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SUSTAINABLE SLOPE LIGHTING HANDBOOK

FOR SUSTAINABLE SLOPE LIGHTING DESIGN AND IMPLEMENTATION

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ABOUT THIS HANDBOOK

Snow sports venues have very particular lighting requirements that must match specific applications. This Handbook provides general guidelines as well as specific illumination objectives. It can be used by mountain operations managers, general managers, racing and freestyle staff, slope designers, lift maintenance managers, sustainability managers, efficiency managers, or anyone who may be involved in slope lighting decisions. New lighting technologies like light emitting diodes (LEDs) or modernized magnetic induction lights (MIL) have only been recently introduced. It is important to have a comprehensive understanding of pertinent concepts from sustainability to Dark Sky compliance and human vision. Effective slope illumination goes far beyond energy efficiency considerations.

OVERVIEW

Slope illumination is increasingly essential for maintaining viable revenue models. Mountain venues are a 24-hours by 365 day proposition that can include recreational activities beyond night skiing and riding like mountain biking, hiking, snowshoeing, snowmobiling, and even more esoteric activities like hang-gliding and wing-suiting. It can even include hosting special events like weddings. Slope lighting standards established in the 1960s were based only upon skiing and involved two standards: 1) recreational, and 2) competitive. For recreational skiing, the goal was to balance the minimum light required for safety against the cost of required infrastructure. Competition standards were based upon minimum light levels needed to activate video equipment that used vidicon tubes requiring levels of 6 to 8 foot-candles (fc) or 60 to 80 lux. Traditional slope lighting uses metal halide, mercury vapor, or sodium vapor fixtures. These technologies are not energy efficient by today's standards. With concerns over climate change, new energy efficiency objectives have become a priority. The ubiquitous nature of light emitting diodes (LEDs) offers high-efficiency alternatives to traditional slope and venue lighting. However, LEDs have substantial drawbacks discovered with increasing deployment. These include premature failure, excessive glare, high-frequency flicker, potential high disposal costs, inappropriate spectral bias, propensity to freeze over with snow and ice, and even health issues. To meet sustainability objectives, technology must be environmentally neutral as well as energy efficient and long-lasting. For slope lighting, the technology must meet visual acuity requirements for recreational and competition applications.

SUSTAINABILITY

Sustainability, as championed by the first Earth Day in 1970, emphasized the elimination of the "Five Ps" of pollution: soil, water, air, **light**, and noise. In the context of slope lighting, foundational principles remain urgent and relevant. Light pollution, in particular, has emerged as a critical concern for both the environment and neighboring communities.

Sustainability in modern slope lighting integrates pollution mitigation with climate-conscious strategies: reducing carbon footprints through energy-efficient technologies, minimizing landfill contributions via long-lasting lighting systems, and encouraging resource conservation through product "thrifting" and lifecycle planning. There are four conditions requiring evaluation: 1) replacing existing lighting with more sustainable lighting, 2) installing night illumination for the first time, 3) reviving previously installed lighting infrastructure, and 4) capital constraints. Thus, true sustainability in slope lighting demands a holistic approach that gives equal priority to pollution reduction, climate goals, economic viability, and long-term resource stewardship.

OBJECTIVES

The primary objective of sustainable slope lighting is to achieve optimal illumination that ensures skier safety and enhances visual acuity, particularly in the complex optical environment of snow. Once that is met, equally important secondary objectives include:

- Application specific illumination; i.e. A) beginner, intermediate, advanced, B) competitive or recreational, C) Alpine, freestyle terrain park (moguls or obstacles) , motocross, D) aerial – jumps (normal hill or large hill), E) Nordic
- Environmental assessment; i.e., A) Location – isolated or near residential properties, B) state of national parkland or forest C) wildlife impact and endangered species
- Minimizing light output (potential light pollution) and associated electrical consumption without compromising visibility, (see “visually effective lumens “)
- Reducing peak energy demand to lower operational costs and avoid utility demand charges
- Complying with Dark Sky guidelines to mitigate light pollution and its effects on wildlife and neighboring communities
- Prioritizing lighting systems with extended lifespans to limit maintenance and landfill contributions
- Avoiding technologies (high-intensity discharge lamps like metal halide, halogen, high-pressure/low-pressure sodium, or even LEDs) that cause glare, flicker, and visual distortion on snow
- Designing lighting infrastructure tailored to slope geometry to avoid wasted light, unnecessary mounting infrastructure and excessive pole height that can cause too much projection.

By combining performance, efficiency, and environmental stewardship, the project aims to set a benchmark for responsible and future-ready ski slope lighting.

IMPORTANT CONSIDERATIONS FOR EXISTING LIGHTING

Do You Really Need to Re-lamp?

If you are operating with **existing** metal halide, high pressure sodium, or even LEDs, you may be able to **lower costs** by changing the way your lighting is implemented. These technologies are associated with **high in-rush current**; the electricity required to turn on. In-rush current affects your entire electricity bill by **increasing "demand charges"** imposed by most utilities. In some cases, you can reduce the impact of in-rush by staggering the way fixtures are turned on. There are also capacitor discharge systems that can "shunt" electrical spikes. **See section on energy for more details.**

Design Guidelines and Technical Criteria

Proper lighting is essential for night skiing/riding safety, performance, and enjoyment. This section provides comprehensive guidelines and technical criteria for designing sustainable slope lighting systems that ensure optimal visibility while minimizing environmental impact. By integrating standards from the National Ski Areas Association (NSAA), Illuminating Engineering Society (IES), Fédération Internationale de Ski (FIS), and the International Organization for Standardization (ISO), we gain insights on ambient light management, and advanced lighting technologies. This handbook is written to provide a benchmark for energy-efficient, visually effective, and ecologically responsible slope illumination.

1. Illuminance Criteria

Illuminance, measured in lux (or foot-candles in the U.S., where 1 fc ≈ 10.76 lux), refers to the amount of light falling on a surface. For ski slopes, emphasis is generally on ***vertical illuminance***—the light striking a vertical plane facing up the slope— which is critical for skier visibility. The following criteria, based on the IESNA RP-6-01 standard developed with the NSAA, apply to **recreational skiing**:

- Maintained Average Vertical Illuminance: 5 lux (0.5 fc)

Minimum Vertical Illuminance: 2 lux (0.2 fc)

Using these guidelines, measurements should be taken at a 1.0-meter (~3-foot) elevation with the light meter pointing up the slope. **For competition and event lighting**, higher levels are required, as outlined in the *Technical Elements for Event Lighting* subsection. These levels ensure safe skiing and riding while minimizing energy use and glare, aligning with sustainability goals. Understand that half a footcandle is a very low level; yet, snow's unique reflectivity provides sufficient visual acuity at these levels using a white light color temperature (Kelvin temperature). Uniformity… meaning consistent light levels from pole-to-pole, becomes a more important criteria to avoid eye adjustments from light-to-dark between poles.

2. Design Considerations

Effective slope lighting must address unique challenges of snow-covered environments, including variable weather, reflective surfaces, and slope topography. The following considerations ensure functionality and sustainability:

- **Illuminance Uniformity**: A uniformity ratio (average to minimum illuminance) of 3:1 or less is recommended to avoid overly dark or bright spots that could disorient skiers/riders. Semi-directional lighting enhances visibility by providing shading and modeling, helping skiers discern terrain features. Excessive uniformity can flatten perception, reducing safety.
- **Weather Conditions:** In foggy or snowy conditions, increase the minimum vertical illuminance by 3 lux (0.3 fc) to compensate for light scattering and reduced visibility. This adjustment maintains safety without excessive energy consumption.
- **Field Measurements**: Measure light levels during clear weather and a new moon with typical snow cover to account for snow's reflectivity, which can amplify illumination. This ensures accurate design and minimizes over-lighting.
- **Luminaire Aiming:** NSAA recommendations are for aiming luminaires downhill, aligning with the skier's direction of travel. This assumes high intensity lighting sources such as high-intensity discharge (HID) lamps and LEDs. Lighting specifically designed for slope applications, like magnetic induction fixtures *<u>that can be aimed uphill</u>* to remove forward shadowing, came after NSAA recommendations were originally introduced. This is particularly important for competition racing, freestyle, halfpipe, and jumps. **(See specific sections on these applications.)** Adjustments must be made using LEDs for slope curvature and gradient to minimize "white-out" (overly bright, flat lighting) and glare. Proper aiming enhances terrain visibility and reduces light pollution. There is technology specifically designed for slope illumination based upon low-glare magnetic

induction lamps. For example, Snow-Bright™ automatically spreads light into slope contours.

