ADAPTIVE ROADWAY LIGHTING

Don McLean—DMD & Associates Ltd

Introduction

Recent blackouts in eastern North America as well as an increasing demand for power have opened all our eyes to what we often take for granted – reliable electricity. Unfortunately we can't continue using electricity at will without considering an increase in power conservation. We must seek out new and innovative ways to reduce our power demands to ensure future generations can benefit from what we have enjoyed – uninterrupted delivery of reliable electrical power. In fact all communities should be strongly encouraged to find innovative ways to save power.

The operation of street lighting consumes a significant amount of electricity, particularly when considered on a provincial, state or national basis. Reducing the amount of energy consumed by street lighting has the potential of providing significant savings to owners and reducing the burden on taxpayers and utility rate payers.

To reduce power and improve overall efficiency new technologies and concepts must be considered

Adaptive Lighting

The need to reduce power consumption has brought on significant research and product development in the world of roadway lighting. The term "Adaptive Lighting" is now being used to define the concept of varying lighting levels to suit activity levels. Simply put by varying the levels of lighting during non peak periods significant power can be saved.

To understand this concept of varying lighting levels one must understand how street light levels are typically determined. Street lighting levels are established through engineering design by applying minimum criteria based on the type of roadway and the level pedestrian conflict/activity. In North America, the Illuminating Engineering Society of North America (IESNA) uses the term "pedestrian conflict" in RP-8 Recommended Practice for Roadway Lighting, while the Transportation Association of Canada's Guide for the Design of Roadway Lighting uses the term "pedestrian activity," for roadways with sidewalks, although the application is identical to the IESNA. The higher the level of pedestrian conflict/activity, the higher the level of lighting recommended. The highest pedestrian conflict/activity level for an area or segment of roadway is used to establish the minimum lighting levels for the portion of roadway under consideration. Once the minimum level is established, street lights have traditionally provided that level of lighting throughout the hours of darkness.

Figure 1 below shows Table 2 from IESNA RP-8. The table defines pedestrian conflict as high, medium or low. A high pedestrian conflict will have a 100 or more pedestrians, a medium 11 to 99 pedestrians and a low under 10 pedestrians over the one–hour period with the highest average annual nighttime pedestrian volume. As one can see from Figure 1 illuminance levels vary greatly depending on the pedestrian conflict.

Road and Pedestrian Conflict Area		Pavement Classification (Minimum Maintained Average Values)			Uniformity Ratio	Veiling Luminance Ratio
Road	Pedestrian Conflict Area	R1 lux/fc	R2 & R3 lux/fc	R4 lux/fc	E_{avg}/E_{min}	L_{vmax}/L_{avg}
Freeway Class A		6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Freeway Class B		4.0/0.4	6.0/0.6	5.0/0.5	3.0	0.3
Expressway	High	10.0/1.0	14.0/1.4	13.0/1.3	3.0	0.3
	Medium	8.0/0.8	12.0/1.2	10.0/1.0	3.0	0.3
	Low	6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Major	High	12.0/1.2	17.0/1.7	15.0/1.5	3.0	0.3
	Medium	9.0/0.9	13.0/1.3	11.0/1.1	3.0	0.3
	Low	6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Collector	High	8.0/0.8	12.0/1.2	10.0/1.0	4.0	0.4
	Medium	6.0/0.6	9.0/0.9	8.0/0.8	4.0	0.4
	Low	4.0/0.4	6.0/0.6	5.0/0.5	4.0	0.4
Local	High	6.0/0.6	9.0/0.9	8.0/0.8	6.0	0.4
	Medium	5.0/0.5	7.0/0.7	6.0/0.6	6.0	0.4
	Low	3.0/0.3	4.0/0.4	4.0/0.4	6.0	0.4

Figure 1 – IESNA RP-8 Table 2.

Pedestrian conflict/activity levels do not necessarily remain constant throughout the hours of darkness, and in most instances the numbers of pedestrians present in a given

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area will be dramatically reduced in the late night and early morning hours when businesses are closed. Numbers of nighttime pedestrians may also be reduced based on the days of the week (weekday vs. weekend), seasonal factors, and other predictable dynamics. During hours of reduced pedestrian conflict/activity, the level of lighting provided could be reduced and while meeting recommended criteria for the actual level of pedestrians present.

