RASC
LIGHT POLLUTION
ABATEMENT PROGRAM

ROYAL ASTRONOMICAL SOCIETY OF CANADA
Light Pollution Abatement Program

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INTRODUCTION

Purpose of Meeting

The purpose of this booklet is to introduce the Royal Astronomical Society of Canada (RASC) and to present the issue of light pollution and its negative impact on the environment, then to suggest positive cost-effective solutions to reduce pollution while improving safety and security.

This booklet has been produced by the Light Pollution Abatement Committee (LPAC) of the RASC.

History of the RASC

The RASC received its Royal Charter from King Edward the VII in 1903. The National Office of the RASC is located in Toronto and co-ordinates the activities of over 3,500 members in 23 centres across Canada. It produces several publications that are distributed around the world.

The aims of the RASC are to promote and support astronomy and allied sciences. It does this by providing a single national organisation for both amateur and professional astronomers

Goal of the RASC LPAP

The goal of the Light Pollution Abatement Program (LPAP) is to reduce the present levels of light pollution in urban and rural areas by advising federal and provincial governments and departments, municipalities, communities and businesses on light pollution abatement.

LIGHT POLLUTION

Purpose of Outdoor Lighting

Proper outdoor lighting enhances the safety of citizens and increases the security of property. Outdoor lighting is used to illuminate roadways, parking lots, yards, sidewalks, public meeting areas, work sites, home and building exteriors. Good lighting increases the visibility of hazards, improves the safety of citizens and provides a sense of security in the community. Visibility can be compromised by light pollution.

Definitions

Light Pollution is the combined effects of glare, light trespass and sky glow. In some cases light pollution can actually reduce the safety and security it is intended to provide, since light may be directed where it was not intended.

Glare is the visual discomfort resulting from insufficiently shielded light sources in the field of view. The light source itself hinders a person's ability to see details not directly illuminated by the light. This degrades safety and security. One should see the hazards, not the light source.

Light Trespass is misdirected light that invades neighbouring property. It creates a nuisance by shining into bedroom windows and other areas. Light should be directed to where it is needed.

Sky Glow is produced by two phenomena. Natural sky glow is produced at night by emissions from gases high in our atmosphere. Artificial sky glow dominates the natural form in and around urban areas. It is caused by light scattered off dust and large air molecules over a city. This light was intended to illuminate the ground but, due to poor design, it was misdirected upward into the sky. It wastes energy and it obliterates the view of the night sky.

Sharp Cut-off Luminaire as used in this report refers to the amount of control the fixture has over the emitted light. It is defined as a luminaire that prevents all light from being emitted above a horizontal plane passing through the lowest portion of the unit. Further, it limits the amount of light directed within 10 degrees below the horizon to less than 10% of the total emitted light. There are two basic versions: flat glass cobra luminaires and shoe box or 'square pack' units. The term "luminaires" refers to the bulb and ballast, the fixture or enclosure, internal reflector (if any), flat plate window or lens (if any).

High Intensity Discharge (HID) lamps have very concentrated light sources. Typical High Pressure Sodium (HPS) and Metal Halide (MH) bulbs are about the size of a small fist. The source inside the bulb is about the size of the end of a small finger. This compact source is ideal for optics to carefully direct the light to exactly where it should go. However, where it goes and how much goes there depends on the design of the optics in the light fixture.

The Issues

There are five benefits from well-designed lighting:

a) it increases the safety of citizens;
b) it improves the security of property:
c) it reduces operating and maintenance costs;
d) it minimises energy use;
e) it can enhance property values.

In an age of fiscal restraint, limited financial resources and political pressure to improve safety and security, these issues are major concerns for progressive communities.

If outdoor lights are not properly selected and installed they can be expensive to install and will be costly to operate and maintain. Poor lighting can also reduce visibility, thereby creating hazards, and it can even reduce the security of property. Poor lighting can create an unattractive neighbourhood and it is harmful to the night environment as it affects the behaviour of ground animals and birds.

Poor lighting gives rise to the following issues.

Glare

Poorly selected and installed lighting causes a glare that can severely hamper the vision of drivers, pedestrians and cyclists, thereby reducing the overall safety of citizens. Glare occurs when a source of light is viewed within our field of view. It makes our eyes less sensitive to the lower illumination levels around the source.

Poor lighting reduces security by producing dark shadows that can mask danger. It can also reduce the visibility of crimes-in-progress since vandals and thieves do not need their own lights. Officials in Tampa, Florida have reduced vandalism by turning off lights! Without lights, vandals had to use flashlights that were more easily detected by neighbours and patrol cars.

Light Trespass

Poor lighting can shine onto neighbouring properties and into windows. This reduces privacy, it can hinder sleep and it creates an unattractive neighbourhood. It is becoming less politically acceptable to tell citizens who complain about the situation to stay away from their windows or to keep their curtains closed from dusk to dawn.

Sky Glow

Up to 30% of the light from unshielded luminaires is directed upwards creating adverse effects over our cities and towns. It affects the behaviour of nocturnal animals and birds. The very poor illumination of standard rural 'Yard Lights' wastes even more light. Sky glow symbolises wasted energy and it washes out our view of the night sky, resulting in the loss to the viewer of such natural wonders as the stars and the Milky Way.

