy effectively promotes and seed markets for solid state and ancillary components, LUTW is looking for industrial partners to provide preferential terms and arrangements. In our master plan, supply chain relationships with manufacturers are essential to dramatically lower system costs and to step up the formation of small 'Pico Power' companies, totally owned and operated by local entrepreneurs.

The burning of firewood is used for both cooking and lighting in 1/3 of the world. This photo is an example of the Interior of a dwelling in Nepal. 2002

The Need for LED Lighting Systems- *"a small solution a large problem"*

The opportunities in the developing world to harness solid state technology are enormous. According to the World Bank, **24% of the urban population and 67% of the rural population in developing countries are without electricity today. 1/3 of world's population uses fuel based lighting.** Even where there is electrification the costs are often well beyond the means of even the relatively well off. Solid state lighting allows for independent power production without the need to pay utility fees.

Light Up The World (LUTW) provides low cost, long lasting, durable and environmentally friendly solid-state lighting solutions to people in need throughout the "developing world". LUTW is the only humanitarian organization globally active in using solid-state lighting to illuminate the lives of over 1.7 billion people without electricity.

LUTW has demonstrated that the exceptionally low power consumption of WLED solid state lighting systems along with the simplicity of design and construction is ideally suited for the particular conditions that exist in the developing world. What is more, solid state lighting technology along with our processes is an ideal mechanism for community economic development. Solid state lighting can do far more than promote sustainable livelihoods and the provision of basic needs.

Man holding a homemade kerosene lamp made of a discarded incandescent bulb. Often these fragile lamps are knocked over and cause house fires. Sri Lanka 2002

LUTW 1-watt LED lamp. 2003

Benefits of LED Lighting Systems

Ultra-low power consumption- **use 5% of the energy of a regular incandescent bulb.** This simple but revolutionary technology can light an entire rural village with less energy than that used by a single conventional 100-Watt light bulb. Our brightest WLED, the 1-Watt Luxeon, produces between 25-40 lumens with an optical efficiency (its ability to 'focus' the light required) far greater than either the incandescent or fluorescent bulbs.

Long Life (100,000 hrs) – with the lighting assembly is correctly designed; a design life of 50,000 to 100,000 hours is realistic. **This represents over 40 years @ 6 hours/ night.** Maintenance requirements are drastically reduced, leading to a fundamental change in design. Life expectancy is unaffected by switching cycles and 100% output occurs with 10 nanoseconds.

Physically Robust – with no delicate glass or filaments, LEDs can withstand severe shock and vibration- a common cause of premature failure with traditional light.

Man with his wife in the background, holding homemade kerosene lamps in Sri Lanka. 2002 Irvine-Halliday

Reliable & Safe Lighting – fuel-based lighting is inefficient, expensive, dangerous and unhealthy**. Burning kerosene and wood fires produces noxious fumes, and because many houses are unventilated, this poses a serious health hazard in the form of respiratory and eye problems.** (*The average life span in these remote areas of the developing world is approximately 42 years*).

Kerosene lamps cause fires - Many families cannot afford a proper lamp and rely on a fragile glass bottle or an old incandescent bulb with a piece of rope for a wick (Molotov Cocktail). Fuel based lighting has more probability of causing fires, than all other forms of electric lighting. **Kerosene oil is a highly combustible, with a very low flash point.** A cloth soaked with kerosene will be immediately engulfed in flames, and usually cannot be put out for 10 to 15 minutes or longer. Typically, the result is that victims receive extensive burns to all or part of their body. **Worldwide, fires caused by kerosene lamps cause 3.5 million deaths annually and disfigure thousands of people.**

Kerosene is expensive – In the developing world the cost of fuel-based lighting (kerosene) is estimated at US$50 Billion/year, or **approximately $100 USD per household.** This is on par with electrically lit houses globally. The high cost of kerosene in remote areas means that much of the family's funds are spent on poor, unreliable lighting rather than food and clothing (*An average Nepali rural family consumes 51 litres of Kerosene a year for light alone*). ***The cost of ($/lumen/Hour) kerosene lighting is 325-times higher than incandescent bulb, and 1625-times higher than compact-fluorescent lighting.***