Other areas where roadway lighting could be optimized are as follows:

- **Over-design -** Because lamp wattages are fixed for high intensity discharge sources (ie; 100W, 150W, 200W, etc) some roadways are over lighted to meet uniformity criteria, which is often the driving factor in the luminaire spacing. To match the required illuminance level a 160-watt lamp, which is not available may be required, so a 200W or 250W lamp is used thus resulting in higher lighting levels than what is required. By varying the lamp lumen output varying wattages can be obtained thus saving power.

- **Maintenance Factors –** When roadway lighting is designed a light loss factor is applied. The main element of the light loss factor is typically the lamp lumen depreciation which will vary depending on the light source. When a lighting system is designed the lamp lumen depreciation applied represents the anticipated end of the lamp life. By adjusting the power to lamp and sensing the lamp output constant lumen output can be maintained thus saving power.

Adaptive Lighting Systems

Some manufacturers offer systems that can control, monitor and record the operating status of luminaires in a lighting system from a remote location using a desktop computer. In addition these systems can control the lumen output of the lamp thus allowing lighting levels to be varied at various times of the night. The systems typically use

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WESTERN PRAIRIE: Contact: Cory J. Bennett (W) 780-412-3837 (F) 780-412-3888 (E-mail) cbennett@epcor.ca miniature solid state control devices that can retrofit into a luminaire. The solid state devices can be used to access data and control the luminaire via wireless technologies.

These systems are typically designed with software to allow an owner to build a database of the asset and monitor performance on an area-wide basis. Additionally, luminaire locations can be identified by global positioning satellite (GPS) coordinates for easy identification, tracking and locating. With these system components in place, there is the potential to identify luminaire outages and schedule maintenance through the use of mapping software to identify and optimize maintenance routes. These systems have the potential to reduce operating costs by reducing power consumed and maintenance frequencies. As a result, they can have short payback periods.

While one might question the overall impact of dimming street lighting, it is estimated outdoor roadway lighting accounts for as much as 30 percent of the average municipality's electricity consumption throughout North America.

Why vary lighting levels in off peak periods? It has been estimate 64 million street lights exist in North America. Estimated power consumed in a year would be approximately 51 billion kWh. Just imagine 20% reduction in off peak hours. That's 5.1 billion kWh hours per year.

The concept of adaptive lighting (also referred to "dynamic lighting or DYNO") is being researched by others around the world. A summary of projects and research are as follows:

- **Dynamic Public Lighting (DYNO), Netherlands (2004) -** In the Netherlands, the origins of dynamic roadway lighting can be traced to the Energy Crisis of the 1970s. During that period, some luminaires were turned off to save energy. While there was an increase in accidents, it was not a large increase. Over the following 15 years, there was movement by the Netherlands to lower the lighting levels from 2 cd/m2 to 1 cd/m2, while at the same time retaining the recommended uniformity ratios. Since 1995, the Netherlands has installed and operated a dynamically lighted roadway that can be adjusted to any of three lighting levels, depending on the amount of traffic, time of day, and weather conditions. The low level is 0.2 cd/m2, the normal level is 1 cd/m2 and the high level is 2.0 cd/m2.

  The different light levels are obtained through the use of electronically controlled, dimmable HPS ballasts. To set a baseline for the dynamic road section, Dutch experts have collected and analyzed accident data.

  Unfortunately, the dynamic section was too short and the statistical sample size was too small to draw conclusions between the 1-cd/m2 and 2-cd/m2 light levels. In an evaluation of an extensive set of methods (inductive loop detectors, instrumented vehicles, video observations, questionnaires), it was concluded that, under low traffic volumes (less than 800 vehicles per hour) and favorable weather conditions, the low level (0.2 cd/m2) can be applied.

- **Dynamic Lighting—The Future of Motorway Lighting (2002) -** The research undertaken by University of Manchester (UMIST), England indicates that significant improvements in driver comfort are obtained where dimmable lighting was installed. While not specifically measurable, it is likely that general road safety is improved by reducing ocular stress, enabling motorists to remain more alert and reduce the risk of accidents.

  As the first motorway in the UK to incorporate traffic controlled dimming, the M65 project represents both a pioneering achievement and a model for future motorway lighting development. With ever-increasing pressure on public bodies to save energy and limit environmental damage, it is likely that dimmable lighting will become a much more common feature of our motorways in the future.

- **The Illuminating Engineering Institute of Japan: Volume 29 Number 1, April 2005—The Influence of Dimming in Road Lighting on the Visibility of Drivers -** This paper presents experimentation with observers, who were asked to assess the visibility of targets on the road surface under different levels of illumination (promoted by dimming). The paper notes dimming does not influence the visibility of drivers. The report concludes, luminous flux reduction must be done with good and homogeneous lighting installations otherwise road users may have problems of visibility and comfort.