An important natural resource and part of our human inheritance is being taken from our children. However, less sky glow means that future generations will be able to enjoy the beauty of the rural environment and our night skies. Children will be inspired, as were past generations, to learn

about our world and sky.

The work of professional and amateur astronomers can be ruined by sky glow as portions of the sky become contaminated by misdirected urban and rural lighting. Operating costs for observatories have increased as dark sites are invaded by artificial sky glow from growing urban centres.

Sky glow can be reduced if artificial light is directed down to the ground. By reducing horizontal light which also contributes to glare and light trespass, artificial sky glow will also be reduced.

Energy Waste

Light is a form of energy. It is wasted when it does not shine where it is needed. Poor lighting gives the public the impression of wasted energy, thus unnecessarily inflating operating costs and environmental pollution from extra transmission lines and power plants. American studies have identified over a billion dollars worth of wasted energy each year because of the light that shines into the night sky. On the local level, a smaller community, with a lower tax base, can have significant savings if they adopt efficient lighting and insure that it is properly installed.

ADVANTAGES / DISADVANTAGES OF VARIOUS TYPES OF LIGHTING

Table 1 Qualitative Comparison of Lamps

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LAMP TYPES	ADVANTAGES	DISADVANTAGES
Low Pressure Sodium (LPS)	• lowest power consumption • relatively long lifetime • constant brightness over lifetime	• poor colour rendering • not in common inventory • poor light control (large bulb)
High Pressure Sodium (HPS)	• low power consumption • fair colour rendering • relatively long lifetime • good light control (small bulb)	• brightness decreases over lifetime • not available in low light outputs
Metal Halide (MH)	• good colour rendering • available from standard inventory • good light control (small bulb)	• less energy efficient than LPS • brightness decreases over lifetime • some colour change over lifetime • relatively short lifetime
Incandescent	• fair colour rendering • readily available in low wattage ratings	• poor energy efficiency

This table compares the qualitative virtues and drawbacks of the different types of lights that are in general use (high intensity discharge and incandescent lights).

To be complete, the table includes low pressure sodium and mercury vapour lights. The mercury

vapour lights have almost entirely been replaced with high pressure sodium or metal halide lights. The low pressure sodium, though apparently attractive in economic terms, are not in wide spread use. It is a monochromatic light source that makes colour recognition impossible and has caused law enforcement and security problems.

Also, their large bulb size makes it difficult to shield the light from unwanted areas and it is difficult to focus the light where it is wanted. The reason for this problem is that the light source is a long tube in which the low pressure sodium gas emits light. The large dimension of the light source is comparable to the size of the focusing optics, making precise control over the illuminated foot print very difficult.

It can be concluded from studying this table that the high pressure sodium lights offer the best overall performance. Their 'warm colour' approximates that of incandescent lights. Thus, if needed for aesthetic reasons, they are a good alternative to the much less efficient incandescent bulbs and are an alternative to the white colour metal halide light sources.HID lamps require a few minutes to warm up before they reach their full brightness. Therefore, incandescent lamps are used where "instant on" characterisitics are required when motion or infrared detectors are used to turn on the lights.

Table 2 Operational Costs of 100 Watt Lamps

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OPERATIONAL COSTS OF 100 WATT LAMPS

LAMPS	LIFETIME (hours)	ILLUMINATION	COLOUR [2]	COST [3] (operating)	COST [3] (maintenance)
LPS	18,000	0.315	0	$2.09	125%
HPS	20,000 [1]	0.513	30	$3.14	100%
MH	10,000	0.384	70	$3.14	150%

1. 1994 ***Cooper Lighting*** Study in Ottawa
2. >20 gives fair colour rendering. >70 gives excellent colour rendering
3. Based on American study

This table provides a numerical comparison of three types of light. The high pressure sodium seems to be the most economical of the three. The data has been drawn from two sources. A study of high pressure sodium lamps by Cooper Lighting in Ottawa reflects the reduced life that is caused by very cold winters.

The other costs have been drawn from American studies (Lighting Consultants, San Diego, Inc.) and are shown for comparative purposes only.

The colour rendering shows, in quantitative terms, the trade off between low pressure sodium, high pressure sodium and metal halide. Where very good colour rendering is required, metal halide lamps may be selected even though they are more expensive to operate.

