Light Up The World - Nepal Light Project and Everest

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Abstract

This article describes the experiences of a scientific team from the University of Calgary which set out to provide a reliable, versatile, inexpensive, healthy and safe form of lighting for developing countries such as Nepal. This particular mission was referred to as Light Up The World (Nepal Light Project). The article demonstrates the utility of using White Light Emitting Diodes (WLED), running on batteries recharged through simple methods. The power for the WLED lamps was derived from various sources i.e. simple Pedal Generators, a Pico Hydro Generator and a Centralized Solar Panel system.

Sommaire

Cet article décrit les expériences d'une équipe scientifique de l'Université de Calgary qui se sont unis pour fournir un éclairage fiable, versatile, peu coûteux, robuste et sécuritaire pour des pays en voie de développement comme le Népal. Cette mission particulière était appelée "Allumer le Monde" (Projet d'éclairage du Népal). L'article démontre l'utilité des diodes électroluminescentes blanches (DELB), alimentées par des batteries rechargées par de simples méthodes. La puissance d'alimentation des lampes DELB était dérivée de plusieurs sources comme de simples génératrices à pédales, une génératrice hydraulique Pico et un système de panneaux solaires centralisé.

1.0 Introduction

The Light Up The World - Nepal Light Project was conceived, almost by accident, in the summer of 1997 when Dr. Dave Irvine-Halliday, having just completed a project at the Institute of Engineering, Tribhuvan University, Kathmandu, Nepal, decided to trek around the Annapurna Circuit.

During his trek, it rapidly became obvious that the majority of rural villages in Nepal lacked adequate lighting. This was especially of concern with regards to the village schools, which also often lacked a teacher. He concluded that there had to be some way to bring some form of lighting to the villagers. Upon returning to the University of Calgary, he plunged into what is referred to as “a wee personally funded project” which had little, if anything, to do with his 'real' research projects involving Fiber Optic Current Sensors and Gyroscopes, and Biophotonics. The rest is history as they say!

2.0 Design Considerations

One important point to note when designing a lighting system for rural villagers in the developing world is that they generally have very little income. For instance, a Nepali villager has an annual average income of a few hundred dollars. Therefore, any intended lighting system must be simple, reliable and economic. This is not the time to get all high-tech if the system reliability may be compromised and the chances of it being repaired in a reasonable time and at an affordable cost are slight. Another important point was that we were not trying to light up the entire home to a North American level of illumination, but only light up those areas of the home where it would be most useful.

3.0 Lighting Systems

The vast majority of rural homes in Nepal are presently lit by candles, kerosene wick lamps or resin soaked twigs, all of which are a fire hazard and a health problem due to the smoke produced. Furthermore, Nepali homes generally have no chimneys due to the belief that the creosote in the smoke from the cooking fires helps to protect the wooden ceilings from insect attack.

Existing technologies which have been employed for some time in Nepal are generally limited to the more affluent communities and particularly in locations with relative ease of access. Implementations typically incorporate some or all of the following components:

Light Source: Incandescent Bulb, Fluorescent Tube, or Compact Fluorescent Light

Power Generation: Fossil Fuel Based: Diesel/Petrol, Photovoltaic Panels, Pico and Micro - Hydro; or Peltric/Ghattas/Vietamese (low head) Wind Turbines (very few)

Transmission/Energy Storage: Direct AC Transmission, AC Transmission with Conversion to DC, Battery Storage, or Combined Transmission with Off-Peak Storage

4.0 The White Light Emitting Diode (WLED) [1]

There are basically two distinct parts to the home lighting challenge; the light source and the energy source. It quickly became evident that none of the existing light source technologies were the long-term solution since not only did the new light source have to provide sufficient light but it had to do so with a dramatically reduced power consumption or else the developing world would simply remain in the dark due to the lack of affordable and appropriate power generators. With a long background in photonics, Dr. Irvine-Halliday went to work in the lab experimenting with various color combinations of LED's trying to make an energy efficient and very reliable 'white' light of acceptable output power. He did not succeed!