Annual light consumption of un-electrified household *(about 12000 lumen-hours)* = *light produced by a 100-watt incandescent bulb in 10 hours.*

Example of Lighting Costs for Villager in Nepal

Annual Combined Cost Kerosene + Batteries
(U.S. $44 – $104/year)

Costs of LUTW Lighting System

One-Time Cost of 2 LED Lamps
(U.S. $40-$70 – Luxeon-life expectancy up to 40 years,
Battery life expectancy - 5 years)

Environmentally Friendly - WLEDs, unlike fluorescent and other discharge tubes, do not contain mercury. They are thus safer to manufacture and are free from end-of-life problems. ***Disposing of a fluorescent tube properly now costs more than buying a new tube.***

Denuding the landscape - When families can't afford kerosene, or it is unavailable, they rely on wood burning fires to light the home. Denuding the landscape in search of wood fuel for lighting is recognized as a primary environmental problem in the developing world and is responsible for habitat loss, mudslides, loss of forest production, soil erosion and water pollution.

Battery disposal - Nepali's alone throw away over 200-300 million "D" cell batteries every year straight into the environment. The resulting pollution to streams, groundwater and fields threatens to be immense. The use of WLEDs in place of the conventional incandescent bulb can reduce the number of batteries thrown away by an order of magnitude and the further use of rechargeable batteries together with the use of WLEDs can decrease the throw away numbers to a few tens of thousands.

Micro Enterprise Development – Micro enterprise development is a fundamental component of LUTW's philosophy and approach. LUTW facilitates the set up of sustainable local enterprises to install, maintain, train and market these systems. Provide a lighting environment that facilitates the establishment of indoor and evening cottage industry.

Recharging 12 volt batteries and rechargeable D-cell batteries in torches have also been shown to save the villagers money within a matter of months and also allow for village entrepreneurship with the establishing of small (women run) battery charging businesses. We have had two such torch battery charging pilot projects underway in Nepal for quite some time.

Educational Benefits – LUTW's primary reason for lighting up homes and villages is to promote literacy and education. Illiteracy is one of the root causes of poverty. In many regions of the world, children must work and cannot access education during the day. Most developing nations experience darkness by 6 pm all year long. The light from kerosene lamps and candles is often inadequate to properly read by. A 1-watt Luxeon lamp provides enough light for a child to learn to read by.

Boy reading by the light of a 1-watt LED lamp in India. 2002

Dave demonstrating a LED home lighting system in Sri Lanka. 2002

LUTW Lighting Systems

Our individual home lighting systems have a one-time cost of between $50.00 - $70.00 USD. Where a communal central solar charging station is employed the cost per home is approximately $40.00 USD. Our "20 - 20 Vision" is -$20.00 USD for 20 years of home lighting.

Full life economics of the entire lighting system must be taken into account when comparing Solid State Lighting (SSL) to Incandescent/Fluorescent lighting. This includes the costs for energy, spare parts, maintenance, safety etc. and of course the environmental impact.

LUTW Individual Home Lighting System:

- Two 1 watt WLED Luxeon lamps (designed to include low voltage cutoff to regulate battery discharge)
- One 5 watt Kyocera PV panel
- One 12V 7 Ah Sealed Lead Acid battery (low voltage cutoff in circuit
- Necessary wiring
- LUTW will provide user manuals, training materials, reference designs and other product materials

There are several different manufacturers of WLEDs including Nichia and Lumileds. Lumileds produces the highest wattage diodes- up to 5Watts. LUTW advocates the use of Lumileds 1Watt Luxeon. The white Luxeon has a current upper level efficiency of 39 lumens/watt. LEDs have, and are projected to continue, following Moore's Law with output to double every 18-24months.