Table 3 Cost Comparison of Luminaires

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COST COMPARISON OF LUMINAIRES

LUMINAIRE TYPES	DESCRIPTION	APPROXIMATE COST
Design without Cut-Off	Standard Cobra Head	$150 - 200 [1]
Visors (After Market)	GE, Cooper Fixtures	$45 - 55 [1]
Sharp Cut-Off Design	Flat Glass Cobra Head	$200 [1]
Sharp Cut-Off Design	Square Pack [2]	$250

1. February 1995 Prices
2. Better Light Control Permits Wider Pole Spacing

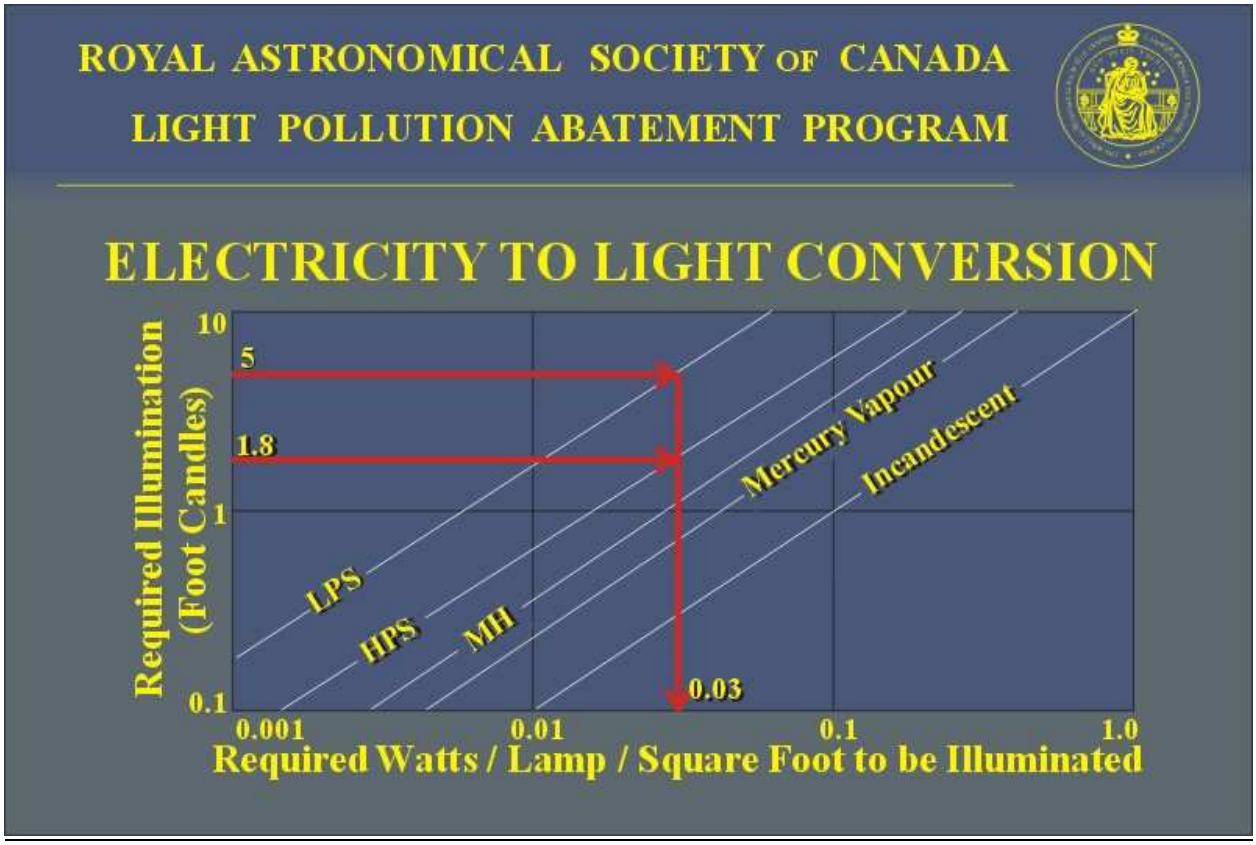
This table compares the approximate cost for various 150-watt luminaires. These costs are from quotes made by distributors in the Eastern Ontario area based on orders of a dozen or so units. Purchases of larger quantities will only slightly reduce the price. Costs of lower wattage fixtures will also reduce the price. The City of Ottawa pays about $70 for its 70 - 100 watt fixtures.

It would appear that the cost of flat glass cobra head type luminaires are essentially the same as the standard cobra designs. To put this in perspective, it should be remembered that the cost of an installation (luminaire, footing, pole, electrical wires above / below ground) is $500 to $5,000.

The use of shields

or visors reduces glare by shielding the light that shines above a horizontal plane that passes through the bottom of the fixture. In terms of the illuminated foot print, this reduces the light that falls far from the installation. However, the illumination at this distance from the pole is only about 1/100 that which falls under the lamp. Therefore, it has a negligible effect on the overall level of light distribution and the shield is very effective at reducing glare. The drawback of a shield is that it is must be correctly installed on each fixture and it does not focus the unwanted light to where it is needed.

Figure 1 Comparison of Electricity to Light Conversion Efficiencies



This figure compares the amount of electricity required to illuminate an area with different types of lamps. For example, doubling the illumination without changing the amount of electricity can be accomplished by changing the lamp and its ballast from high pressure to low pressure sodium, or from metal halide to high pressure sodium (approximately). The figure also shows, at a glance, the improvement in electrical efficiency by changing from mercury vapour and incandescent lights to sodium lamps.