- **City University of Hong Kong -** Through the support of a City University associated company, Energy Technology, a central dimming technology (patent pending) has been successfully applied to road lighting systems. It is suitable for applications both in indoor and outdoor large lighting systems such as roads and highways, parks and gardens, multi-storey car parks, public housing estates, industrial and commercial buildings, airports, hotels, universities, and sports stadiums.

  The central dimming control system has been tested in China since September 2004, registering an average electricity savings of 30%. "Not only can this technology reduce power consumption and pollution in China, it can be exported as a global technology from China," said Dr Chung. It is now being installed in a mainland city, Heshan, in Guangdong province, for controlling over 7000 street lamps.

- **Institution of Lighting Engineers in the UK—TECHNICAL REPORT 27 CODE OF PRACTICE FOR VARIABLE LIGHTING LEVELS FOR HIGHWAYS—Advice and information on dimming and enhancement of road lighting levels -** This Code of Practice defined recommendation for applying variable lighting technologies to roadway lighting systems.

North American Projects

One such adaptive lighting product, the Streetlight Intelligence (STI) Lumen IQ, was used on major road in the

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City of Prince George, British Columbia. The project was undertaken by DMD and Associates for BC Hydro, the local electrical utility, provider to determine the viability of this technology.

For this project the STI Lumen IQ was retrofitted into existing and new cobra head street light housings (refer to Figure 3). The Lumen IQ system was designed to vary lighting output, monitor lamp depreciation, sense and report outages and measure power usage. A copy of the detailed report for the Prince George project can be found on the DMD web site at www.dmdeng.com. The purpose of this paper is to define some of the features of the system installed in the Prince George Project.