Fate lent a hand with the timely development in 1997 of the world's first White Light Emitting Diode (WLED) by Nichia of Japan who were kind enough to send samples for evaluation to see if they were in fact suitable for the embryonic “Nepal Light Project” (NLP). The specifications for the WLED's suggested that they might just be the futuristic alternative light source that was being sought, so their arrival was awaited with some nervousness. The WLED test day in the photonics lab will never be forgotten. On switching on that single WLED in the pitch dark, Dr. Irvine-Halliday said to his technician, John Shelley, “Good God John, a child could read by the light of a single diode!” It was a defining moment!

Table 1 illustrates a subjective comparison between a 25 W incandescent bulb and a 12-cluster WLED lamp and clearly demonstrates the advantages of the WLED lamp.

Numerous WLED configurations are possible when making lamps and many square, rectangular, triangular and circular forms were tested. At this time, the chosen design for Nepal is the concentric circular that allows either a 3, 6 or 9 WLED configuration using the same printed circuit (PC) board (see cover photo also). Since a room in a typical Nepali rural house can be lighted to an acceptable level with either 6 or 9 WLED lamps then it is perfectly feasible to light up a home with a power consumption of approximately 1 W!

Table 1: Comparison Between an Incandescent Bulb and a WLED Lamp

Lamp Type	Input Voltage	Input Power	Cost (C$)	Relative Heat Output	Ruggedness	MTBF (Hrs)	Luminous Efficacy	Improvement Potential
Incandescent	110 V AC	25 W	1	Very high	Very low	1,000	10-20 lm/W	Very low
12 WLED	12 V DC	1 W	20	Extremely low	Extremely high	100,000	15-20 lm/W	Extremely high

To date a number of other companies have joined Nichia in producing WLED's such as: Hewlett Packard-Phillips; Panasonic; Sumitoma; Toyoda Gosei (Toyota); GE-Osram and Fujitsu.

5.0 The Generator

It is very important to realize that with the advent of the WLED that the 'rules' of the game have changed forever! No longer is it necessary to think in terms of kilowatts for developing country village lighting but "Pico Power" suddenly becomes the norm. It is feasible to light up an entire village with 100 Watts!

Once various configurations of WLED lamps had been constructed and tested in and out of the lab and found to satisfy all the requirements for our NLP, the search was on for a "Pico Power Generator". After much analysis of the conventional power sources i.e. Solar, Hydro and Wind, it was concluded that none of them fitted the personally funded budget at that time, and therefore another solution would be needed, at least for the short term. After experimenting with various forms of human-powered treadle, pedal, push and pull systems it was determined that by far the most appropriate approach was the Pedal Generator (PG) for the following reasons. It was low tech; it could operate 24 hrs/day if required; it was economic and safe; it could charge multiple batteries simultaneously; it was rugged and reliable; it was easily maintained & repaired; it could be manufactured in the developing world; it was multi-functional and it could be easily transported to the remote villages.

6.0 Field Testing 1999

In the summer of 1999, different types of WLED house lamps and torches (flashlights), plus two PGs were taken to various villages in East and West Nepal to test them in the real environment (Figure 1). The following places were visited:

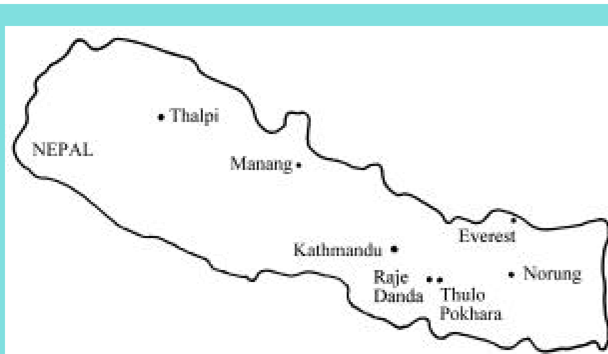

Figure 1: Location of the villages in Nepal

Majhigaun (Fisherman's Village) - installed Nepal's very first WLED household light.

Feedback: the householder wished to have more light so we doubled the number of WLED's.

Manthali (District of Ramechap) - demonstrated the PG WLED home lighting system and torches to a gathering of 150 villagers.

Feedback: the District Chief advised the audience to spend less on weddings and more on their children's futures by investing in Solar Home and PGSs. He also said that they could sell 2000 of our WLED torches straight away if we could supply them.