Figure 2 Comparison of Illumination Foot Prints from Various Luminaires

These two figures compare the illuminated footprints of a standard cobra head design with two sharp cut-off luminaires (shoe box design and flat glass)

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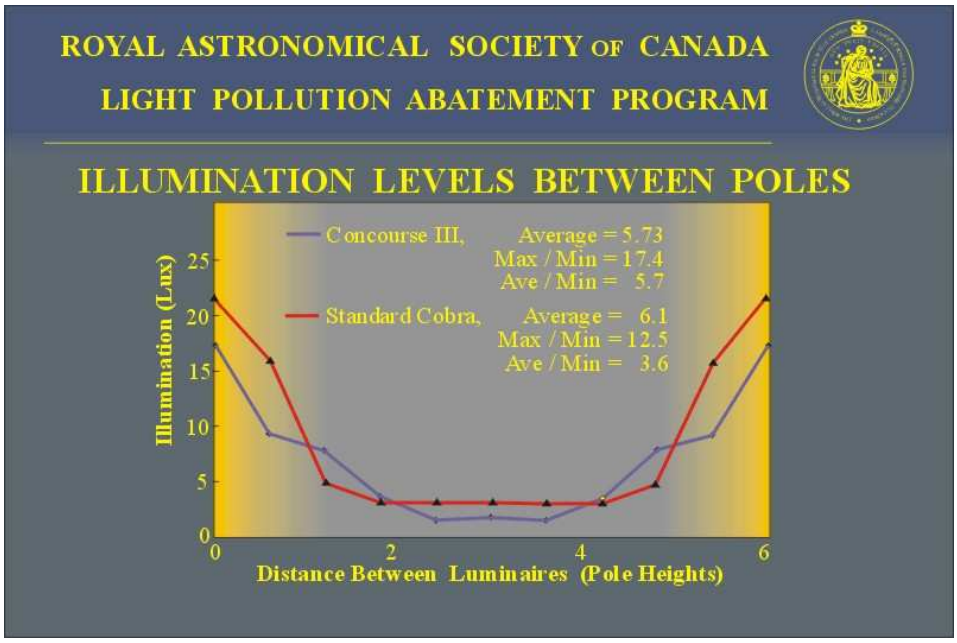
The optics for these luminaires were selected to provide the best roadway illumination. The sharp cut-off luminaires do not direct light out as far as the standard cobra, however, at a distance of three poles, the illumination level is already much less than 1/10 of that directly under the lamp and the slight deficiency is negligible.

A more useful comparison are the levels from one to two pole lengths from the lamp, since, along well travelled streets in the Ottawa area, installations are usually spaced about every five to six pole heights. The sharp cut-off luminaires have a larger useful illuminated area under the lamp than the standard cobra luminaires. Furthermore, the sharp cut-off designs provide good illumination of the sidewalk behind the pole. This can be exploited to reduce the need for additional installations for only pedestrian use. The nominal extra cost of the sharp cut-off luminaire may be rewarded with fewer installations.

Figure 3 Illumination Distribution for Various Luminaires



These figures are plotted with data from an Ottawa Hydro Study. Figure 3a shows that the sharp cut-off luminaire (Concourse III by Cooper Lighting) takes light from under the pole and projects it to the distance of one to two pole heights. The cost of this is a reduced level of illumination under the lamp and at mid-pole spacing.

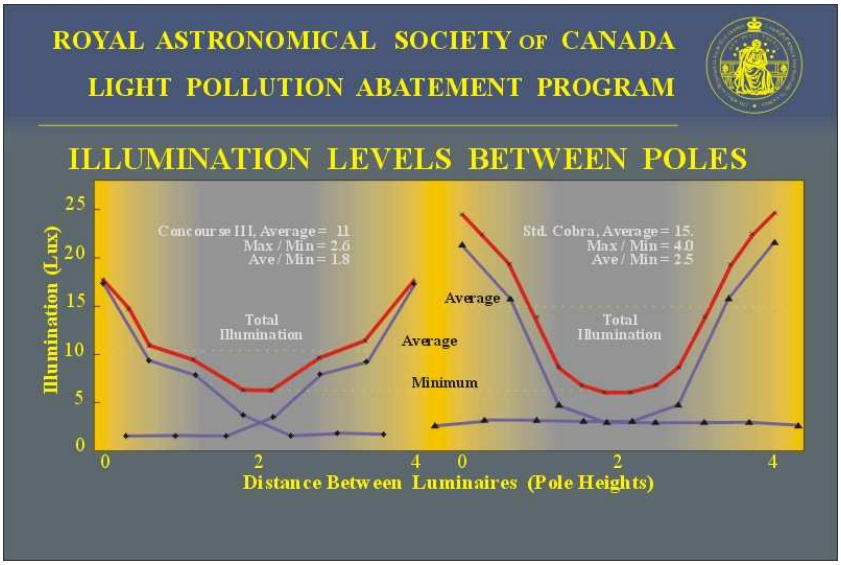


Figure 3b shows that for a shorter spacing, illumination levels are as good or better than for standard cobra luminaires.

SOLUTIONS

Lighting Design

The increase in our standard of living that began with the industrial revolution is continuing with today's proliferation of advanced technology. This is seen by many as a positive force for beneficial change but it has brought with it some negative effects.