Men installing solar panels on a centrally located school house in Sri Lanka. 2003

LUTW Power Systems

1. Centralized Solar

This system is used in villages where homes are widely distributed. Solar panels are installed on top of the central school house or community centre situated right in the centre of the village. These solar panels charge a number of large (car battery size) lead acid batteries, which then become the source of energy for the smaller (12 Volt, 7 Amp Hour) Sealed Lead Acid batteries which each home owner possesses. Every one or two days the home owner brings their small SLA battery to the school and gets it topped up.

All of LUTW's Solid State lamps have a pre-set voltage cut-off to protect the SLA from being deeply discharged. The solar panel charging system has a voltage regulator to ensure that the batteries receive the correct charging voltage and that the batteries do not discharge into the solar panels when the sun goes down.

In this lighting system each home would consist of the SLA battery, a few metres of twisted pair electrical wire, an electrical switch and one or two 1 Watt White Light Emitting Diode lamps.

2. Distributed Solar

In this system a village is divided into equal sectors and the 'central' home in each sector is chosen as the one on which the solar panel is erected and the main battery installed. Since the homes were very close together it was economic to run buried electric cable from the central home to all the others in it sector. The entire system consisted of eight completely independent sectors, with each 16 home sector containing a single 40 Watt solar panel and a large lead acid battery. Each home had one 1 Watt WLED lamp.

3. Pedal Generator

Pedal Generators were used in our very first villages because they appeared at that time to be the most economic method of recharging SLA batteries. The PG consists of a industrial DC motor run in reverse by either a belt driven system or directly by a bicycle wheel and tire. The DC motors have ranged from: 30 Volt, 2 Amp, 3000 RPM, to 90 Volt, 3 Amp, 2400 RPM.
One PG is dedicated to serving eight to twelve homes. The PG is installed in one home and the home owner then becomes its custodian and is responsible for ensuring that it works and is maintained properly.

Pedal generator

Each of the other home owners brings their SLA battery to the PG each day and tops it up. It requires only about 30 minutes of gentle pedaling to top up the SLA battery. The custodian also has a digital voltmeter with which the batteries can be checked to ensure that they are properly topped up.

The PG system is similar to the Centralized Solar except that the PG can be used 24 hours a day and that a small grind stone is attached to it in order to help the villagers keep their working tools sharp.

4. Pico Hydro – Induction Generator

In this system an induction motor is adapted to operate as an electrical generator. To date we have used two different methods to mechanically rotate the machine, the classic Pelton Wheel and the Vortex turbine. Both generators supply approximately 200 Watts of power. An AC voltage of 240 Volts is generated and transmitted by overhead or underground cable to each home, where it is converted to 12 Volt DC to power the WLED lighting system. Though back up batteries in the generator shed would normally be employed they are not necessary for the system to operate properly.

5. Pico Hydro – Ghatta Water Mill

This system is based on the ancient Water Mill, or Ghatta, which has been used for over one thousand years in Nepal. The traditional wooden turbine is replaced by a more efficient one made of steel, but retaining the same head and water flow rate. An electrical generator is then added to the mill grind stone shaft and the power can be used during the day to operate e.g. a rice husker etc., and at night to light up the homes. Back up batteries may be used.

Ghatta

6. Pico Hydro - Chinese Bike Dynamo

This very simple system can only be used in special circumstances and consists of a 12 Volt, 6 Watt Chinese bike dynamo ($3.00) which runs continuously day and night for as much as three years before being required to be replaced. It provides sufficient power to light two to three homes. A battery may be installed in each home so that more than two watts can be drawn during the evening lighting.

Bike Dynamo

7. Output of LUTW WLED lamps

From 1998 to the summer of 2002 all LUTW lamps were made using either six or nine 0.1 Watt Nichia (Japan) WLEDs. From December 2002 onward we will be using the 1 Watt Luxeon WLED by Lumileds (USA). We will however continue to use the Nichia 0.1 Watt WLED in our torches (flashlights) as they provide a simpler and, as yet, more economic solution for such purposes.