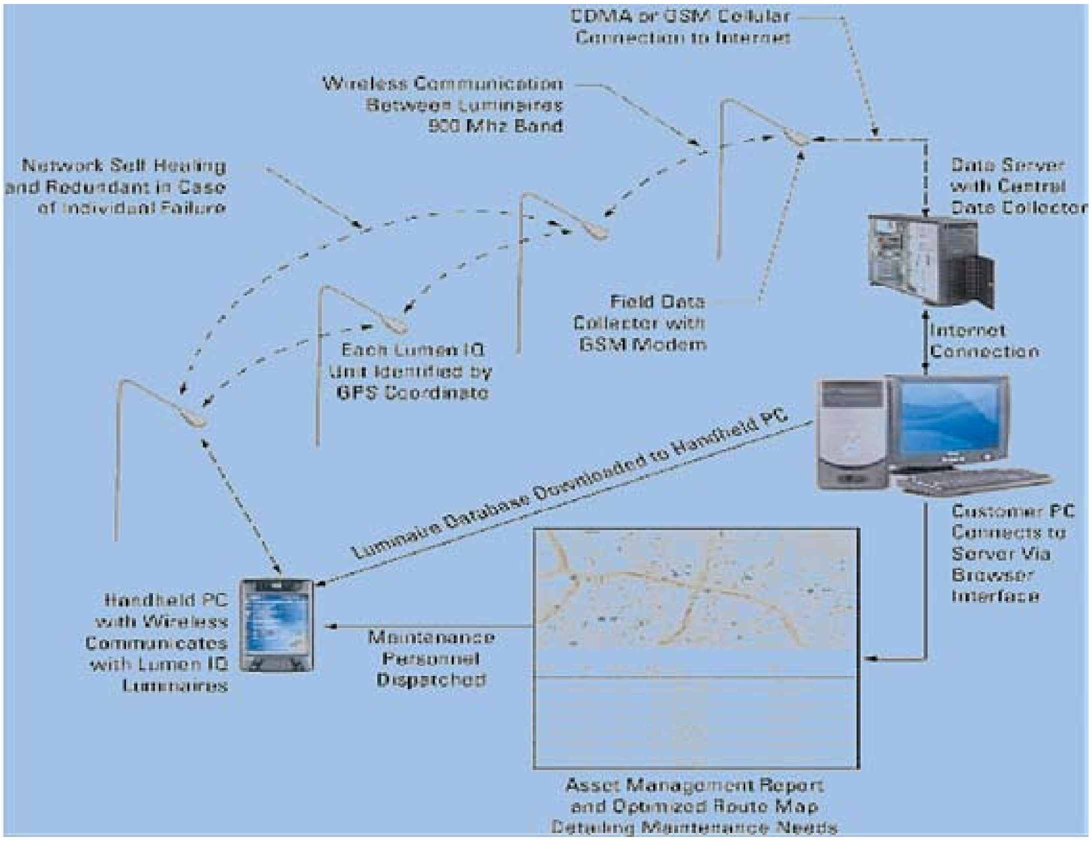

Figure 2 – Lumen IQ System

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The Lumen IQ, when implemented, allowed the light output of individual street lights to be varied at defined times of the night which reduced energy consumption. The street lighting control was provided from a central location over the Internet. Signals are sent from the Internet through wireless links to each luminaire. Figure 2 defines a basic overview of the system.

Additionally, the product allowed owners to monitor performance of individual street lights, assess energy consumption and savings provided by dimming, perform data collection and provide improved maintenance through the use of their software that provides data analysis and information integration.

A) Microprocessor B) WiFi Interface C) Lamp Lumen Sensor D) Day/Night Sensor

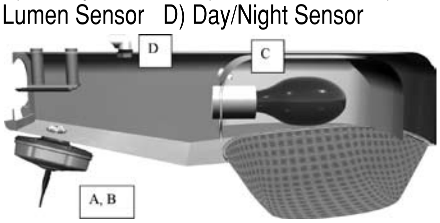


Figure 3 – Lumen IQ in Cobra Head Luminaire

From our investigation other products are available which retrofit into street lights to allow for the variation of lighting levels. The projects we have undertaken to date have focused on the STI product as a result of its many features.

From the Prince George pilot project we found the application of the STI Lumen IQ technology system provided a number of benefits to owners and the public. These benefits include significant energy conservation, reduction in obtrusive light during periods when the luminaires are dimmed, improved maintenance efficiency, electrical component protection for cycling luminaires, accurate measurement of power usage, and monitoring of equipment performance. Findings from the Prince George project were as follows:

- **Energy Savings -** The STI Lumen IQ technology provides up to a 40 percent reduction in energy consumption based on dimming. This has been verified through both independent laboratory and field testing. The Lumen IQ technology did not provide a 1:1 reduction in power consumption for a corresponding reduction in lumen output due to electrical losses of magnetic ballasts. Laboratory testing showed the following energy savings for various levels of dimming:

Percentage of Lumen Output	Approx. Percentage of Energy Savings
50%	40%
45%	36%
40%	32%
35%	28%
30%	24%
25%	20%
20%	16%
15%	11%
10%	6%

  The Lumen IQ dimming technology allows for 60 steps of dimming at approximately 1 percent increments. This allows the unit to dim the street light from 100 percent of output (no dimming) to 31 percent of full output.

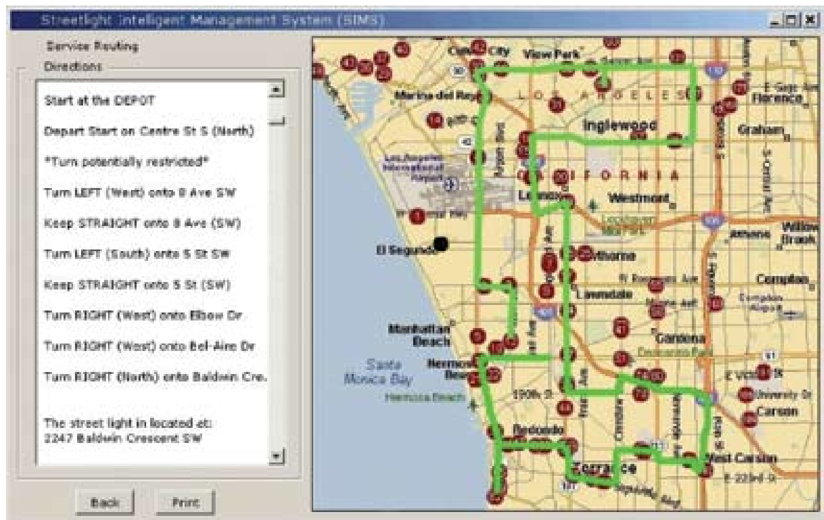
  Application of the Lumen IQ technology would allows the street light to operate at its maintained level for the entire maintenance cycle based on reduced power input and saving energy. To accomplish this, the Lumen IQ units are programmed to reduce the lamp lumen output when the lamp is new and as the lamp output depreciates over time the system increases the lumen output. The result being maintained lighting levels

- **Improved Maintenance Efficiency –** Monitoring the operation and performance of individual street lights from a desktop computer for conditions requiring maintenance will allow owners to provide maintenance in a more efficient manner. Individual street lights that are inoperable for any reason (electrical supply problem, component failure, knockdown, etc.) are identifiable using the Lumen IQ technology.