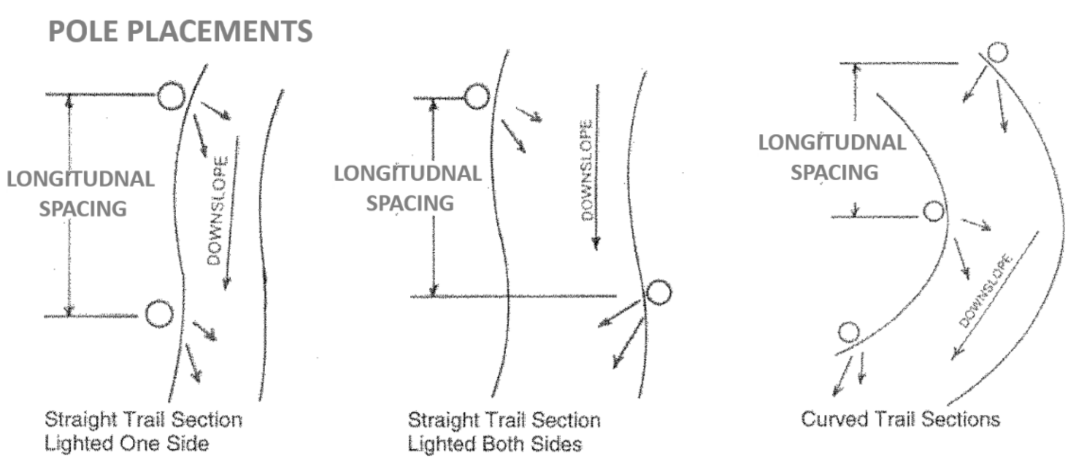
- **Effective Pole Height:** Calculate effective pole height by adding pole height above snow, snow depth, and vertical differential between poles.   Poles should be at least 25 feet (7.6 meters) above the snow surface to ensure coverage while optimizing pole spacing for energy efficiency. Consideration should be given to expected annual snow accumulation that can impact pole height above the surface. There are companies like Musco® Lighting that recommend and supply ski area lighting using high-intensity LEDs mounted on high poles measuring 60 feet (18.28 meters) or more. This allows the LED beam to spread over a wider area. This approach can flood an area beyond the intended targeted slopes. The result can be too much light encroachment. Generally, this type of design is more suitable for stadium and field illumination.

3. Pole Location and Luminaire Aiming

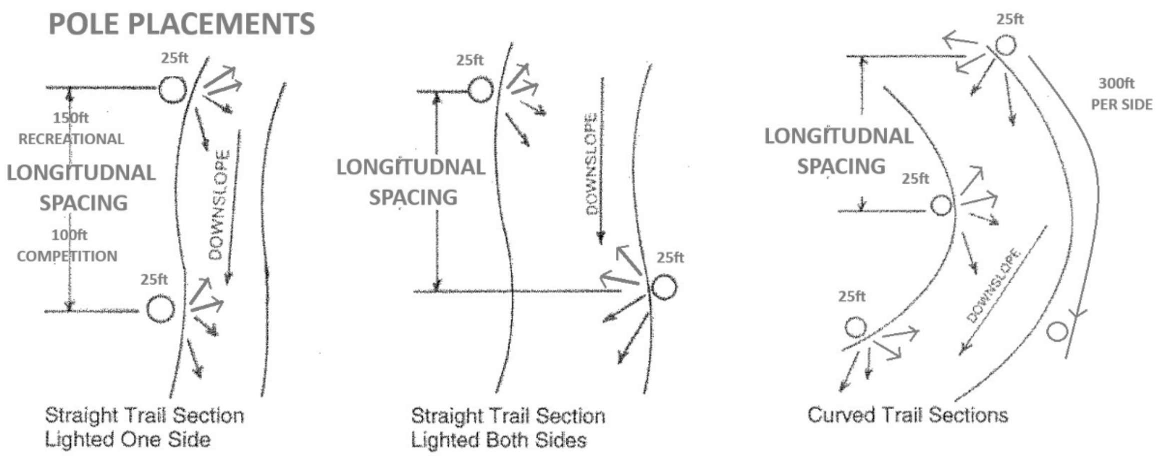
Strategic pole placement and luminaire aiming achieve uniform light distribution, reduce infrastructure needs, and limit environmental impact:

- **Straight Trail Sections:** Single-sided lighting can be used for narrow trails to save on infrastructure (wiring and pole installation), however bilateral lighting on both sides is best, particularly for wider trails.
- **Curved Trail Sections:** Poles should be located to maintain continuous coverage around bends, with luminaires aimed to uniformly illuminate a skier's path.

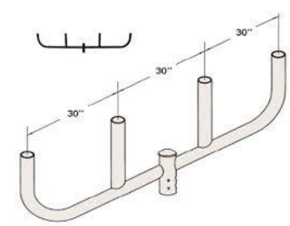
The illustrations provided by NSAA for conventional lamps and LEDs are:



These configurations seek to optimize light coverage while reducing the pole count, lowering costs and environmental footprint. (**NOTE:** Snow-Bright™ magnetic induction fixtures can be aimed across as well as ***uphill*** to eliminate forward shadowing which can be dangerous. **If the mountain already has LEDs, reference section on this technology.** ***See Technical Elements for Event Lighting section.)*** Equally advantageous, aiming fixtures uphill increases pole utility, often reducing pole locations. Consider the illustration using multidirectional lamping to achieve more versatility and consistent illumination.



In addition to pole mountings, most *ski lift towers* can be used for fixture mounting. The ski lift manufacturer *must be contacted* with fixture specifications to determine if they can be safely installed. In most cases, the towers will need to be fitted with "bull horn" pipe fittings to accommodate "slip-fitter" brackets. The lift manufacturer will determine how brackets should be mounted. This is usually with through-bolts and other removable attachments. Welding is not usually recommended.



Make sure the bull horn orientation is correct for the specific fixture mounts. Common positions are vertical and horizontal; facing the sky, or parallel to the slope. These positions facilitate focusing at various angles. Since pole installation can be expensive, any existing infrastructure that can be used to mount lighting should be investigated. This includes buildings and structures like sheds. For example, lighting can be installed at the entrance and exit of chair lifts to illuminate boarding and exiting.

Aiming luminaires is a mounting function. Many arears are subject to high winds ranging above 100mph. This requires careful consideration of the lamp's structural strength and capacity of mounts that can include U-brackets, slip-fitters, flat-mounts, and other configurations.   Check for wind ratings if available and try to see a sample.



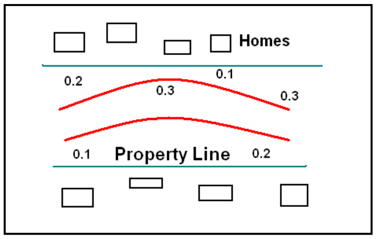


These are *general slope guidelines* that do not pertain to *specialty lighting situations* like terrain parks, mogul runs, jumps, halfpipes, and even aerial slopes. These applications will be reviewed in later sections.

4. Understanding Ambient Light and Effective Zero

Sustainable lighting design must account for natural and artificial ambient light to avoid over-illumination and reduce energy waste:

- **Ambient Light:** Natural sources, like moonlight, can provide up to 0.3 lux on snow-covered mountains, amplified by snow's high reflectivity. Artificial sources, such as nearby streetlights, also contribute.
- **Effective Zero**: In photometric studies, "effective zero" occurs when artificial light's impact drops below 0.25 lux, blending with ambient levels. Designers should minimize artificial output in areas where ambient light suffices, reducing energy use and light pollution. In addition to natural ambient light, accurate photometric studies may indicate the effects of surrounding artificial light sources such as street lighting or neighboring buildings. The combined impact of natural and ambient light will almost always be greater than 0.2 lux. This means that the effective range of a light source becomes zero when expected reflected levels drop to approximately 0.25 lux or less. This is generally referred to as "effective zero" since it is impossible to attain an absolute reading of zero.



When a 0.0 reading is displayed on a photometric layout, it usually means the area is *beyond the data scope*. Therefore, no reading is generated by the computer model. In residential areas, readings below 1.0 lux are considered ambient light. This implies that there is no net increase in light being generated by an artificial source, even if the specific light source like a street lamp is visible.

Leveraging snow's reflectivity *allows lower artificial light levels*, enhancing sustainability without compromising visibility.

5. Technical Elements for Event Lighting

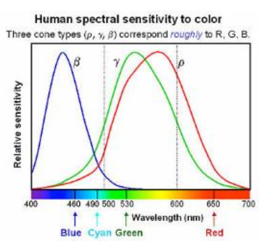
Event lighting must balance athletic performance and broadcast quality , exceeding recreational standards. The International Ski and Snowboard Federation (FIS) guideline of 80 lux **is outdated and insufficiently detailed**.

- **FIS Guidelines:** The 80 lux standard, based on old television vidicon tube technology, was developed more than half a century before 2025 and overlooks modern CCD camera capabilities. It lacks specifications for color temperature, color rendition index (CRI), glare, and spectral balance which are critical for visibility and video or even film. It also does not consider snow's unique reflectivity. To be sure, FIS attempts to set forth reasonable lighting expectations based upon the era when developed. As seen below, specifications contained in sections 655 FIS guidelines remain in effect as of 2025 as follows:
  - 655 Competitions under Artificial Light
  - 655.1 Competitions under *artificial lights are permitted*.
  - 655.2 Lighting must meet the following specifications:
    - 655.2.1 The light level anywhere on the course must not be less than 80 Lux, measured parallel to the surface. The lighting should be as uniform as possible. (**NOTE:** there is no specification for height from the parallel snow surface or definition for uniformity; i.e., lux differentials over the course.)
    - 655.2.2 Floodlights must be placed so that the light does not alter the topography of the course. The light must enable the competitor to discern the terrain and must not alter the depth perception or definition. (**NOTE:** light does not alter topology, only its perception. Depth perception can be negatively impacted by the strobe effect of high-intensity LEDs.)
    - 655.2.3 The lights should not cast the competitor's shadow into the racing line and should not blind the competitor by glare. (**NOTE:** high-intensity lights cannot be oriented facing uphill because the glare will blind the athlete. When facing downhill, high-intensity lights will cast a shadow in front of the competitor.)
    - 655.3 The TD ("Technical Delegates") together with the Jury must check in advance that the lighting conforms to the rules.
    - 655.4 The TD must submit a supplementary report on the quality of the lighting.