The Nichia 0.1 Watt WLED will typically emit approximately 2 lumens into a solid cone of 20 degrees to 70 degrees. The 1 Watt Luxeon will emit a maximum of approximately 40 lumens into a solid cone of 110 degrees.

LUTW has designed, manufactured and tested an array of very efficient and economic reflectors, which can convert the Luxeon output to any desired solid cone angle between 20 degrees and 60 degrees.

A woman receiving a LED home lighting system in Sri Lanka. 2003

Project Work

LUTW is really a facilitator of knowledge and not a hardware organization, we facilitate the development of sustainable local business to manufacture, install and maintain renewable energy based lighting systems. We provide in-service training, project management and supply chain management to our delivery partners to foster entrepreneurial innovation and economic growth. Through volume purchasing and preferential pricing arrangements with suppliers LUTW can source components at prices far below retail.

LUTW Role in Project Development is to provide:

1) **Training - business and technical**
2) **Reference design manuals**
3) **WLED's and circuit drivers**
4) **Technical and business support**

Three Basic Partnership Requirements:

1. LUTW requires all partnership candidates to demonstrate the social, humanitarian and environmental impacts of their project or venture. As well, as provide well-defined, short term, outcome goals that are relatively easy to measure in terms relating to the proposed project.

2. LUTW partners only with strong, capable, and reputable host country organizations to ensure that delivery is undertaken by local interests. Projects require the formal acceptance by the community, a high degree of village mobilization where the community participates actively in all aspects of the project.

3. All LUTW projects are initially identified and fully funded by the host partner. Projects should be fully sustainable at project completion and should demonstrate the capacity to replicate.

Host country partners to date include the Centre for Rural Technology (Nepal), Nepal Schools Project, SASAC - Saint Alphonse Social and Agricultural Centre (West Bengal, India), Rotary Clubs: Central Calcutta Rotary, Human Development Centre (Dakshin Barasat, India), University of Moratuwa (Sri Lanka).

	TYPICAL PROJECT SCHEDULE
1)	Site Assessment
2)	Delivery Partner Qualification
3)	Community Acceptance & Participation
4)	Project Design & Resource Assessment
5)	Lighting System Design & Prototyping
6)	Budget and Scheduling
7)	Social Impact Measurement
8)	In Service Training & Knowledge Transfer
9)	Installation Services in conjunction with delivery partners
10)	Social Impact Measurement

Awards

LUTW recently won the 2003 Saatchi & Saatchi Award for Innovation and has won a number of prestigious international awards and prizes in 2002 including the Rolex Award for Enterprise **(Geneva),** The Tech Museum Award for Technology Benefiting Humanity **(San Jose), and the** President's Special Achievement Internationalization Award **(University of Calgary). Dave Irvine-Halliday has also been recognized for the following awards:** Canadian Foundation for Innovation Award 2003, IEEE Third Millennium Medal for Outstanding Contributions 2000**,** APEGGA Summit Award for Contributions to Society 2000 and Women in Science & Engineering Mentor of the Millennium Award 2000.

Quotes

"Good God John, a child could read with the light of a single diode" *Canada 1998*

"This is the first time in the lives of my children that they could read at night"
Sri Lanka 2001

"We always pray to God for you and your family for sending us the beautiful gift of light"
St. Alphonsus Social & Agricultural Centre – Kurseong, West Bengal, India 2001

"A foreigner has come and made Thulo Pokhara heaven!"
Nepal 2000

"This project particularly appeals to me because it touches a very basic need that has huge ramifications for the quality of life. If there is no light, you can do nothing. The gift of illuminating a home brings almost incalculable benefits to the inhabitants of remote villages in the poorest parts of the world. Cutting-edge, simple technology is the hallmark of great science."
Baroness Susan Greenfield 2002