  In addition, the integrated mapping software, using Microsoft MapPoint server, is able to provide routing for maintenance activities. Figure 4 – Maintenance Routing Map shows an example map. An owner's current process is typically driven by logging trouble complaints from the public which may take many man hours per day in a large city. The database software not only marks the location of the luminaire, it provides information regarding the fault and optimizes the best route for repairs.

  When maintenance personnel arrive at the trouble call site, the flashing LED on the bottom of the luminaire allows for easy identification in daylight, and through use of a handheld device the that contains maintenance and asset information, the maintenance personnel can switch the light on to observe its operation.

Figure 4



- **Electrical Component Protection for Cycling Luminaires -** A key feature of the STI Lumen IQ product is the ability for the individual unit to turn off a lamp that is experiencing cycling, reducing negative impacts on other components of the street light (ballast, capacitor, igniter, etc.). This feature is provided by internal algorithms built into the Lumen IQ microprocessor unit that sense the characteristic electrical feedback associated with cycling. If cycling is detected, the Lumen IQ unit turns off the street light, energizes a flashing LED indicator visible from the street, and transmits a flag to the server noting the state of the luminaire and that it has been shut off due to cycling.

- **Accurate Measurement of Power Usage -** Most street lights in North America are provided power on an un-metered (flat rate) basis, with power charges based on the hourly energy consumption of the devices for approximately 4100 hours of use per year. For un-metered street lights, the STI Lumen IQ technology allowed for accurate measurement of power consumption regardless of the state of the street light (dimmed or undimmed). Once accepted by utilities as an accurate means to measure power consumption, owners will be billed for power actually used, taking full advantage of the energy saved. Use of this technology will end the shortcomings

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and abuses of the flat rate system, and make the full financial benefit of dimming available to owners. Power consumption data gathered by the Lumen IQ units and concentrated into the database will be available to the power company by online access through a web browser interface for billing purposes.

- **Equipment Performance Data** - Because detailed records are kept with respect to individual street lights as measured by an accurate photoreceptor unit, and date-logged activities, the database of power use, lumen maintenance and other factors will serve as an accurate picture of the performance of luminaires, lamps and other components in the field. This information was not previously available and will allow them objectively compare the performance of products, track knockdowns and other maintenance problems, and provide for other analysis that may be specifically relevant to design, operations, and maintenance.

As a pilot project for a new technology, numerous measures were developed to evaluate the success of the project, including the following:

- **Testing** - Under laboratory and field conditions the Lumen IQ was tested and met the performance requirements.
- **Public Feedback** - The public was informed about the project, and public comments were monitored for both positive and negative feedback. To date no negative comment has been received.
- **Traffic Impacts** – Night traffic has been assessed and functions the same before and after the project

Key Considerations

Engineering expertise is needed in the application of and adaptive technology. Experienced roadway lighting designers should be able to assist owners in choosing the sites best suited for the technology. Key considerations are as follows:

- **Development of Design Criteria** - Establish design criteria for the proper application of dimming in line with standard practice for the jurisdiction who own the road system. The design criteria would establish lighting levels and requirements.
- **Inventory of Existing Facilities** - An inventory of existing facilities will be required including pole spacing, roadway classifications, pedestrian conflict levels, existing lighting levels and uniformities, configurations, etc.
- **Undertake Lighting Calculations** – Computer lighting calculations may be necessary to establish existing lighting levels.
- **Development of Cost Benefit Analysis** – Undertake a cost benefit analysis to determine payback on investment. In the case of the Prince George project the payback was approximately 7 years. Payback will typically be less for new installations. The greatest impact on the payback will be energy rates so payback will vary from area to area depending on the cost of power.
- **Verification and Testing** – As new technologies are developed and brought to the market it is recommended independent testing and verification be undertaken.
- **Master Planning** - Because communities and roadway networks are complex, development of a lighting master plan is recommended. The master plan will define how adaptive lighting would be applied, and coordinate the retrofit of existing systems and new installations. In general, the application of adaptive lighting to new installations (new roadways or new lighting in conjunction with roadway improvements) should be prioritized to take advantage of energy savings, while retrofitting existing lighting may depend on a number of factors.
- **Utility Agreements** - Because most street lighting in North America is

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NEW PRODUCTS . . . *Continued from page 51*

Reno A & E Releases Automatic Vehicle Identification (AVI)

Reno A&E is a leading manufacturer of traffic control devices, including reliable inductive loop vehicle detectors. Inductive loop vehicle detectors are utilized in many different types of vehicle control systems including: Traffic signal controllers, Railroad grade crossing controllers, Gate operator controllers and Overhead door controllers.