In the past decade there has been increased awareness of the pollution of our air and waterways by toxic chemicals, and other deleterious refuse from our modern society. In addition to the chemical pollution, our sky is receiving light pollution from expanding towns and cities. Along with the physical effects of environmental pollution there is a psychological loss with the degradation of our natural environment. The combined effects of glare, light trespass and sky glow produce an artificial environment in and around our cities and towns. On the economic side, this can contribute to the devaluation of one's home and property by reducing its attractiveness to potential buyers.

Clearly, it would be irresponsible to do nothing while the situation deteriorates. Many progressive communities have started to take corrective action and the RASC is participating in this process.

There are as many sources of light pollution as there are luminaires: roadway, commercial signage, parking lot, residential property. There are three basic points that should be considered in the layout of roadway lighting.

1. Glare should be minimised to reduce masking hazards. This has been discussed in the sections on the *Purpose of Outdoor Lighting* and the *Lighting Design*.

2. Safe working conditions require a minimum amount of light. The installed lights must provide at least this minimum illumination over the specified area.

3. Lights should provide uniform illumination. Large variations in illumination can cause bright areas to effectively mask the areas under lower illumination, thereby masking a potential hazard.

The tables and figures included in this booklet provide a rational basis for decision making. They show the advantages and disadvantages of various types of lighting with other considerations such as the quality of illumination and the installation, operating and maintenance costs.

The selection of proper roadway luminaires has a major impact on the installation, operation and maintenance cost of the system. It will also define how well it improves the safety and security of the neighbourhood as well as how much it will enhance the appearance of the community. This section provides background information on the selection of appropriate luminaires.

The manufacturers of lighting systems are very happy to help their clients select the best products for their purpose. They have computer programs that will calculate the ideal spacing and power requirements for a system. The RASC suggest that they be consulted early in the system study phase to determine the most cost effective layout for a lighting project.

Solutions

Minimum Glare

Sharp cut-off luminaires prevent light from being emitted above the horizon. Further, it limits the amount of light that shines within 10 degrees below the horizon to less than 10% of the peak brightness. This reduces the amount of light that shines directly into the eyes of motorists and pedestrians as they look toward the light.

This requirement is not easily achieved with standard cobra head or simple light designs. A now classic example of bad lighting is the use of "Yard Lights". These spray light in all directions. Almost a third of the light is lost to the sky. Another third is directed at angles that cause extreme levels of glare leaving only 1/3 of the light to provide ground illumination. When placed along highways they create hazards by reducing the motorist's view of the road.

> *Therefore, unshielded luminaires should be phased out and replace with the safer shielded or sharp cut-off luminaires.*

Minimum Light Levels

Acceptable average light levels may not create a safe environment. Non-uniform lighting will dramatically affect the level required for safe lighting. The minimum acceptable level is approximately 1/3 the average illumination. This ensures that bright lights do not compromise visibility in adjacent areas with lower levels of illumination.

The minimum required light level depends on the illumination levels in the neighbourhood. An otherwise adequately illuminated roadway may appear poorly lighted if a business is opened with extremely high levels of illumination or with a few luminaires that produce a great deal of glare. "Adequate" lighting may require the town to 're-lamp' with much brighter roadway luminaires than previously required. This cost would be borne by the municipality. To avoid this re-lamping cost, after roadway lighting has been installed, future lighting must not be allowed to create a

hazardous condition through glare or excessive localised light levels.

> *Therefore, control must be exercised over the type of luminaires and the illumination level around businesses and homes to ensure that safe lighting is maintained. This should be done by a lighting by-law based on a light pollution abatement policy.*

Uniform Illumination

The standard cobra luminaires distribute light through the scattering of light in the bulbous lens beneath the fixture. The scattering process is, by its nature, somewhat random and poorly controlled. Typical illumination patterns under a standard cobra head show high levels of illumination and a rapid fall-off further away. A series of closely spaced installations (every two or so pole lengths) are required to provide uniform illumination along a street. High wattage lamps are required to maintain minimum levels of illumination between poles. There is little flexibility with the standard cobra head lens.

Sharp cut-off luminaires provide much more control over where the light is directed. These designs distribute the light more uniformly between the poles, providing more uniform illumination and allowing wider separation yet maintaining good illumination levels along the road. Fewer installations may be required with modern luminaires.

The sharp cut-off luminaires, such as the "shoe box" or square pack designs using reflective optics, focus the light onto the edges of the illuminated footprint. This is one of the exciting features of modern lighting technology. Indeed, these new luminaires are slightly more expensive than the standard cobra head but they effectively limit glare, place the light where it is intended, and fewer installations may be required thus reducing the overall system installation, operating and maintenance costs.

Most manufacturers market sharp cut-off luminaires that carefully control the placement of the illumination footprint. These products offer improvements over the standard cobra head design.