"As the world's resources diminish, Dr Irvine-Halliday's imaginative application of new technology to help improve the lives of people in some of the poorest and most remote regions of the world is a very encouraging enterprise that kindles optimism in my heart."
Mr. Fumihiko Maki, 2002

"In my childhood village outside Moscow, we had no electricity. In the evenings my brother and I tried to read using a kerosene lamp or a candle. My grandmother would get angry because she wanted to save every penny for food. With his noble action, Irvine-Halliday will bring paradise to many houses and to thousands of children's hearts." Dr. Anatloy Sagalevitch, 2002

"It has been true since the beginning of the industrial revolution that technology alone solves nobody's problems unless someone clever and with foresight comes along to apply it where needed and wanted. Dave Irvine-Halliday's project to bring efficient and affordable lighting to poor rural villages in developing countries is bolstered by using batteries that recharge with a simple application of human energy. Dr Irvine-Halliday can indeed light up the lives of those in rural homes in developing countries.
Dr. Neil De Grasse Tyson, 2002

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Appendix

LIGHT UP THE WORLD – MEDIA COVERAGE
www.lutw.org

Printed Articles

21st December, 2002	**Calgary Herald**
December, 2002	**Libération,** France
25th November, 2002	**The Business Times,** Singapore
24th November, 2002	**Melbourne Sunday Herald-Sun**
6th November, 2002	**The Nation -** Bangkok, Thailand
2nd November, 2002	**The Economist**
31st October, 2002	**Far Eastern Economic Review,** Washington DC
22nd October, 2002	**Globe and Mail**
3rd February, 2002	**San Jose Mercury News** (The newspaper of Silicon Valley), USA
November 2001	**APEGGA-PEGG**
20th July 2001	**National Post,** Canada
30th June 2001	**Bangkok Post,** Bangkok
Summer 2001	**Sphere Magazine,** USA
31st May 2001	**Energy Edge**
24th February, 2001	**National Post,** Canada
January/February 2001	**EP & T Magazine**, Canada
December, 2000	**Silicon Valley North Biophotonic** Fiber Optical Sensor article
August, 2000	**APEGGA-PEG**
Summer 2000	**Arch Magazine**
30th July, 2000	**Kathmandu Post,** Nepal

Magazines

Spring 2003	**Imperial Oil Review Magazine,** Canada
January 2003	**Spotlight Magazine Germany**
January 2003	**Materials Today,** UK
December 2002	**Silverkris, Singapore Airlines Inflight Magazine**
December 2002	**Photonik/Rolex Germany**
December 2002	**Electrical Business Magazine**, Canada
December 2002	**National Post Business News,** Canada
December 2002	**Scientific American (Rolex Award Laureates)**
November 2002	**Discovery Magazine**
October 2002	**The Economist (Rolex Award Laureates)**
October 2002	**Time Magazine (USA) (Rolex Award Laureates)**
November 2002	**Macleans Magazine**, Canada
22 October 2001	**Time Magazine (Canadian Edition**

TV & Radio Interviews

October 2002 - February 2003	**National Geographic Special on LUTW world wide – "*The Man Who Lit Up The Mountains*"**
25th December, 2002	**CBC "NewsWorld Morning"**
14th November, 2002	**Discovery Channel TV "Daily Planet"**
1st November, 2002	**National Public Radio "Living on Earth",** USA
3rd May, 2002	**"NewsWorld Today",** CBC