The good news is that FIS allows the TD to override 655.2.1 through 655.4 if the review of the course is deemed acceptable for safety and performance. As of 2025, these standards remained in place *without sustainability considerations*.

- **Athlete and Broadcast Needs:** Lighting must provide glare-free, consistent illumination for athletes' depth perception and terrain comprehension. For video, a high CRI (>0.90) and balanced spectrum (450–650 nm) ensure accurate color rendition in conjunction with white balance. (**IMPORTANT**: Do you need broadcast quality lighting? Unless your venue intends to host events that will be professionally filmed (videoed) or aired on television and/or high-resolution internet sites, there is no reason to design for such purposes. Today's cell phone cameras can achieve excellent resolution for personal videos and photos under recreational slope lighting levels.)

The 80 lux guideline was written for a conventional light meter measuring photopic lighting from any source. These measurements include ultraviolet and near-ultraviolet light as well as infrared that *cannot be seen by the human eye*. The result is that a typical measurement of 80 lux for a hot metal halide fixture may contain only 60% to 70% of usable light that falls



into the effective range of human vision. The ratio of various wavelengths within the spectrum determines how well the eye can detect color, contrast, and even depth perception. Visually effective lumens (VELs) as a criterion for snow venue lighting is critically important because unbalanced high intensity lighting can seriously distort the visual perception of the snow surface and interfere with the eye's focusing mechanism. Technical reasons for this include pupil dilation, lighting angle relative to the field of vision, and slope angle. In a research paper addressing the reaction of the human eye in the dark by H. S. Gradle, M.D; Walter Ackerman, B.S. published by *JAMA* back in 1932, the following conclusions were reported:

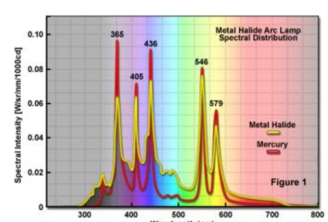
> The reaction time of the normal pupil was established by **cinematographic means**. Briefly, it was found that when light is flashed on a normal eye that is accommodated for the dark, there occurs a latent period of 0.1875 second before the pupil begins to contract. Then there follows a rapid primary contraction for 0.4365 second at the rate of 5.48 mm. per second. This is succeeded by a secondary contraction of 0.3125 second at the slower rate of 1.34 mm. per second.

Emphasis is added to "cinematographic means" because virtually all lighting standards for *filming* were derived from early studies. For example, the typical movie camera filmed at 24 frames per second (fps). This is the slowest rate that can provide reasonably smooth visual frame transition while saving the most amount of physical film. Today, physical film is not a consideration and has no bearing upon video. Even now, video standards tend to fall within the same film guidelines to save on memory requirements. Unless there is a slow motion function, the frame rate is between 23.97fps and 30fps. The conscious visual frame rate of the human eye is somewhere between 60fps and 100fps. Subliminal detection can be as fast as 1/1,000th of a second. Race car drivers and fighter pilots have been tested using a strobe light to arrive at these results.

Ski and snowboard athletes fall within the same visually elite categories. For example, a freestyle mogul skier must judge distance, contour, horizontal angle, speed, and vertical depth, simultaneously. A slalom skier must visually compute distance, snow contour, horizontal angle of attack, vertical depth, speed, pole color, snow markings... all while achieving maximum speed and maintaining stability. New Olympic events like freestyle aerial jumping inject incredibly complex visual challenges that require different lighting considerations for the approach, the ramp, air hang time, and the landing. In addition to the competitor, lighting must provide the maximum visual experience for judges while meeting technical specifications for new video recording equipment.

Unfortunately, very little attention has been paid to technical aspects of night time event lighting as evidenced by the entire FIS §655 inclusive. When the television standard was originally conceived, freestyle skiing and snowboarding didn't exist, nor the half-pipe, aerial jumps, motor cross, and mogul competitions. Speeds were slower and even artificial snow-making and grooming lacked today's sophistication. The primary importance is **athlete safety and performance**. Lighting must provide maximum visual acuity for the least capital and operating cost. Thus, light quality should be combined with energy efficiency to accomplish the ultimate goal.

Today's video camera technology can resolve images in less than 1 lux. Color rendering can be clear at 5 lux or less than half a foot candle. The more important elements of television lighting are color temperature, spectral balance, consistency, and stability. Having uneven lighting that spot measures at 80 lux will not provide good video results if the intensity is uneven or there is spectral bias that distorts the image color. A spectrum balanced for video at an intensity of only 10 lux can produce better results than a conventional metal halide lamp that provides 80 lux. As the chart illustrates, conventional metal halide and mercury arc lamps produce spectral concentrations in the ultraviolet range at 365nm, 405nm, and 436nm. More than 30% of the spectral balance is outside the eye's most sensitive visual range. As it happens, video cameras are designed to accentuate wavelengths within the visually effective range. There is a significant spectral void from 450nm to 535nm, which is right in the middle of human visual acuity and the preferred range of modern video equipment.



Given the expense of developing snow sports professional competition venues, it is highly advisable to consult a design firm with specific ski resort design experience specializing in slopes, terrain parks, and jumps. Resources include the National Ski Area Association vendor members, Ski Area Management (SAM), and *Snow-Ops Magazine*. Ensure that the design firm has expertise in snow venue lighting with access to photometric design software.

6. Sustainable Lighting Technologies

Sustainable slope lighting prioritizes energy efficiency, durability/longevity, minimal environmental impact, and economic viability. If the resort is using metal halide or high pressure sodium lamps, certain measures can be taken to keep this lighting infrastructure viable within many sustainable parameters. As mentioned, energy savings related to demand charges (in-rush current) can be lowered using staggered activation, capacitor discharge start-up current, load shunts, and pulse-start ballasts. These measures can increase longevity, lower energy bills, modestly decrease operating electricity, and lower impacts on landfill through extended lifecycles. **IMPORTANT:** Make sure consideration is given to **"grandfathering"** regarding lighting upgrades. If the municipality, state, National Forest Service, National Park Service, or Federal government agencies have implemented light pollution ordinances (Dark Sky compliance), upgrading lighting will likely 1) ***lose grandfather status***, and 2) require adherence to regulations. Any required approvals should be gotten ***in advance*** of moving forward with a lighting upgrade. Equally important are regulations and fees regarding lamp disposal. *See section on disposal requirements.*

Given the major emphasis upon energy efficiency and climate change, technologies like traditional HID lamps (e.g., metal halide, high-pressure sodium, mercury vapor, halogen) *are being phased out*. In many cases, bulbs and ballasts are no longer being manufactured for obsolete lighting brands. This forces mountain operators/managers to seek rebuilt or used parts that are becoming increasingly scarce and expensive. Thus, old technologies *are no longer sustainable* from a practical as well as environmental standpoint.

This leaves two technologies capable of snow venue illumination: 1) LEDs, and 2) magnetic induction lights (MILs). It is worth noting that only one U.S. lighting brand is marketed as "specifically designed to meet the unique requirements for snow sports venues." It is branded Snow-Bright™ which is manufactured by Ultra-Tech Lighting Ultra-Tech Lighting Co; formerly Ultra-Tech™ Lighting, LLC. This product was introduced in 2012 and remained available as of 2025. In Europe, the Arctic Beam LED fixture is sold as a snow sports venue floodlight. Unfortunately, the offering does not accommodate U.S. or Canadian electricity at 60/Hz. A review of the Arctic Beam specifications as of 2025 reveals the use of a *standard LED form factor* of either 4,000K or 5,000K color temperature and a color rendition index (CRI) of 70. No U.S./Canada models appear to be available. For the purpose of evaluating sustainability and compatibility, two technologies will be reviewed.

LED Technology

Most widely known for **energy efficiency**, LEDs have become the **universal standard** for modern high-intensity artificial lighting. LEDs are ubiquitous to the extent that other lighting has effectively been displaced (incandescent, fluorescent, metal halide, high and low-pressure sodium, mercury vapor, halogen). Frequently, LEDs are the *only technology under consideration* because few people are aware of alternatives like ***magnetic induction lighting***. This is one of the *most compelling arguments* favoring LEDs when re-lamping or for a first-time installation. There are literally dozens, if not hundreds of brands. However, it is important to know that LED technology is still being developed, and is advancing to overcome serious problems and deficiencies. This rapid evolution ***represents risk*** as models are constantly being improved and changed. *Often, it is impossible to replace LED fixtures with the original installation model because of rapid development and deployment of new revisions.* Some early LED adopters have ended up with a hodgepodge of mismatched lamps because brands have disappeared along with designs, parts, and support. A majority of high-intensity LED floods suitable for *wet and cold environments* are sealed units that *cannot be serviced*. If such an LED unit fails, it must be completely replaced.

Unique Snow Venue Conditions

One of the most remarkable LED features is the lack of heat at the lamp face; diode lighting elements. This is one reason LEDs can be so energy efficient. However, this lack of heat on the lamp face has been a serious problem for many ski areas *because they can freeze over with accumulated snow and ice*. Since the lighting elements are sensitive, snow and ice cannot be removed mechanically; i.e., chipped or scraped off. Even the use of an industrial shrink-wrap dryer is not recommended because heat can damage the seal between the lamp face and containment vessel. Very large and significant LED projects such as traffic light replacement unexpectantly encountered this problem. Several ski areas have encountered the same problem. Keep in mind that a driving snowstorm can coat LEDs, rendering them ineffective.