Khimti (District of Ramechap) - demonstrated the WLED torches in the hydroelectric Project tunnels and penstocks (1 km deep in the mountain).

Feedback: the engineers working on the Khimti Hydro Project would very much like to be able to buy our WLED torches and they provided us with some very insightful comments regarding the design features.

Chandrawati - first full-scale field demonstration in Nepal of the entire Pedal Generator WLED Home Lighting System.

Feedback: the guest house owner used the PGS in his dining room for the entire evening and was delighted with the results and lack of smoke and fumes. The villagers would also like to buy the WLED torches.

Annapurna Base Camp (ABC) - demonstrated the WLED Home Lighting System at numerous villages and teahouses all the way to ABC at 4,130 meters).

Feedback: there was a great deal of interest in using the WLED lamps for the kitchen, dinning room and sleeping quarters since they are energy efficient, non-polluting and safe. The WLED torches were used extensively and approved with great enthusiasm - so much so that it was difficult to get them back at times!

Sherpa - one of our WLED torches, complete with spare batteries and a recharging system was given to a Sherpa to field-test.

Figure 2: Dave I-H showing the Pedal Generator and WLED lamps to the great Nepali mountaineer, Babu Chiri Sherpa, who has summited Everest eleven times and all without oxygen. He would like to use the WLED lamps in a school he is building. Photo by DI-H.

Feedback: after one year it was still working perfectly and he had nothing but praise for its powerful and beautiful white light and the many weeks he could go between recharges. As it had been accidentally dropped many times he was very impressed by its ruggedness and dependability.

Overall the feedback from the villagers was thoughtful, comprehensive and very positive. What was a little 'surprising' was the strong desire of the villagers to get hold of our WLED torches since a 3WLED torch gives at least as much light as a typical incandescent bulb torch. Our data shows that a three D cell WLED torch has at least seven times the battery life of it's incandescent bulb cousin! It is interesting to note that even if non rechargeable D cells are used then there will be seven times less old batteries thrown away (because they are) which is environmentally beneficial. Of even greater significance however is the fact that if rechargeable D cells are used then they will last approximately 200 times as long as the non-rechargeables, saving much money for the user.

With this information we returned to Canada more than ever determined to return to Nepal in 2000 with complete WLED home lighting systems for a number of villages [2].

7.0 Project Planning: 1999-2000

In collaboration with Mike Rojik, Director of the Nepal School Projects (NSP) [3], a Canadian-Nepali NGO, several villages were selected for a trial of the innovative new WLED system developed at the University of Calgary. Extensive lab and field-testing of the WLED lamps and Pedal Generators proved that they were a viable and possible alternative for the villages, located south east of the capital Kathmandu (Figure 3).

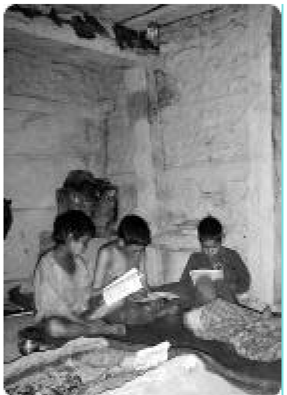

Figure 3: Three older children studying with the light of their 6WLED lamp in Thalpi. The light is seen fixed on the ceiling at the top of the photo. Photo by A. Zahnd.

The villages were chosen on the basis of need and their remoteness and that none were deemed likely to be electrified via the national grid in the foreseeable future. After field surveys and consultation with the respective Village Development Committees (VDC), two villages were accepted: Thulo Pokhara and Raje Danda which are two days hard trek southeast of Kathmandu.

8.0 Oops Everest 2000!

Just to complicate the situation even more, an invitation to be a member of the "AGF (American General Funds) Everest 2000" expedition could not go a begging. As Everest base camp (5,364m) communication engineer and education expert for the web based interactive education program for Canadian school children there was much to do. We did however find time to erect and test our Pico Power Wind Generator and the PG. Of great joy to the team cooks from many expeditions was the little grind stone that was part of the PG since they were always looking for ways to get their knives sharpened. Our Pico Wind Generator did in fact charge our sealed lead acid batteries but we required a fair bit more wind velocity than usual due to the very much reduced air density at these altitudes. The University of Calgary engineering students ("Team Pico") [4] who designed the system did a terrific job and so much so that we brought it back to Calgary for more testing and upgrading and fully expect to take it back to Nepal in 2001 - for use at much lower altitudes! The technical trials and tribulations of a month and a half at Everest Base Camp (EBC) were made so much easier to bear due to the assistance of my son, Gregor, and wife, Jenny. Gregor's reputation for being able to fix anything be it the team radios, computers or video equipment was such that he was referred in emails to the Canadian Broadcasting Corporation (CBC) as "Amazing Gregor" and he fully deserved the title.