Presentations

19th – 25th June, 2004	**Young president's Organization,** Istanbul, Turkey
1st - 4th October, 2003	**Sustainable Resources 2003 Conference,** University of Colorado
12th -15th September, 2003	**ITESM International Conference on Leadership –"*Sharing the Challenge of being Authentic*", Monterrey Institute of Technology and Higher Education,** Chihuahua, Mexico
2nd April, 2003	**Commonwealth Club of California,** San Francisco, USA
24th March, 2003	**Solar Program Review Meeting – National Renewable Energy Laboratory,** Denver, USA
13th March, 2003	**Okanagan University College**, British Columbia
19th November, 2002	**Illuminating Engineering Society of North America**
8th November, 2002	**Tech Museum Award,** San Jose, California
24th October, 2002	**International Christian University,** Tokyo, Japan
23rd October, 2002	**LEDs 2002 Conference,** San Diego, California, USA
21st October, 2002	**Illumination Society of Japan,** Tokyo
3 July, 2002	**Central Calcutta Rotary Club,** Calcutta, West Bengal, India
28th June, 2002	**World Bank,** Colombo, Sri Lanka
26th June, 2002	**University of Moratuwa,** Colombo, Sri Lanka
25th June, 2002	**Shell Renewables,** Colombo, Sri Lanka
16th April, 2002	**Illuminating Engineering Society of North America**, Calgary
18th January, 2002	**LumiLeds,** San Jose, California, USA
19th October, 2001	**LEDS 2001 Conference,** San Diego, California, USA
18th July 2001	**Institute of Engineers,** Colombo, Sri Lanka
2nd May, 2001	**Dr. David Suzuki Lecture**, Calgary
14th October, 2000	**IEEE Third Millennium Gold Medal Awards**

Professional Articles

"LUTW – Solid State Lighting for Human Development", LEDs 2002 Conference (Invited Speaker), San Diego, California, 21 – 23 October 2002

"Pico Power – Lighting Lives with LEDs", Australasian Universities Power Engineering Conference (AUPEC), 29 Sept. - 2 Oct. 2002, Monash University, Melbourne, Australia

"**Lights of Nepal**", Renew Magazine of Australasia, Fall 2001

"**Does the Overdeveloped World Appreciate the Win-Win-Win Opportunities for High Brightness LEDs in the Developing World?**", LEDs 2001 Conference (Invited Speaker), San Diego, California, 17 –19 October 2001

"**White LEDs for Lighting Remote Communities in Developing Countries**"; Paper (LUTW), Solid State Lighting and Displays, SPIE Conference, San Diego, California, 29 July – 3 August 2001

"Demand Side Management for Rural Nepal", Boiling Point, Intermediate Technology Development Group (UK), No. 45, Fall 2000

"**Light Up The World – Nepal Light Project and Everest**", IEEE Canadian Review, No.36, Fall 2000.

Potential Benefits of Solid-State Lighting (SSL) Cumulative savings potential in U.S. 2000-2020

- **It is estimated that by 2025 SSL could reduce the global amount of electricity used for lighting by 50%**
- Most of the electricity from burning fossil fuel – eliminate 258 million metric tons of carbon emissions
- Alleviating the need for 133 power stations (1000 MW each)
- Financial savings of $115 Billion
- **Will create lighting industry over $50 Billion/year**
- Flat arrays of inorganic LEDs or laminates of organic OLEDs can be mounted in any pattern or shape on walls, floors and even furniture

The Promise of Solid State Lighting For General Illumination'. Conclusions and Recommendations Co-sponsored by U.S. Department of Energy (DOE) and Optoelectronics Industry and Development Association (OIDA)

Solid State Lighting Technology in the Developed World

"Light-emitting diodes have evolved significantly in the last 5 years, with growth rates as high as **58% a year**. **The newly forecasted market size is $3 billion by 2006.** LEDs claim 20% of the traffic signal industry in North America, up from just 8% a year or two ago. The success of LEDs lies in their longevity (LEDs outlast incandescent lamps by a factor of 10), energy efficiency, durability, low maintenance cost, and compact size. **Replacing conventional lamps with LEDs in the United States alone will bring energy benefits of up to $100 billion by 2025, saving up to 120 gigawatts of electricity annually**".
Light Emitting Diodes 2002, The Strategic Summit for LEDs in Illumination