Environmental and End-of-Lifecycle Issues

With the rapidly increasing LED installed base, particular issues present major challenges for *sustainability and cost-effective implementation*. From an environmental perspective, LEDs are often **not considered sustainable** due to toxic components and a lack of recyclability. This is being addressed by states and municipalities that implemented disposal and ***recycling fee schedules***. Consider the following material available through an artificial intelligence (**AI) web search**:

The emergence of **disposal charges for LED fixtures** is a ***recent but growing issue***, driven by increasing awareness of the **hazardous materials** and **complexity** of end-of-life (EoL) LED recycling. This particularly pertains to states like **California;** however, other states are adopting similar regulations. Many LED users are now being told that removing failed LED fixtures will incur a **significant disposal cost— often ranging from $50–$500 per fixture** depending on size, location, and service provider—due to a combination of regulatory, logistical, and material factors. While LEDs are more energy-efficient and longer-lasting than traditional lighting (reducing replacement frequency), their end-of-life management is complicated by electronics, potential hazardous components, and strict e-waste laws.

It's best not to be surprised by this possibility. Exposure stems from the following timeline and policy evolution:

📆 When Did This Happen?

📌 ~2019–2023: Growing Regulatory Attention

- EU members and U.S. states began classifying **some LED drivers and chips** as **e-waste**, especially due to:
    - Electronic components (PCBs, capacitors)
    - Lead solder
    - Rare earth phosphors
    - Plastic/metal bonded parts (difficult to disassemble)

California, under the **DTSC (Department of Toxic Substances Control)**, increased scrutiny over electronic lighting waste. **What can you do in California or a *similar state*?**

- LED boards are often considered Universal Waste under California Title 22.
- **Generators** (like UCSC) are **responsible for compliant handling and recycling**.

📌 2023–2024: Enforcement Begins

- CalRecycle, DTSC, and e-waste haulers started charging per-fixture or per-pound disposal fees.
- LED fixtures now require processing by certified e-waste handlers.
- Landfilling is prohibited in California for e-waste; fines apply for noncompliance.

💰 Why Are Disposal Charges High Now?

1. **Labor-intensive dismantling**: LEDs are integrated assemblies (not bulbs + fixtures).
2. **Hazardous components**:
    - Some drivers contain **brominated flame retardants** or **lead solder**.
    - Certain phosphors used in high-CRI or specialty LEDs are **rare-earth based** and require special handling.
3. **Low resale/recovery value**: Unlike copper-heavy MH ballasts or aluminum reflectors, most LED parts **lack salvage value**.

🛠️ What Can You Do?

✅ Short-Term:

1. **Classify as Universal Waste** and work with **certified e-waste recyclers** (some offer lower university or bulk rates).
2. **Request cost-sharing or take-back** from the original vendor:
    - **California SB 20** (e-waste law) and **extended producer responsibility (EPR)** discussions may allow leverage.
    - Ask if the manufacturer participates in a **voluntary take-back program**.
3. **Document early failure** as a **breach of warranty** and seek compensation or warranty-based replacement—including disposal cost reimbursement.

✅ Medium-Term:

4. **Negotiate with waste handlers**:
    - Large-volume clients can request a **reduced or capped fee per fixture**.
    - Combine fixture removal with **other e-waste** to lower cost per unit.
5. **Contact CalRecycle or DTSC in California or similar agencies in other states such as the Department of Environmental Protection (DEP) or Department of Environmental Control (DEC)**:
    - Ask if your venue qualifies for **institutional exemptions** or **pilot program waivers**.
    - Consider submitting for a **small waste generator reduction** if volumes are low; less than 20 fixtures.

Real-World Precedents

- **San Diego Unified School District** encountered LED disposal issues during lighting upgrades. Disposal costs exceeded installation costs by several multiples requiring exceptional budget revisions.
- **Santa Monica City** bundled old LED removals into a separate recycling contract to save 40% in fees after discovering removal charges would exceed the lighting maintenance budget.
- Some end users successfully obtained **vendor-funded removal** under performance contracts when early failures occurred.

Diving deeper into LED technology

Key Positive Features:

- Consumes up to **75% less operating electricity** than incandescent bulbs, converting more electricity into light rather than heat. This can reduce electricity bills and supports sustainability by reducing the carbon footprint.
- High-quality LEDs can last 25,000–50,000 hours or more, far outpacing incandescent (1,000 hours) or high intensity discharge (HID) (5,000 hours) minimizing replacement needs in hard-to-reach outdoor locations.
- Lower energy use and longer life translate into significant long-term savings—often 50–80% on operating costs—despite possible higher upfront prices.
- Substantial offerings from many vendors provides cost competitive environment for lowering capital expenditure.
- High lumen output can be 100 to 150 lumens per watt (lpw) to provide more light per fixture.
- Long range projection allows for lighting longer distances.
- Controllable for on/off, dimming, and color changing flexibility
- Most popular lighting technology that's more universally known

Key Deficiencies:

- High glare – cannot be aimed across or uphill.
- Downhill orientation creates dangerous forward shadowing.
- High flicker rate causes "strobe effect" which distorts depth and speed perception.
- Strobe effect is known to cause headaches and even "strobe epilepsy."
- Can freeze over, becoming inoperable.
- High blue spectrum bias has been linked to health hazards.

- Contains toxic compounds that cannot be easily recycled.
- Often fails to meet Dark Sky (light pollution) guidelines and ordinances.
- High in-rush current that can adversely affect electricity demand charges.
- Low Power Factor (PF) can increase demand charges.
- Known to have premature failure rates associated with turning purple, blinking on and off, individual diode burnout, and ballast (driver) overloads.

Consideration should be given to toxic compounds in all LEDs that include:

- Aluminum gallium indium phosphide (AllnGaP) - **"toxic"**
- Aluminum phosphide (AllaP) - **"highly toxic"**
- Indium Gallium Nitride (InGaN)- **"toxic"**
- Gallium Arsenide (GaAs) - **"highly toxic"**
- Aluminum Gallium Arsenide (AlGaAs) - **"highly toxic"**

Safer States published its *Analysis of State Legislation Addressing Toxic Chemicals and Plastics* on February 8, 2024. Overall, at least **36 states** will consider more than ***450 bills on toxic chemical*** and plastics related policies. The analysis further finds that banning "forever chemicals" will continue to dominate beyond 2024, with at least 35 states introducing policies. Other significant legislation anticipated beyond 2024 will address toxic plastics, safe drinking water, and hazardous chemicals in cosmetics and personal care products. Regulations could be instituted at the Federal level through the EPA.

If LEDs are already widely deployed, there are ways to address some of the issues as seen in later sections.

MIL - Magnetic Induction Technology

This system is based upon magnetic induction lighting (MIL) invented by renowned Nikola Tesla, father of alternating current (AC). Unlike conventional lighting that uses filaments, Tesla's "tubes" circulate energy with opposing magnets without the need for pressurization or a vacuum. When introduced at the ***1893*** Chicago World's Fair, Tesla called his MIL the "Forever Bulb," boasting an almost indefinite lifecycle. Ironically, MIL technology was never fully embraced as commercially feasible because of its longevity and energy efficiency. The goal at the time when distributed power (the grid) was being developed was to *consume as much electricity as possible with bulbs that needed frequent replacement.* Because MIL was invented in the 1890s, most lighting consultants and engineers believe it is "old technology," or even "obsolete." These opinions stem from a lack of understanding.

Several well-known companies have MIL offerings, but not for snow sports venues. These include Osram Sylvania (Icetron® Quicktronic® System) and Philips (OL System). These were limited offerings as of 2025. Brands are marketed on the basis of extreme longevity exceeding 100,000 hours. Ultra-Tech™ Lighting, which is now Ultra-Tech Lighting.

introduced modernized MIL in 2009 under application-specific tradenames like Port-Bright™ for marine applications and Tennis-Bright™ for tennis courts. ***Snow-Bright™*** floods were introduced in ***2012*** at Mount Peter in Warwick, New York and Steamboat Springs Ski Resort in Steamboat Springs, Colorado in ***2013***. Snow-Bright™ is marketed as scientifically designed for snow sports venues, using a balanced spectrum (450–720 nm) *optimized for snow*, with a CRI of 0.95 and color temperature ~6,500K. A 300-watt fixture replaces a 1,000-watt metal halide or 1,500-watt high pressure sodium, ***cutting energy use by over 85%***. This has been verified by several resorts that replaced 1,000-watt metal halide and/or high pressure sodium with 300-watt Snow-Bright™.

Marketing material describes the product as non-flicker, low-glare, energy efficient, and fully recyclable. The goal is to be sustainable and environmentally friendly while addressing unique lighting requirements such as freezing temperatures, high winds, snow-making and snow-preserving chemicals, Dark Sky compliance, wildlife compatibility, and cost savings. These claims can be verified through the internet.

MIL uses solid mercury amalgam as compared with fluorescent bulbs that contain dispersed mercury. The amalgam encapsulates mercury in an inert form to avoid environmental contamination if bulbs break or are thrown away. Snow-Bright™ electronics pass component RoHS-2 certification; the latest as of 2025. Mercury content adheres to the strict standards of the European Union (EU). Ultra-Tech Lighting has adopted "cradle-to-grave" manufacturing for all products to ensure 100% recyclability.