Cost Effectiveness

In this booklet the unit installation costs for outdoor lighting are considered to be constant since they will be approximately the same for the wiring (above or below ground), pedestals and poles (wooden, concrete or spun aluminium) regardless of the type of luminaire mounted on the pole. However some of the more expensive luminaires, with well designed optics, may result in a lower system cost by reducing the number of installations required for the same quality of illumination (minimal glare and good uniformity).

Sharp cut-off luminaires using reflective optics provide more uniform illumination on the ground. By reducing the maximum brightness under the lamp, a more pleasing and effective illumination can be achieved with the same or lower wattage lamp.

In addition to the glare they cause, the Yard Lights are wired to remain on from dusk to dawn. No one will notice someone passing across the yard unless people are awake. Although modern luminaires are more expensive, they may be purchased with motion sensors so that they turn on only when necessary and actually act as visual alarms to property owners, vandals and prowlers. The energy they save, even for incandescent bulbs, and security they offer, will pay for the

increased cost within a few years.

> *Therefore, we should actively encourage the use of motion detectors on security lights and discourage the use of "dusk to dawn" timer switches.*

RECOMMENDATIONS

The Royal Astronomical Society of Canada recommends the development of a lighting policy that will result in minimising glare, light trespass and artificial sky glow. Further, we recommend the adoption of sharp cut-off luminaires:

a) for all new exterior lighting including roadways, commercial signage, parking lots and buildings,
b) undertake a long term phased-in program as part of a program of on-going infrastructure renewal of retrofitting existing luminaires with more efficient sharp cut-off luminaires, and
c) develop a lighting by-law that will result in the reduction of glare, light trespass and artificial sky glow.

CONCLUSIONS

The purpose of outdoor lighting is to create a safe environment for persons that must be outside after dark and to increase the security of property. It is also used to enhance the architecture of the urban nightscape. This is accomplished by illuminating hazards and by discouraging theft and vandalism as well as illuminating surfaces to produce a "sense of place" for motorists and pedestrians. These goals are met by selecting appropriate luminaires that minimise glare and provide well defined illumination.

Luminaires are available to meet these goals. Further, products are available that provide cost effective solutions to the problems of glare, light trespass and sky glow.

Many communities have already upgraded their old fixtures with High Pressure Sodium lamps, but they have not upgraded to sharp cut-off luminaires or retrofitted older units with shields or visors that minimise glare, light trespass and sky glow. A cost study reveals that:

a) Retrofitting or installing new sharp cut-off luminaires, the average cost per luminaire need not exceed $200,
b) Existing luminaires may be retrofitted with shields (visors) that cost no more than $55 each,
c) Sharp cut-off luminaires are the least costly and most efficient means of correcting existing glare, light trespass and sky glow.