"The next generation of white lighting technology is upon us. It involves the use of solid state diodes and conductive polymers to produce white light ten and two times more efficiently than traditional incandescent and fluorescent lights, respectively. It has the potential to displace our traditional lighting industries, which are based upon technologies that Thomas Edison invented over 100 years ago. I believe that Congress has an obligation not only to maintain our leadership in the industry our nation created but to promote new technologies for the more efficient consumption of the energy we produce".
Issues in Science and Technology Spring, 2002, 'Supporting the Next Generation of White Lighting Technology', Jeff Bingham U.S. Senator, New Mexico

"The opportunities for Sandia National Laboratories and DOE in solid-state lighting and in the important GaN material system are very large. **The market for high-brightness LEDs grew by 58% last year and achieved worldwide revenues of around $1.2B**…The Optoelectronics Industry Development Association is continuing to promote interest in a National Initiative in Solid-State Lighting on behalf of the solid-state lighting companies – including sponsorship with the National Research Council of a workshop on solid-state lighting at the National Academy of Sciences…The opportunity of solid-state lighting (10X and 2X improvement in efficiency compared to incandescent and fluorescent lamps, respectively) for energy reduction is simply too important to pass".

Dept. of Energy and Sandia National Labs ' Revolution in Lighting: Building the Science and Technology Base for Ultra-Efficient Solid-State Lighting'.

“Lighting consumes a massive 20% of the world’s electricity, but its continued reliance on the technology of hot wires and gas filled envelopes is reminiscent of the age of the thermionic valve. All of this is about to change. Lighting is going solid state, with the humble light-emitting diode (LED) making the application leap from power-on indicator to mainstream light source. **When complete, this revolution in lighting technology could halve lighting-related electricity demand, massively reduce maintenance requirements and change lighting design philosophies forever”.**
IEE Review September 2002

Traditional lighting manufacturers ,including Phillips, GE and Osram, have formed partnerships with semiconductor manufacturers to develop next-generation lighting technology based on semiconductors, and a number of [US] government sponsored industry consortia have been set up to exploit the potential of SSL.
IEE Review September 2002

In July 2001, the US Senate enacted the Next Generation Lighting initiative, which if its aims are realized, should result in a 25% market penetration by white-light LEDs into the incandescent and fluorescent lighting markets by the year 2012.
IEE Review September 2002

For more information on Solid State Lighting

lighting.sandia.gov
www.lumileds.com

Table. 1

Cost/Benefit Analysis and Light Source Comparison of CFL, Incandescent bulbs, and Luxeon Lamps over 50,000 hours

	Bulb (25W)	CFL (7W)	Luxeon (1W)	Kerosene wick
Lamp cost $US	1	**5**	**10**	$1
Lumens Output	250	**250**	**40**	10
Lamp life (hours)	1,000	**6,000**	**50,000+**	5,000
Lamp Lumen-hours per $	250,000	**300,000**	**200,000**	50,000
Fuel cost*	1	**1**	**1**	0.25
Lamp consumption**	25	**7**	**1**	0.05
Lifetime energy***	1250	**350**	**50**	2500
Energy cost $	1250	**350**	**50**	625
Total system cost (Lamp + Energy) $	1300	**392**	**60**	635
System Lumen-hours per $	9,615	**31,888**	**33,333**	787
Total system cost per lumen $/lm	5.2	**1.57**	**1.50**	63.5