Diving Deeper Into MIL Technology

Key Positive Features:

- High energy efficiency.
- Little to no in-rush current with high power factor (PF) limits demand charges
- Concentrates spectrum within the visually effective range of human vision known as "visually effective lumens" or "pupil lumens," to use less intensity while achieving better visual acuity.
- Eliminates flicker and glare using nano-particle diffusion.
- Real world 100,000 hour lifecycle equals 11 years, operating 24 hours X 365 days; reducing maintenance and recycling waste.
- Maintains 90% of lumen output over 90% of service life.
- Reduces light pollution with adjustable Vari-Beam® technology.
- Dark Sky compliant under most rules, regulations, and guidelines.
- Features "constructive wavelength interference" to eliminate dark spots and facilitate wider pole spacing, less infrastructure.
- Generates sufficient heat to shed snow and ice… won't freeze over like LEDs.
- Is fully recyclable

Key Deficiencies:

- Does not cast light long distances as a result of Dark Sky compliance design.
- May require lighting from two sides of wider slopes.
- Fewer manufacturers and vendors.
- Unfamiliar technology or associated with being old and obsolete.
- May be considered more expensive compared with generic LED floods.

Case Studies: Ski areas like Steamboat Springs and Mt. Peter report >85% energy savings and improved visibility with Snow-Bright™ MIL fixtures.

Designers and mountain managers should assess various sustainable options, selecting technologies that align with slope-specific needs and sustainability goals.

- Before-and-after comparison of Holiday Mountain, New York with HPS (right) vs. Snow-Bright™ (left), showing improved uniformity and clarity. Originally, orange monochromatic color makes snow appear flat with less contrast. This also interferes with color rendition. Although lower color temperatures may be recommended for general public lighting like streets, it is not appropriate for athletic applications that include snow sports venues, playing fields, golf driving ranges, tennis/pickle ball courts, outdoor basketball courts, and more.

By integrating these guidelines and technologies, ski areas can achieve sustainable slope lighting that ensures safety, enhances performance, and minimizes environmental impact. Consult lighting professionals experienced in sustainable design to tailor solutions to specific slopes. Make sure any lighting consultant is *fully familiar with* MIL.

Environmental Compliance and Dark Sky Standards

Light pollution, a critical environmental concern since the inception of the dark-sky movement in the ***1950s***, significantly impacts ecosystems, human health, and the visibility of stars in the sky. For "ski areas," achieving Dark Sky compliance is increasingly vital due to stringent regulations aimed at preserving natural nighttime environments. These regulations, driven by organizations like the International Dark-Sky Association (IDA), focus on minimizing glare, light trespass, and skyglow to protect wildlife, reduce energy waste, and maintain community aesthetics. Ski slope lighting, historically reliant on high-intensity discharge (HID) lamps like metal halide (MH) and high-pressure sodium (HPS), often fails to meet modern Dark Sky standards due to excessive glare and reflected light off snow. This section outlines Dark Sky compliance principles, evaluates lighting technologies, and presents case studies demonstrating sustainable solutions tailored for ski areas.

Dark Sky Compliance: Principles and Challenges

Dark Sky compliance involves adhering to guidelines that limit light pollution through strategic lighting design and technology. The International Dark Sky Association (IDA's) Five Principles for Responsible Outdoor Lighting provide a framework for ski areas:

- **Useful**: Lighting must serve a clear purpose, such as ensuring skier safety.
- **Targeted**: Light should be directed only where needed, using shielding or full cut-off to prevent spillover.
- **Low Level**: Use the minimum illuminance necessary, leveraging snow's reflectivity to enhance visibility.
- **Controlled**: Employ timers, dimmers, or motion sensors to activate lights only when required. ***(Not necessarily feasible for slope lighting)***
- **Warm-Toned**: Prefer lighting with color temperatures of 3000K or lower to minimize blue light emissions, which disrupt wildlife and human circadian rhythms. ***(Not appropriate for proper slope visibility to use low Kelvin temperatures.)***

For ski areas, compliance is challenging due to the reflective nature of snow, which amplifies light pollution. Traditional MH and HPS fixtures, operating at 400W to 1,500W, produce significant glare and infrared heat, wasting energy and failing to comply with ordinances restricting reflected light. LEDs, while energy-efficient, exacerbate light pollution with their blue-biased spectrum, high glare, and inability to be aimed uphill or across slopes without risking retinal damage or creating forward shadowing. These limitations often result in non-compliance with local Dark Sky ordinances, which rarely offer grandfathering provisions for existing installations, posing operational risks for ski venues reliant on nighttime activities.

Snow-Bright™: A Dark Sky-Compliant Solution -

According to the literature, Snow-Bright™ lighting, developed by Ultra-Tech Lighting LLC addresses these challenges with proprietary LumenTec® technology, offering a sustainable alternative optimized for ski slopes. Key features include:

- **Optimized Spectrum**: A balanced 450–650 nm spectrum with a color temperature of ~6,500K and a Color Rendering Index (CRI) of 0.95 maximizes Visually Effective Lumens (VELs), enhancing visual acuity while refracting through snow to reduce skyglow.

- **Low Glare and Rapid Diffusion**: Nano-particle reflectors and Vari-Beam® technology diffuse light, eliminating hot spots and flicker, ensuring uniform illumination, and allowing flexible aiming ***including uphill***) without compromising safety or compliance.
- **Energy Efficiency**: A 300W Snow-Bright™ fixture replaces a 1,000W MH or 1,200W HPS, reducing energy consumption by over 85% and in-rush current by 95%.
- **Longevity and Sustainability**: Rated for 100,000 hours, Snow-Bright™ fixtures are fully recyclable, minimizing landfill contributions and maintenance costs.
- **Dark Sky Compliance**: The technology meets stringent ordinances by minimizing blue light emissions and light trespass, as validated by installations near sensitive ecological and astronomical sites.

Unlike LEDs, which suffer from strobe effects, icing issues, and toxic components, Snow-Bright™ provides glare-free, high-contrast illumination that enhances terrain perception for skiers and racers while adhering to environmental standards. (See YouTube video at: https://www.youtube.com/watch?v=oHN_io0n59w)

Case Studies: Successful Dark Sky Compliance

The following case studies illustrate how Snow-Bright™ lighting has enabled ski areas to achieve Dark Sky compliance while improving visibility and reducing environmental impact:

Snow King, Jackson Hole, WY

Snow King Mountain, located within the Town of Jackson Hole and bordering the National Forest Service, upgraded from 1,000W MH and HPS fixtures to 300W Snow-Bright™ lamps to support nighttime race training. The retrofit, evaluated by the Jackson Hole Land Trust, Teton Conservation District, and National Forest Service, achieved a 75% reduction in energy use and a 96% drop in in-rush current. The installation met strict Dark Sky standards, exhibiting less light impact than amber lamps, and secured grants from the Teton Conservation District and incentives from Rocky Mountain Power. The project's success highlights Snow-Bright™'s ability to balance environmental compliance with operational needs in ecologically sensitive areas.

Snowy Range, Laramie, WY

Snowy Range installed Snow-Bright™ lighting for a new tubing park within the Medicine Bow-Routt National Forest, 20 miles from the University of Wyoming Infrared Observatory. Facing concerns about blue light interference and wildlife disruption, the project underwent rigorous scrutiny from the Observatory Director, National Forest Service, and a bat advocacy group. Snow-Bright™ fixtures demonstrated no detectable blue spectrum emissions above ambient levels, noise levels below 20dB at 2.54cm, and light dissipation below full-moon ambient levels beyond park boundaries. The installation's approval underscores Snow-Bright's compatibility with astronomical and ecological requirements.

Steamboat Springs Ski Resort, CO

Steamboat Springs introduced night skiing across 1,100 vertical feet, including advanced slopes for race training, using Snow-Bright™ technology. Bordering National Forest land and residential areas, the project faced opposition from environmental advocates. A demonstration proved the technology's controlled light dispersion, leading to approval by the Town Council and National Forest Service. The installation, covering beginner to advanced terrain and a half-pipe, achieved near-zero light pollution, with stars visible from the slopes. Racers, clocking speeds over 80mph, reported superior visibility compared to daylight, attributed to the 0.95 CRI and elimination of forward shadowing. The project's success led to a new race venue, "All Out," hosting the 2016 NCAA Championships.

Mt. Peter, Warwick, NY

Mt. Peter, the first Snow-Bright™ installation, retrofitted its advanced slopes, beginner areas, and tubing park from generic magnetic induction and MH/HPS fixtures. The upgrade addressed inadequate visual acuity and non-compliance with local Dark Sky ordinances. Photometric layouts demonstrated uniform illumination and minimal light trespass, with the park area beyond tubing boundaries remaining unaffected. The installation's clarity and compliance enabled expanded nighttime operations, including race training and outdoor seating areas, setting a precedent for sustainable slope lighting.

Implementation Strategies

To achieve Dark Sky compliance, ski area managers should:

- **Conduct Photometric Studies**: Use tools like those in Section 4 to identify "effective zero" zones (light levels below 0.25 lux) and minimize over-illumination, accounting for snow's reflectivity and ambient light from natural (e.g., moonlight) and artificial sources.
- **Select Certified Fixtures**: Choose IDA-approved or Snow-Bright™ fixtures with full shielding, and low BUG (Backlight, Up light, Glare) ratings (e.g., 1-0-1).
- **Engage Stakeholders**: Collaborate with local councils, environmental groups, and observatories to address concerns and secure approvals, as demonstrated in Snowy Range and Steamboat Springs.
- **Leverage Incentives**: Pursue grants and utility incentives, as at Snow King, to offset retrofit costs.
- **Monitor and Report**: Use sustainability metrics (e.g., energy savings, light trespass reduction) to document compliance and environmental benefits, enhancing community support.