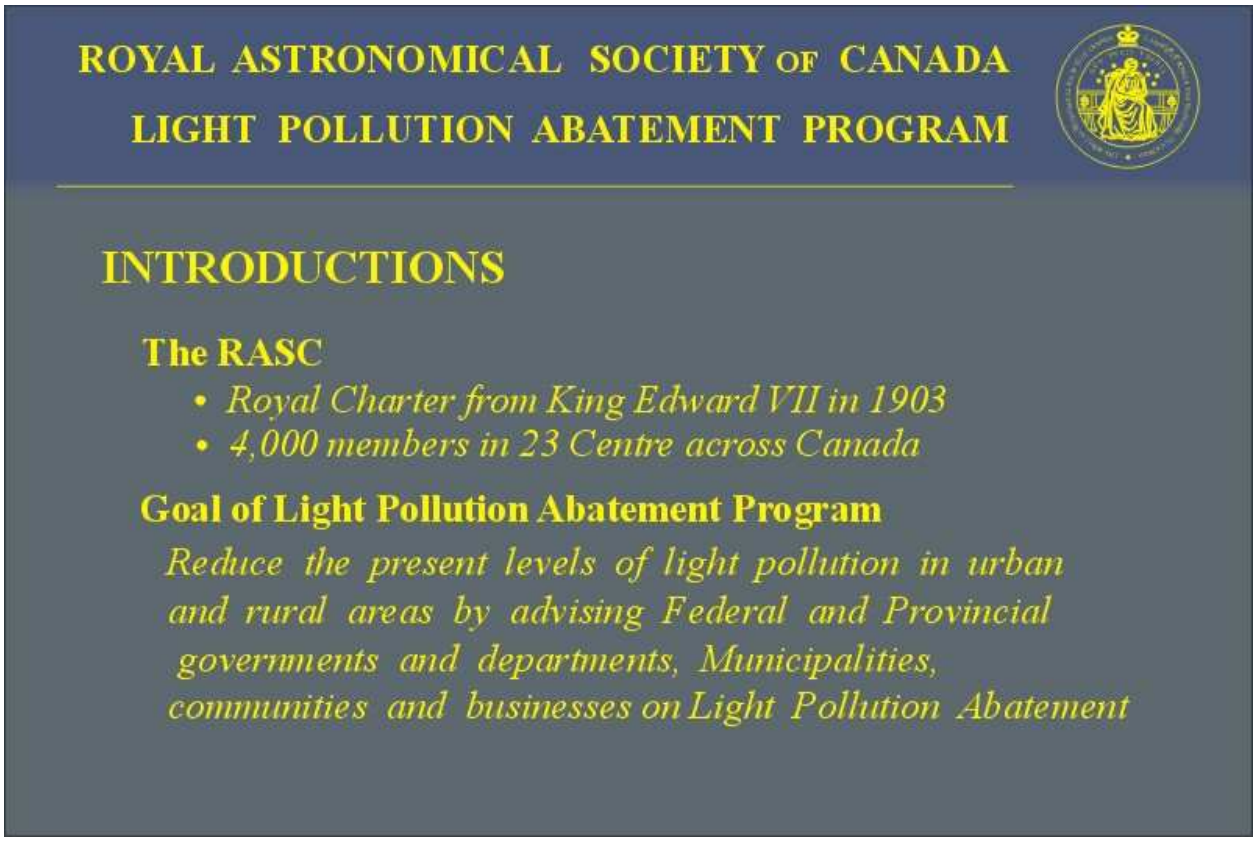
SLIDES FOR MEETING

This chapter contains a listing of the text presented in slide form at the meeting. (The Tables not included).

1. PURPOSE OF MEETING

- The RASC
- The Light Pollution Abatement Program
- Light Pollution Issues
- Solutions
- Recommendations
- Discussion

2. THE ROYAL ASTRONOMICAL SOCIETY OF CANADA



The RASC

- Royal Charter from King Edward VII in 1903.
- 4,000 Members in 23 Centres Across Canada and Abroad

Goal of Light Pollution Abatement Program

- Reduce the present levels of light pollution in urban and rural areas by advising federal and provincial governments and departments, municipalities, communities and businesses on light pollution abatement.

3.LIGHT POLLUTION – Definitions

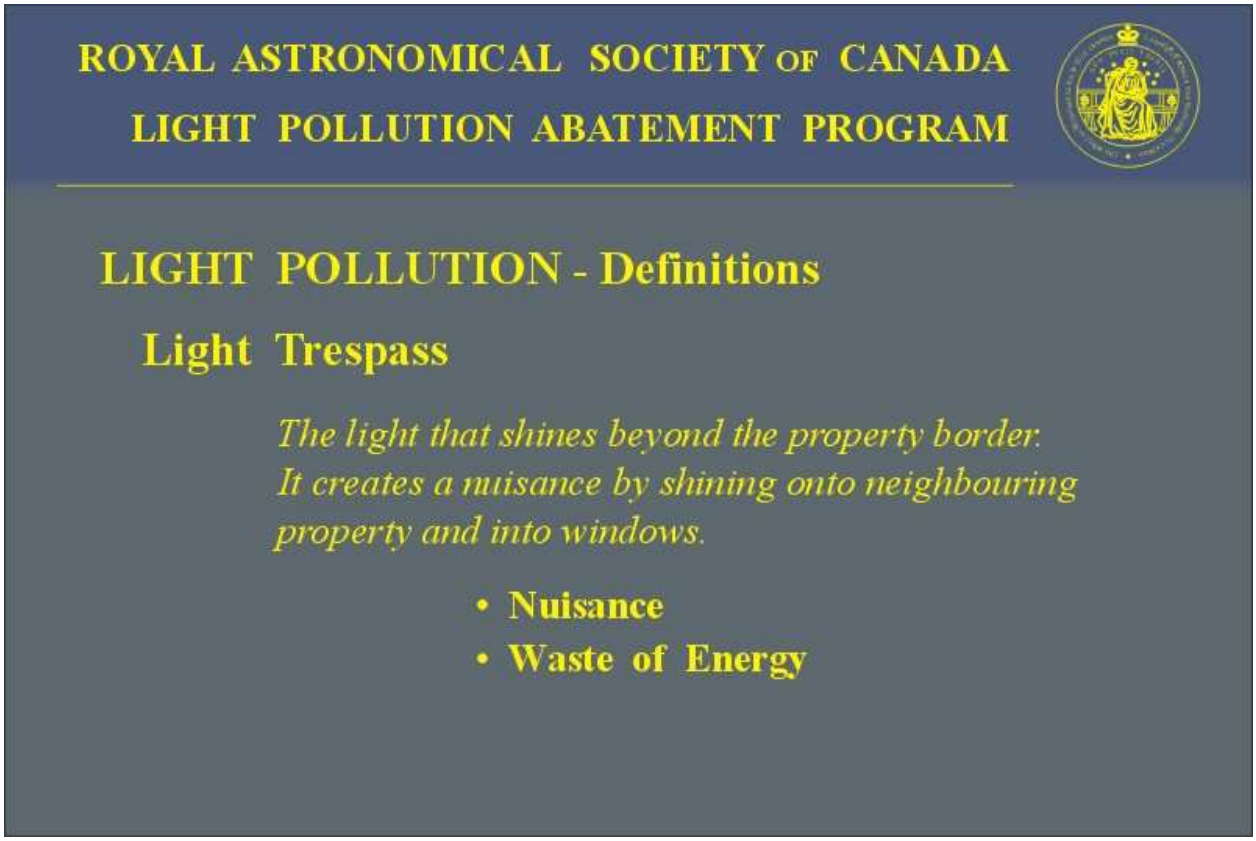
The Combined Effects of: Glare, Light Trespass and Sky Glow.