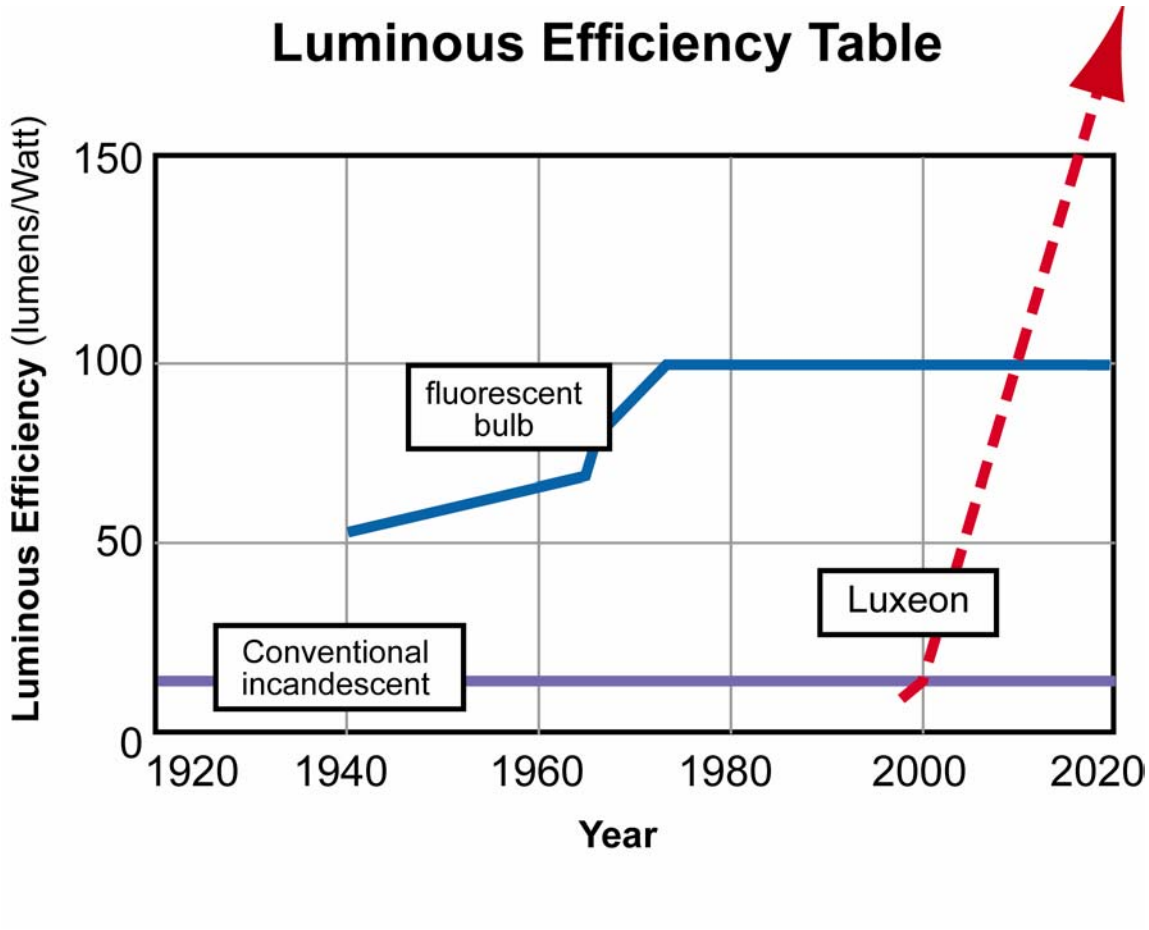
Source : Solid State Lighting for Human Development – Intertech Conference Paper, San Jose California, 2002

*$/kWh for electric lamps, $/L for kerosene. Since LUTW normally uses only pico power systems all three of the electrically based lighting units were accorded the same fuel cost in order to make the comparisons realistic.
**Watts for electric lamps, L/hour for wick lamp.
***kWh for electric lamps, litres for kerosene.

Summary of CFL & Luxeon lamp comparison over 50,000 hours

1. **CFL has a [6:1] advantage in total lumen output**
2. **System lumen-hr/$ are virtually equal**
3. **Total system costs/lumen are virtually equal**
4. **Total system costs are [6:1] in favor of Luxeon**
5. **Power supply for Luxeon smaller by a factor of [7:1]**
6. **Luxeon has at least a [8:1] lifetime advantage plus ruggedness**
7. **Luxeon has approximately a [4:1] optical efficiency advantage**

Table. 2


Luminous Efficiency Table
Luminous Efficiency (lumens/Watt)
150
100
50
0
1920
1940
1960
1980
2000
2020
Year
fluorescent bulb
Conventional incandescent
Luxeon