Dark Sky compliance is not merely a regulatory hurdle but an opportunity to enhance **sustainability** and operational efficiency in ski slope lighting. By adopting technologies like Snow-Bright™ or compliant fixtures, ski areas can meet stringent environmental standards, reduce energy and maintenance costs, and improve skier safety and experience. The case studies of Snow King, Snowy Range, Steamboat Springs, and Mt. Peter demonstrate that sustainable lighting solutions can align with ecological, economic, and performance goals, setting a benchmark for responsible slope illumination. Ski area managers must prioritize Dark Sky-compliant technologies and engage with stakeholders to ensure long-term viability in an era of increasing environmental scrutiny.

Economic Considerations and Incentives

Implementing **sustainable slope lighting** is not just an environmental decision—it is a financially sound investment that delivers immediate and long-term returns. Upgrading from traditional 1,000-watt metal halide or 1,500-watt high pressure sodium fixtures to 300-watt magnetic induction technology (such as Snow-Bright™) dramatically reduces operating costs, enhances energy efficiency, and avoids costly utility penalties.

Caution is required

Many mountains are discovering that switching to LEDs ***does not reduce energy bills***. Although operating energy may be significantly lowered, the unique nature of LED drivers (ballasts) and their propensity to waste energy as heat can actually increase particular electricity billing categories. ***Much depends upon the electric utility's billing***. This is by no means universal. ***It is imperative to fully investigate how your electricity is provided and charged.*** There are five usual categories the include:

1) Delivery Charge
2) Consumption/usage
3) Peak versus off-peak rates
4) Demand Charge
5) Power Quality (power factor) surcharge

From these categories, there are additional fees associated with peak and off-peak demand, seasonal rate adjustments, and load variability. The following is an example of using the artificial intelligence (AI**) ChatGPT** to inquire about how LEDs can impact electrical charges. Given this tool, the more information provided to the AI platform, the better the decision. Actual electric bills can be inputted for analysis related to changing lighting infrastructure. **This is an actual inquiry you can perform**:

Question: If I changed from 1,000W pulse-start metal halide flood lamps to 600W LED floods in order to save energy and money, what should happen to my utility bill considering all factors including wattage, power factor and in-rush current?

Summary: Switching from 1,000W pulse-start metal halide (MH) flood lamps to 600W LED floods should significantly lower your utility bill, **but the savings might not be as high as you'd expect** if you don't account for power factor, in-rush current, and demand charges. Here's a breakdown of what's going on.

Answer:

1. Lower Wattage = Lower Energy Consumption (kWh)

- ☑ Advantage: A direct drop from 1,000W to 600W per fixture equals a 40% reduction in input power.
- If you had, say, 10 fixtures:
  - Old setup: 10 x 1,000W = 10,000W (10kW)
  - New setup: 10 x 600W = 6,000W (6kW)
  - Over 100 hours of use:
    - Old: 1,000 kWh

        - New: 600 kWh

          ➤ **This part of the bill should go down proportionally.**

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2. Power Factor (PF)

- Pulse-start MH fixtures typically have a PF > 0.9 (especially if they're CWA ballasts), meaning they draw real power efficiently.
- LED drivers vary. Many cheaper or lower-quality LEDs have a power factor between 0.7 and 0.9.
    - If your 600W LED has a PF of 0.8, it actually draws:
        - Apparent Power = 600W / 0.8 = 750 VA
    - Utilities may charge for kVA demand or penalize for low PF (depends on your rate structure).
    - ➤ **Poor PF = higher apparent demand and potential surcharges.**

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3. In-Rush Current

- LED drivers often have high in-rush current when first powered on — sometimes 20–50x normal current for a few milliseconds.
- Usually NOT billed directly, since meters average usage over time.
  However:
    - If all fixtures switch on at once, the spike might impact your demand charge, depending on your utility's metering window.
    - Metal halides have warm-up time and don't exhibit sharp in-rush peaks.

- Demand Charges (kW)
- Many utilities charge based on peak 15-minute (or 30-minute) usage window each month.
- If all your LED floods are switched on simultaneously and cause a high momentary demand (due to in-rush or load peaking), your demand charge may not drop as much as your energy usage (kWh) does.
- ➤ **Staggering startup or using soft-start drivers can help.**

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5. Other Possible Issues

- LED fixtures may run hotter at the driver level due to compact electronics, which affects:
  - Driver longevity and potential failure (maintenance cost).
  - Slight increase in real input wattage beyond nameplate under high ambient temps.
-

Bottom Line

If your utility bill hasn't dropped as much as expected:

☑ What *should* be happening:

- Lower kWh usage → lower energy charge
- Lower average demand → potentially lower demand charge

❌ **What might be going wrong:**

- Low power factor → utility is charging for excess apparent power
- In-rush spikes → elevating your demand charge
- All lights switched on simultaneously → demand peak
- Drivers drawing more power than rated under load/heat

☑ **Recommendations**

- Check your LED fixture's power factor — aim for PF ≥ 0.9.
- Ask your utility if you're charged for low power factor or kVA.
- Use a clamp meter or energy logger to measure real-time kW, kVA, and PF.
- Stagger switching to avoid simultaneous in-rush events.
- Review your utility bill details — look at the demand charge line and any PF penalties

This inquiry was made ***after an actual installation*** because results were far from what was expected based upon the **preinstallation analysis**. It was too difficult to anticipate utility bill intricacies. Consider a follow-up AI inquiry on the same AI platform for the post-installation experience:

QUESTION: "I changed from 1,000W pulse-start metal halide flood lamps to 600W LED floods in order to save energy and money. The new energy bills are almost twice as much due to increased demand charges and a "power factor surcharge." Why did this happen?"

ChatGPT said:

That's a frustrating and surprisingly ***common issue***—especially in **commercial or outdoor lighting upgrades**. While **LEDs are vastly more efficient on paper**, the **electric utility**

billing structure (especially with demand charges and power factor penalties) can **negate or even reverse** the savings.

Such AI inquiries are encouraged to ensure against post-installation surprises. The ChatGPT analysis provides important insight into the realities of lighting upgrades; whether LEDs or MILs. Even in situations where an LED *is recommended by your utility* with an enticing rebate incentive, ***the end result can unexpectedly be higher energy bills***. It is important to understand that in-rush current and low power factors can be associated with higher demand charges that apply ***to your entire bill***. In-rush current and power factor are not necessarily highlighted on lighting cut-sheet specifications.

Energy Savings and Incentives

To maximize lighting upgrade benefits, you need a comprehensive plan. Many utilities and government agencies offer incentives for energy efficiency upgrades. However, as seen by the example of higher energy costs using LEDs, careful analysis is required. Important first steps include:

- Contacting your utility and gaining access to a dedicated representative
- Researching available incentives from your utility
- Researching possibly local and state grants for energy upgrades
- Researching Federal Department of Energy Grants
- Researching parkland or forestland grants if you qualify
- Researching Department of Agriculture Rural Energy for America Program (REAP) grants
- Researching Department of Education grants if you have a school program

This is not a comprehensive list, but provides a framework for expanding your reach for incentive programs associated with energy efficiency or even environmental sustainability. There are even situations where local communities will assist in a lighting retrofit if it achieves lower lighting levels, light intrusion, or Dark Sky compliance.

Data You Will Need

The highest incentives are usually achieved through a "**custom application**." Unfortunately, most mountain managers opt for a prescriptive rebate which offers a fixed dollar amount for specific, pre-defined energy-efficient equipment or measures. These rebates are often for common upgrades like replacing old lighting with LEDs, upgrading to approved snow-making systems, or improving pumps and motors that are recognized and scheduled by the utility. Prescriptive rebates are straightforward, require minimal application, and are typically available for a wide range of projects.

IMPORTANT: Utilities will ask about hours of operation. Too often, managers will only report operations during night skiing, neglecting to add hours for snow-making and grooming. Calculate any and *all* hours lights might be operating. This is more the case for prescriptive rebates.

The National Grid incentive program illustrates the compelling financial case for magnetic induction lighting. At the Frear Park Ice Rink in Troy, New York, thirty 1,000-watt metal halide fixtures were replaced with thirty 300-watt Rink-Bright™ magnetic induction lamps; a model similar to Snow-Bright™. This upgrade achieved:

- **Annual energy savings** of 133,041 kWh
- **Annual electric cost savings** of $21,287
- **A simple payback period of only 0.5 years** with utility incentive support.

These savings stem not only from the reduced wattage per fixture, but also from a major reduction in electrical overhead. Metal halide fixtures typically require an additional 150 watts to operate ballasts, bringing total system draw to 1,150 watts per unit. In contrast, a high-quality LED may only add 15 to 20 watts on an equivalent fixture that would range from 215 watts to 400 watts; however, LED in-rush current can still be far more at 40 amps to 60 amps, equaling 4,800 to 7,200 watts on a 120V circuit. Snow-Bright™ magnetic induction fixtures operate with 15 watts of driver overhead when using a 300-watt fixture — totaling just 315 watts per unit with negligible in-rush of 1 to 5 watts.