Though not equipped for it, and thanks to the assistance of Noel, the technician for the successful British team, I was able to build a 5WLED headlamp which our climber, Tim Rippel, took to 8,500m before he had to turn back due to hypothermia. Though it should have been brighter it got much praise from Tim and other climbers for the quality of its light. It was the very first WLED lamp on Everest and given different circumstances (that's another story) it would have summited!

A nearly catastrophic tent fire due to a faulty connection on a butane lamp proved to us forever the value of WLED lighting in a tent.

The Everest expedition was the best and the worst of times but we were glad to have had the opportunity to play our part in its eventual success and we learned a great deal about human egos! Always however at the back of our minds was the thought that we could hardly wait to get on with our real work - the Nepal Light Project.

9.0 System Design Modification and Appropriate Technology

Preliminary site inspection of the two villages in June 2000 revealed limited local potential for a possible Pico Hydro development. At the time neither village's water delivery system offered sufficiently reliable flow for Peltric sets. Additional concerns were raised in regard to maintenance and seasonal flux (May-Aug. comprise the Nepalese monsoon).

Wind generation was judged inappropriate due to inadequate local data and cost. After due consideration, including the remoteness of the villages and technical abilities of local artisans, the PGS was confirmed as the most appropriate power source for the villages of Thulo Pokhara and Raje Danda (Figure 4).

Figure 4: Early morning battery charging in Raje Danda. Photo by DI-H.

Late into our scheduling period Fate again seemed to influence our plans with the discovery that there was an experimental 200 Watt Pico Hydro Generator (PHG) operating in the village of Thalpi in the remote northwest Jumla district. On investigation it was also discovered that it powered only three homes fitted with incandescent bulbs. An offer was made to the village elders, and accepted, that we wire the entire village of 28 homes with 220 V AC, convert it to 12 V DC and then equip each home with two WLED lamps.

10.0 PG and PH System Implementation

On the basis of the research carried out in Canada and in Nepal, a PGS coupled with widely available 12 V batteries was designed and subsequently manufactured in Kathmandu by local technicians. The form of electrical generator for this phase of the NLP was chosen such that it would be affordable, simple, safe, dependable, multi-functional and independent of sun, wind and rain.

Each village dwelling was provided with a single 6WLED lamp including a wall/roof fitting, a 12 V sealed lead acid battery, and adequate wiring. Six to eight households share each PG with one householder being responsible for its well-being. Data from testing confirms that approximately 30 minutes or less of slow pedaling is sufficient to meet the daily lighting needs of each home which is roughly between four and five hours per night. Each PGS recharges four SLA's simultaneously and this number could be easily and safely increased.

The generator consists of a locally manufactured flywheel, low RPM DC motor/generator, voltage regulator, digital multimeter, and poly-fibre belt. Each generator was also equipped with an attachable rotating grinding stone, much appreciated for sharpening tools. Also provided was a small chuck, used for holding small carving tools or whatever else the imaginative villagers could think of. The Thalpi PHG system implementation was relatively straightforward in that

Table 2: Description of NLP Year 2000 Projects

Location	Thulo Pokhara	Raje Danda	Manang	Thalpi	Bhaktapur	Norung
Power source	PGS	PGS	Ghatta Generator	Pico Hydro (200W)	220 AC	Centralized Solar
# of Homes	23 (+Gompa & School)	31	15	28	12 lamps total	45
LED's/ Lamp	6 (homes) 9 (others)	6	9	9 + 6	Varies (3 to 9)	9
NGO	NLP-Nepal School Projects	NLP-Nepal School Projects	NLP-N. Eagle	NLP-KCST Jumla: A.Zahnd & S.Craine	NLP-Child Haven Int. (Canada)	NLP - A. & F. Harckham (Canada)

Figure 5: The proud custodians of the Thulo Pokhara Pedal Generators about to take them home. Photo by DI-H.

the power source already existed and was reasonably well regulated so all that was required was a dependable 220 V AC to 12 V DC converter [5]. The villagers dug all the trenches, laid all the plastic pipes to protect the electrical wiring between the generator and the village and wired their own homes.