Glare:

The visual discomfort resulting from insufficiently shielded light sources in the field of view. It reduces a person's ability to see details not directly illuminated by the light. This degrades safety and security.

- Creates Hazards
- Reduces Safety

4. LIGHT POLLUTION – Definitions

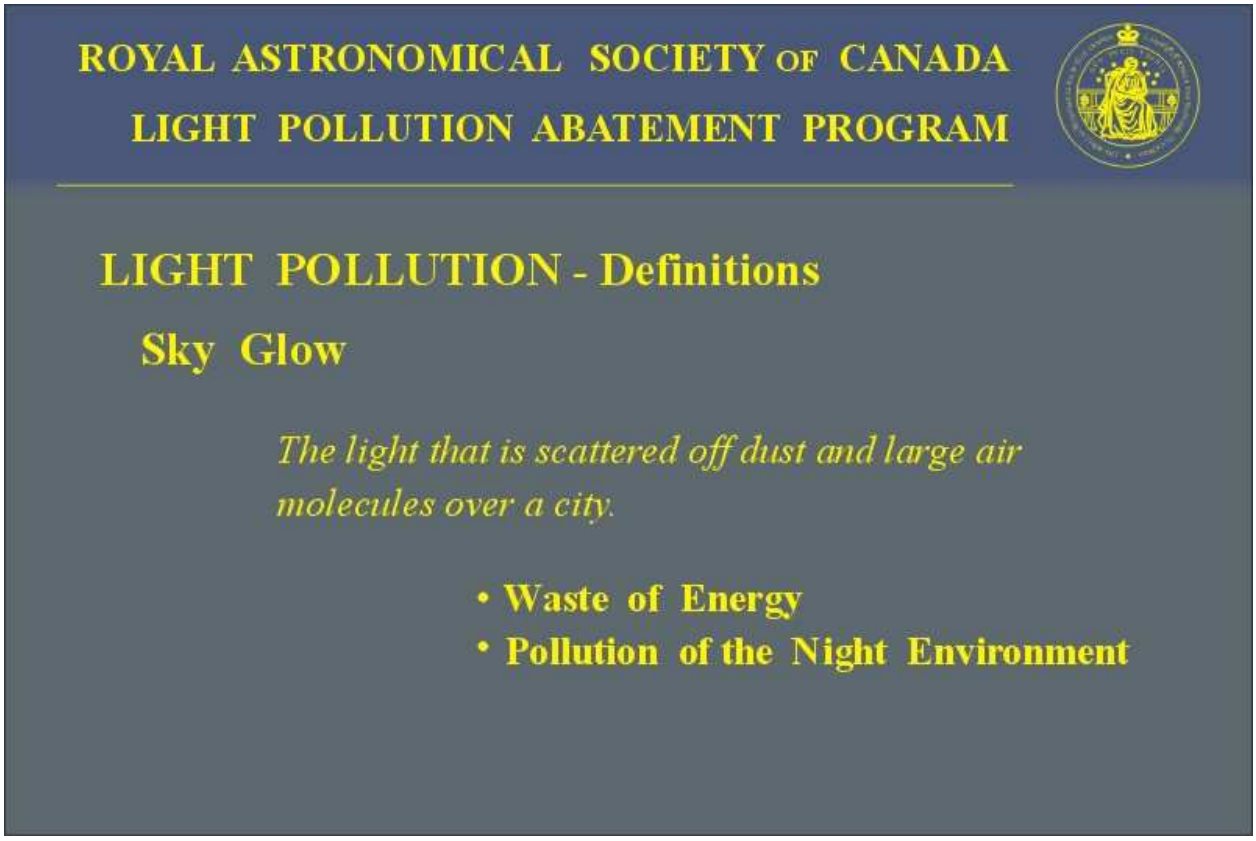


Light Trespass:

The light that shines beyond the property border. It creates a nuisance by shining onto neighbouring property and into windows.

- Nuisance
- Waste of Energy

5. LIGHT POLLUTION – Definitions



Sky Glow:

The light scattered off dust and large air molecules over a city.

- Waste of Energy
- Pollution of the Night Environment

6. LIGHT POLLUTION - Solutions

Minimising Glare and Light Trespass

Specify luminaires with sharp cut-off optics

- Flat Glass Cobra Heads
- Flat Glass Shoebox Designs
- Flat Glass Hatbox Designs

Retrofit Existing Cobra Head Luminaires with Visors

7. RECOMMENDATIONS

Short Term

- incorporate non-light-polluting luminaires on all future projects requiring outdoor lighting (buildings, parking lots and access roads)
- retrofit existing installations with sharp cut-off luminaires in accordance with a rational schedule of system renovation and upgrade

8. RECOMMENDATIONS

Long Term

- develop a light pollution abatement policy to be followed on all future projects requiring outdoor lighting
- enact a lighting by-law to limit glare, light trespass and artificial sky glow