Peak Demand and In-Rush Charges

Another critical financial advantage is the substantial reduction in **in-rush current**, which affects utility **demand charges**. Metal halide and even LED fixtures can generate in-rush currents up to 15–20 times their rated wattage at startup. For example, switching on 50 metal halide fixtures simultaneously can spike demand to over **862,500 watts**, driving up the “peak demand” charges applied across an entire billing cycle.

In contrast, magnetic induction lighting has an in-rush multiplier of only **1.5x**, dramatically reducing peak startup demand. This not only minimizes the risk of triggering high demand charges but also provides a **more stable load profile**, making this technology ideal for ski resorts facing utility fees based on momentary peak usage.

Power Quality Benefits and Longevity

Poor power quality (PQ)—including low power factor (PF), harmonic distortion, and electrical “noise”—can significantly increase facility maintenance costs and energy losses. Metal halide and many LED systems degrade PQ, leading to inefficient power usage and increased infrastructure wear. It is possible to counteract degradation using capacitor discharge systems that carry the initial load of high intensity discharge lamps (HID) like metal halide or high pressure sodium as well as LEDs. Magnetic induction lighting, by contrast, has a **power factor of 0.98**, meaning nearly all of the incoming power is productively used.

Additionally, magnetic induction fixtures like Snow-Bright™ are rated for **over 100,000 hours** of lifecycle while retaining more than 90% of initial light output. This exceptional **lumen maintenance** surpasses that of both LEDs and metal halide systems, and reduces maintenance by up to **600%**. Fewer replacements mean fewer disruptions, lower labor costs, and less waste—aligning perfectly with sustainability and budgetary goals.

Summary of Economic Benefits

Metric	**Metal Halide (per unit)**	**Magnetic Induction (per unit)**
Operating Wattage	1,150 W (incl. ballast)	315 W (incl. driver)
In-Rush Multiplier	Up to 15x	1.25x
Power Factor	~0.7 (typical)	0.98
Rated Lifespan	~20,000 hours	>100,000 hours
Maintenance Frequency	High	Extremely Low
Lumen Retention	~60-70% at EOL	90% at EOL
Utility Demand Impact	High	Minimal

By reducing energy consumption by over 70%, virtually eliminating peak demand surcharges, and minimizing maintenance needs, magnetic induction lighting provides an unmatched return on investment. These performance advantages are further enhanced by available **utility rebates, grants, and sustainability funding** programs. LEDs are usually eligible for prescriptive utility incentives and can be made more efficient using systems that intervene in in-rush current and/or power factor.

Carbon Footprint and Credits/Incentives

Carbon footprint reduction is a ***paramount goal*** for many snow sports venues and corporate owners. Retrofitting with high-efficiency lighting will ***significantly reduce the carbon footprint***. To track CO_2 reduction, decreases in energy usage must be compared with the utility's carbon profile per kilowatt hour (kWh); the amount of CO_2 generated per kWh. In many cases, the utility will provide your carbon reduction with any rebate filing. This documentation must be kept to 1) track carbon reduction goals, and 2) file for any potential "carbon credits" or CO_2 reduction incentives.   All CO_2 reductions should be documented, whether incentives or credits exist or not. This is because climate change policy is constantly changing. The record of CO_2 mitigation may be used to avoid penalties such as carbon taxes or carbon fees that may be implemented at the Federal, state, or municipal level(s).

NSAA Golden Eagle Awards and Sustainable Slopes Grant Program

The sustainability officer or director should explore all climate change opportunities that include private organizations like the National Ski Area Association (NSAA) or International Ski and Snowboard Federation (FIS… in French, *Fédération Internationale de Ski et de Snowboard*) .

1. Golden Eagle Awards – Sustainability Categories

The **Golden Eagle Awards**, NSAA's premier environmental honors established in 1993, spotlight ski areas excelling in sustainability initiatives—this includes energy efficiency and carbon reduction efforts. Key award categories include:

- **Environmental Excellence**: Honors ski areas demonstrating holistic sustainability across operations—from renewable energy to waste diversion. Examples:
  - *2024 winner:* Arapahoe Basin Ski Area attained **100% renewable electricity** and became carbon-neutral ahead of schedule.
  - *2025 winner:* The Summit at Snoqualmie, WA, earned the award by reducing propane use, transitioning to renewable diesel, and achieving 95% landfill diversion.
- **Climate Change Impact**: Awards projects that result in measurable carbon reductions or climate resilience. Examples:
  - *2025 winner:* Sun Valley Resort's geothermal snowmelt system eliminated natural gas use and cut Scope 1 emissions by ~101 metric tons CO_2 per year.
- **Innovation in Sustainability**: Recognizes creative solutions that push the industry forward.
  - *2025 finalist:* Blue Mountain Resort (Ontario) used telematics to reduce fuel use by 15%.
- **Hero of Sustainability**: Highlights an employee making a significant environmental impact.
  - *2025 finalists:* Anna Nason (Mt. Rose, NV), Hunter Wright (Eldora, CO), and Megan Wagaman (Copper Mountain, CO).

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2. Sustainable Slopes Grant Program

Established in 2009 and still active in 2025, the **Sustainable Slopes Grant Program** provides funding (cash and/or in-kind) to support ski area sustainability projects, particularly in energy efficiency and footprint reduction.

- Grants support **lighting or energy-efficient snowmaking technology**, **recycling programs**, and related initiatives.
- *SnowIndustryNews* (May 2025) lists multiple grant recipients this year, including:
    - **Cash Grants:** Wisp Resort (MD), Arapahoe Basin (CO), Steamboat (CO), Mt. Ashland (OR).
    - **Snowmaking Grant:** Big Sky (MT), Sugarbush (VT).
    - **Recycling Grant:** Big Sky (MT), Copper Mountain (CO), Bridger Bowl (MT).

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3. Climate Challenge Program

Under NSAA's long-running **Climate Challenge**, participating ski areas voluntarily:

- Develop **greenhouse gas inventories**.
- Set **carbon reduction goals**.
- Undertake energy-saving and advocacy actions.

By 2018:

- Scope 1 and 2 emissions totaled 167,251 $MTCO_2e$ for participating resorts.
- Combined on-site carbon reduction projects and renewable energy credits achieved cumulative savings of ~252,169 $MTCO_2$ since 2011.

Summary Overview

Program / Award	Focus Area	Recent Highlights
Golden Eagle Awards	Sustainability achievements	Renewable energy (A-Basin), geothermal systems (Sun Valley), landfill diversion, innovation
Sustainable Slopes Grants	Energy/efficiency infrastructure grants	Funded energy-saving snowmaking and recycling projects for multiple resorts
Climate Challenge	Carbon inventories and reduction strategies	Industry-wide CO_2e reductions through GHG reporting and renewable energy initiatives since 2011

For Europe and other regions, FIS provide several climate change/environmental incentive and/or recognition programs. FIS includes guidelines for establishing practices and programs using their "Snowball Sustainability Guide." This includes basics like appointing a

Sustainability Manager, forming a sustainability committee, and set measurable key performance indicators (KPIs). The guide focuses on eleven core areas, including ***energy efficiency***, water reuse, sustainable logistics, ***waste reduction,*** biodiversity, and community engagement—each rated by impact using their "snowflake system". FIS even provides a carbon footprint calculator. Lighting addresses waste reduction and energy efficiency as well as environmental compatibility… impact on wildlife.

Rebate Summary and Confirmation

A typical utility rebate summary/confirmation would contain annual kWh reduction that would be correlated to the utility carbon profile. The example below is an actual filing with National Grid (NGrid) that lists 146,345 pounds of CO_2 associated with 133,041 kWh energy reduction.

Savings Summary		Incentive Summary	
Gross Annual kWh Savings	**133,041 kWh**	Authorized Incentive:	**$17,428**
Estimated Customer Cost per kWh	**0.16**	Total Cost of Installed Measures:	**$27,990**
Annual Electric Cost Savings	**$21,287**	Simple Payback	**1.3 years**
		Simple Payback with Incentive	**0.5 years**
	146,345 lbs	System Bonus	**$0**
CO2 Savings (lbs)*	**146,345 lbs**	Total Incentive	**$17,428**

NOTE: Lighting upgrades using technologies like LEDs or magnetic induction like Snow-Bright™ should be viewed as ***capital improvements*** that immediately begin contributing to the bottom line while fulfilling long-term climate and ***sustainability goals***.

UNIQUE SNOW SPORTS VENUE LIGHTING APPLICATIONS

Many slope lighting installations predate the evolution of terrain parks, freestyle competitions, snowboarding, halfpipes, and aerial events. These areas have particular requirements that include low glare, back-lighting, high contrast and competition environments.