Table 2 illustrates typical village home lighting assemblies and Table 3 the total projects that the NLP was involved in for 2000.

Table 3: Typical WLED Home Lamp Assemblies & Power Requirements

Fixture	Type	Application	Power
Flexible Table Lamps	3 WLED	Reading	0.22 W
Fixed type, box shaped	2 WLED	Torch	0.15 W
Ceiling Light	6 WLED	Main Room	0.43 W
Ceiling Light	9 WLED	Main Room	0.65 W

11.0 Discussion

With respect to sustainable development and long-term viability, there is reason to believe that the NLP-initiated projects have set the trend to follow. The above data does not begin to demonstrate the substantial savings that accrue from the durability/longevity of WLED lighting. Initial transport and installation costs comprise 99 % of the predicted costs for WLED's, whereas owners of less capital-intensive forms must endure the cost of continual replacement, on an unpredictable basis with costs varying according to market fluctuations. One would have to make a concerted effort to damage a WLED and evaluations made by high altitude climbers on Everest, Sherpa guides and field-testing all indicate that the WLED torch can withstand damage that would destroy conventional halogen/incandescent bulbs installed in the same assembly. Fixed interior lighting would not likely be subjected to such conditions.

The relatively high initial capital cost for WLED's will drop precipitously through the next five years, principally through competition and increased output achieved by economies of scale. It is likewise predicted that WLED output power per dollar will increase accordingly.

Tables 4 and 5 illustrate approximate costs for typical lamps and batteries for a sample village of 100 homes.

12.0 Ongoing Research and Development

To reach a greater number of households, schools and workplaces (Figure 6) the NLP has founded and funded a company (Pico Power Nepal) in Kathmandu for the development, production, and marketing of WLED technology and its concomitant power generation systems. The advantages of domestic Nepalese production include reduced costs, local employment and training, incorporation of local market knowledge, and reduced vulnerability to currency fluctuation or regional instability. In keeping with our philosophy regarding gender equality the CEO of PPN is a 21-year old woman! In Nepal, WLED technology is emerging as an important component of rural electrification: no other technology can provide light for as many people for the same power input. A notable advantage to the adoption of WLED lighting for torches and homes is environmental since the significantly increased battery life reduces waste including toxic heavy metals found in single-use and rechargeable batteries, a serious problem in developing countries like Nepal where disposal facilities are primitive or non-existent.

A team of fourth year mechanical and electrical engineering students at the University of Calgary are currently designing a new low-flow, high head Pico Hydro Generator and it will be field tested in Nepal in 2001.

Table 4: Approximate calculations for different lighting-only plant (Costs in Nepali Rupees, NRs)

Lights	Cost per lamp	Cost of lamps for all households	Total capital cost for all households	Power cost per lamp	Battery cost per lamp	Total capital cost per lamp
Bulbs	60	17,850	1,120,350	3675	-	3,735
AC Compact Fluorescent	1040	312,000	721,500	1365	-	2,405
DC Fluores-cent	603	180,900	946,543	945	1607	3,155
DC WLED's	1750	525,000	610,071	105	179	2,034

$1.00 Canadian = 46 Nepali Rupees (NRs)

Table 5: Approximate Calculations for Different Battery Costs in Nepali Rupees

Type of Lights	# of households	# of lamps per household	Power required per household	Cost of power for all households (NRs)	Battery Cost per household (NRs)
Bulbs	100	3	105 W	1,102,500	-
AC Compact Fluorescent	100	3	39 W	409,500	-
DC Fluorescent	100	3	27 W	283,500	4,821
DC WLED's	100	3	3 W	31,500	536

Figure 6: Dave and the lama of Thulo Pokhara in the Gompha. (We do not have his name unfortunately). The PGS is seen near the right hand bottom of the photo and the lamps are in the top left hand corner.

Photo by Gregor Irvine-Halliday.