Reno A & E is pleased to announced the release of our Automatic Vehicle Identification (AVI) systems for controlling vehicle movement into and out of secured areas controlled by gates, barriers, etc. Vehicles equipped with a Reno A&E low frequency digitally encoded AVI transmitter emit a short-range signal from the vehicle to the in-pavement loop located near a gate or barrier. When the transmitter is above the in-pavement loop the low frequency digitally encoded signal is coupled to a Reno A&E AVI receiver, which is an auxiliary component of the gate operator equipment. The signal from the AVI receiver provides hands free operation for opening gates. Each vehicle equipped with a Reno A&E AVI transmitter will automatically open gates equipped with a Reno A&E AVI receiver, thus providing immediate access without delay. This insures emergency vehicles respond to calls in a minimum amount of time.

Reno A&E AVI technology has been operating reliably in the Las Vegas Valley for over fifteen years. The AVI system has, and continues to, insure Las Vegas Valley Fire Departments with no delay access through gates. The Reno A&E AVI system minimizes response time for emergency calls when emergency vehicles are required to enter controlled access areas.

Reno A&E AVI technology reliably tracks individual vehicles at specific locations. The City of Los Angeles uses this technology to identify Rapid Buses at various intersections within the City of Los Angeles. Each Rapid Bus is equipped with an AVI transmitter coded with the bus number. When a Rapid Bus travels through Los Angeles intersections equipped with AVI Receivers the AVI transmitter is read and the Rapid Bus location is immediately known at the Traffic Management Center. If a Rapid Bus is behind schedule the traffic signal system can modify signal timing, therefore assisting the Rapid Bus in getting back on schedule.

Reno A&E AVI technology is used for controlling fuel dispensers. Inductive loops placed in the pavement near fuel dispensing pumps prevent unauthorized vehicles from obtaining fuel. The in-pavement loop, connected to the AVI receiver, requires an authorized code from a vehicle's AVI transmitter before the fuel dispenser can be unlocked and dispense fuel.

The Reno A&E AVI system has many different and exciting applications!!

The Reno A&E technical support team offers assistance in: Understanding product features, capability, and operation, Applying Reno A&E technology in solving application requirements.

The rugged Reno A&E AVI transmitter is permanently mounted to the underside of vehicles and is powered from the vehicle's electrical system. The AVI transmitter requires no adjustments or setup. Problems of forgotten codes and lost or stolen hand-held devices are eliminated.

For more information contact Reno A & E, 4655 Aircenter Circle, Reno, NV 89502-5948 Tel: (775) 826-2020, Fax: (775) 826-9191 sales@renoae.com or www.renoae.com.

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un-metered, an agreement between the utility company and the owner will normally be required for the owner to receive the monetary benefit associated with dimming. The agreement should provide for the utility's acceptance of the Lumen IQ calculation of power consumed and utility company access to the metering aspects of the luminaire database for verification.

Conclusions

With today's wireless world new emerging technologies like adaptive lighting are being brought to the market. Such technology can reduce energy consumption, and improve operations and maintenance. We encourage those who design, own and operate roadway lighting systems to source out and apply such technology.

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Don McLean has 27 years of experience in the design of transportation-related lighting systems, traffic signals, and power distribution and control systems. Throughout his career, he has focused on roadway lighting and has participated in well over 4,000 roadway lighting projects. Mr. McLean is an active member of the Illuminating Engineers Society of North America (IESNA) Roadway Lighting and Outdoor Lighting Committees, the Transportation Association of Canada's (TAC) Traffic Operations and Safety Committee (TOMSC) and well as the CSA Luminaire Performance Committee.

As a member of the IESNA's Roadway Lighting Committee he is involved in the American National Standard Practice for Roadway Lighting (RP-8) and most recently authored the TAC Guide for the Design of Roadway Lighting.

He has developed numerous outdoor electrical and lighting standards in use today. Standards include those for design, product, construction and maintenance.

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