Such generators will allow power production at sites previously considered unsuitable for hydro development. PPN designed and manufactured the entire WLED lighting system for the Norung project. PPN is also pursuing research into commercially viable spin-off technology to fund rural development and numerous designs have been developed for both Nepali and international markets.

13.0 Conclusion

The year 2000 has been exciting for the Light Up The World (LUTW) - NLP with Thulo Pokhara and Raje Danda being the first two communities to be permanently lit by WLED lighting, and the Thalpi PHG powered system was the icing on the cake. Foundational projects have successfully gone ahead with the collaboration of Nepalese and international Non Government Organizations (NGOs), and feedback has thus far been very positive. Additional villages are being selected for illumination and there is no shortage of requests - only a shortage of funding!

The complete cost to light a Nepali home by PG is approximately $100 Canadian and this can be most definitely reduced significantly.

The future expansion of activities in Nepal is certain, while NGO's and businesses from India, Bangladesh, Africa, South America and other developing regions have expressed their desire to introduce WLED technology to their nations. LUTW is attempting to address this interest while continuing its pioneering efforts in Nepal.

If any incentive to continue this work were required (which it isn't) one only has to remember the words of a villager who visited Thulo Pokhara days after it was lamped: “A foreigner has come and made Thulo Pokhara heaven.”

It is a fundamental obligation for us in the so called developed world to assist those in the developing world to raise their standard and quality of life, by their own efforts and in the manner which they chose - it is also our privilege.

14.0 Acknowledgments

Sincere thanks go to: Alex Zahnd and Ghanashyam Ranjitkar for their timely advice and unselfish assistance in lamping Jumla; the Nichia Corporation for their extremely generous donation of 2000 WLEDs for the NLP; the Nepal School Projects; the UofC ECE technicians John Shelley, Frank Hickli and Rob Thomson; the University of Calgary for the NLP research grant and the citizens of Calgary for their very generous donations to the LUTW Fund. Also very much appreciated were Jenny Irvine-Halliday's nimble fingers in helping to build the Thulo Pokhara and Raje Danda WLED lamps and of course the banks for allowing us to overdraw all of the Irvine-Halliday's credit cards.

15.0 References

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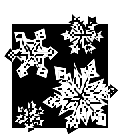

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Dave Irvine-Halliday, graduated with a B.Sc. from Dundee and a M.Sc.and Ph.D. degrees from Aberdeen Universities in Scotland.

He emigrated to Canada in 1970 and joined BNR in Ottawa. After 5 years, he moved to Edmonton and worked for AGT for 4 years, and then moved to Calgary University where he has been for the past 18 years. His research topics are in Fiber Optic Sensors and Communications, and Biophotonics. His present research projects include: the networking of fiber optic electrical current sensors; the use of the fiber optic gyroscope in the precision drilling of horizontal oil and gas wells; the optical properties of biological tissue with regard to the measurement of strain and the healing process, and the "Light Up The World -Nepal Light Project".

Dave has been a mountaineer and trail runner for nearly four decades - "You can never have too many mountains". Halliday@enel.ucalgary.ca

Stewart Craine graduated from Wollongong University in 1998 with first class honours in civil engineering, as well as a second degree in applied mathematics.

He has been in Nepal for 15 months as a rural electrification engineer, focusing on micro hydro installations. This work is with the Australian Volunteers International program. The focus of his work is to reduce the cost of rural lighting for villages in Nepal and other developing countries. This work focuses on the use of energy efficient lighting such as white LEDs, compact fluorescent lamps (CFLs) and battery charging.

Stewart also enjoys running around big mountains, taking photographs, eating at cheap restaurants and sampling the Nepali wines. stewart@wlink.com.np

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His technical experience covers the following: since 1972 as Proprietor: 'Radio & Electronic Works' 1975; Design Engineer for Solar Photovoltaic system manufacturer 'Wisdom Light Group (P) Ltd.' 1995-1997; Production Manager for Solar Photovoltaic system manufacturer 'Wisdom Light Group (P) Ltd.' 1997-1999; Technical Supervisor & Executive partner in 'Pico Power Nepal (P) Ltd.' 2000 to date. Since 1989, he is also the Assistant Administrator for the 'Institute of Engineering, Pulchowk Campus'. muniraj@wlink.com.np

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