The following sections are not substitutes for detailed area designs. It is always best to use a landscape architect specializing in snow sports venues that has a slope project portfolio. As described on their websites as of 2025, these may include:

SE GROUP

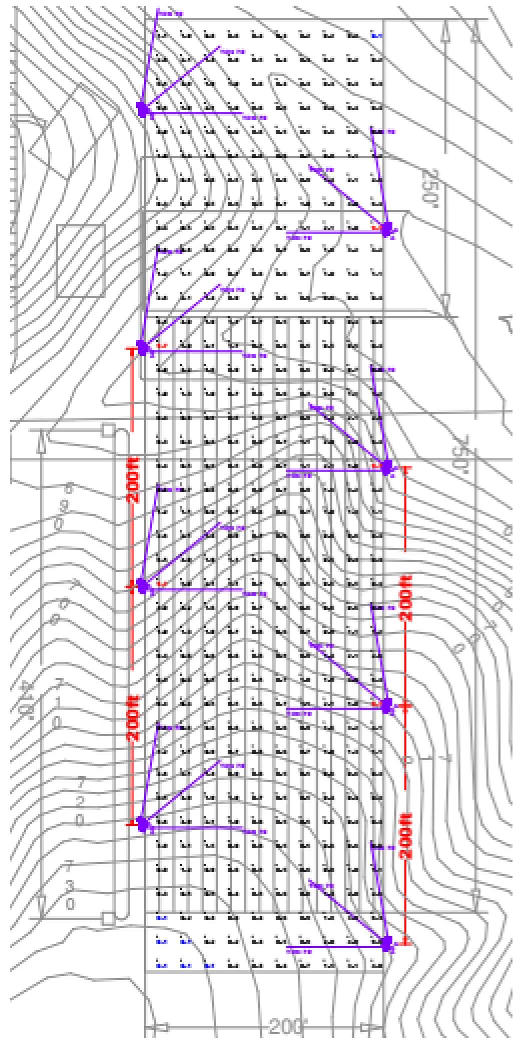
Overview: A globally recognized leader in mountain resort planning since 1958, with a team of landscape architects, environmental analysts, and community planners. - **Expertise:** Provides a full range of services, including master planning, ski trail design, lift layout, and environmental permitting. They specialize in creating balanced resorts that offer a range of experiences for different skill levels - **Projects:** Has worked on thousands of resort projects worldwide, including Copper Mountain, Loon Mountain, and Keystone.

ECOSIGN MOUNTAIM RESORT PLANNERS

Overview: Considered one of the most experienced mountain resort planning firms in the world, with a portfolio of over 450 projects across 47 countries - **Expertise:** Specializes in creating profitable, successful, and award-winning resorts. Their work includes designing competition venues for multiple Olympic Winter Games - **Services:** Provides comprehensive ski area design, including master planning and aerial lift system planning

You can also contact the NSAA for vendor references. Keep in mind that the NSAA has a "vendor agnostic" policy.

TUBING PARKS



Tubing parks (hills) have become increasingly popular as an adjunct to skiing and snowboarding. Tubing allows non-skiers/riders to participate in snow venue activities. Tubing is particularly popular as a nighttime activity. Lighting requirements are less technical, but remain critical for safety and comfort. Unless the tubing area is intended for multi-purpose evening applications, overall lighting levels can be as low as a 5 lux (~0.5 fc). Some operators are interested in multi-color or seasonal color lighting; red and green for Christmas or changing colors for special effects. Supplemental LED color fixtures are best suited for adding these features because they can easily and quickly be adjusted for different hues. However, it is important to avoid direct high-intensity colored LED enhancement due to potential blinding effects. Colored lighting is not good for lane illumination.

Lighting plans depend mostly upon hill width. Typical tubing lanes are between 6 and 8 feet wide (1.8m – 2.5m). Multi-rider or "tandem" lanes might be 10 feet wide (~3m). Lane separations can range from 1 to 2 feet. A ten-lane hill would be approximately 100 feet wide, which can easily be illuminated using a wide-angle (spread) floodlight from one side. Up to 250-foot widths can be accommodated from a single side. Mounting fixtures along a magic carpet or rope tow doubles the utility for illuminating the hill and its access. Pole separations can be approximately 150 feet (~46m) with at least 10 feet (~3m) of offset from the first lane to isolate poles from the course. Poles should be padded for safety.

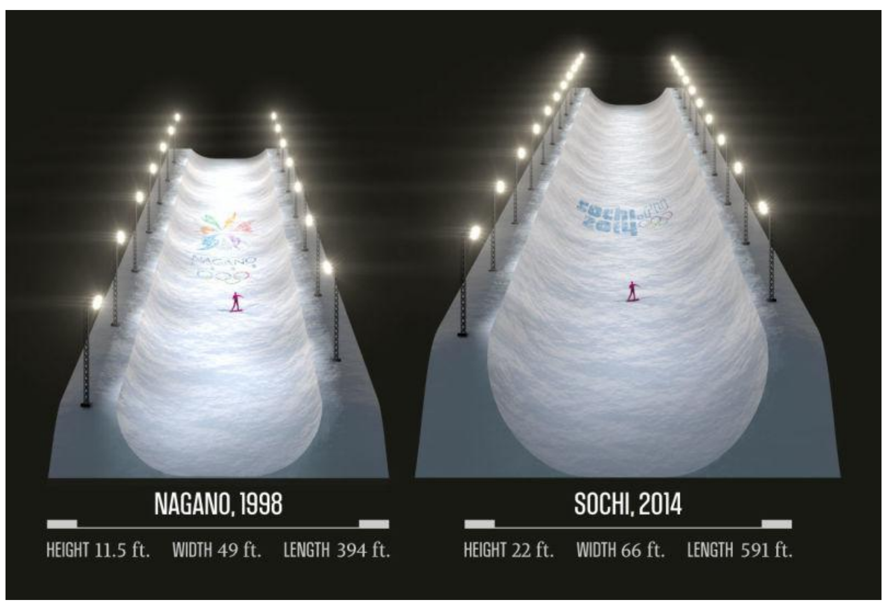
The illustration displays a 200-foot (~52m) area with 200-foot pole separations, side-on-side. Pole heights are 30 feet (~9m) above grade. This site selected 300-watt Snow-Bright™

magnetic induction floods with three fixtures per pole. This would be considered particularly well illuminated and can be used for other activities if recommissioned.

If upgrading from metal halide or high-pressure sodium, a color temperature above 4,000K should be used for the course, while any color enhancement should be supplemental. This is because visual acuity degrades in monochromatic (single color) lighting. Thus, a combination of low-glare Dark Sky compliant magnetic induction could illuminate lanes while multi-color LEDs can be added for special effects. If the area is also intended for other applications like using narrow lanes for race training or free-style practice, lighting should be increased to meet such requirements.

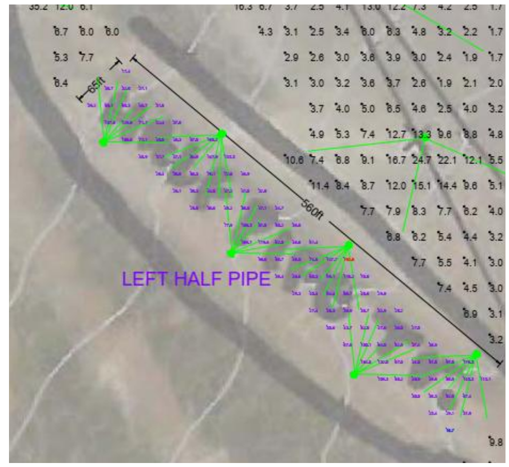
HALFPIPES

Halfpipes are increasingly popular, particularly as a nighttime activity. Two high-profile halfpipe projects speak to complexities. The 1998 Olympics in Nagano, Japan used metal halide floodlights originally designed for field and stadium lighting to illuminate the first halfpipe. Since LEDs were not available at the time, metal halide represented the only lighting option. As the event evolved, we see the challenge was increased. From 1998 to the Sochi 2014 Olympics, halfpipe dimensions expanded from an 11.5 foot height – 49 foot width – 394 foot length to almost twice the height at 22 feet, a 66 foot width, and 591 foot length. In all instances, the challenge is to provide uniform light distribution without excessive glare that could blind athletes in the air or on landing.



The Sochi halfpipe competition was marked by a disappointing performance by Shaun White, considered the best and anticipated to be the gold medalists. Sochi illuminated the halfpipe using high-intensity LEDs that were thought to exhibit a high frequency flicker, causing "strobe effect." Shaun White claimed he was having difficulty resolving his landings as did several other competitors. Retrospectively, visual problems athletes experienced may have been due to lighting. This exemplifies the critical nature of halfpipe lighting as performances become more complex with increasingly challenging terrain. Nagano used fourteen 15-meter opposing poles with 2,000 watt metal halide fixtures while Sochi deployed twenty 20-meter poles with LEDs.

In a project layout for a proposed halfpipe at Mammoth Mountain, the designed called for six staggered poles using seven 300 watt Snow-Bright™ magnetic induction fixtures on 35 foot poles to light a 560 foot length by 65 foot width; height was variable depending upon accumulated snow. Using magnetic induction eliminates glare and flicker issues. By staggering opposing poles, light is uniformly distributed without hotspots. Each pole compliments the opposing pole. Highest intensity occurs at the banks with as much as 192 fc. Intensities drop to a comfortable level just shy of 50 fc in the contact area.



The Mammoth Mountain halfpipe was specified for televised competition. At the recreational level, only half the fixtures would be required, saving on energy. Any project should be defined using a photometric layout based upon “IES files” provided by the fixture manufacturer. A white light with a color temperature of at least 5,000 Kelvin is recommended for visual clarity. Attention should be paid to eliminating forward shadowing to avoid landing into darkened areas. For recreational areas, lighting levels can be dropped to between 5 fc and 15 fc depending upon dimensional difficulty. Keep in mind that lighting controls can address competitions versus recreation use by simply raising or lowering the number of activated lamps. Dimming may also be applicable.

JUMPS

The 90 meter ski jump at Lake Placid, NY was built for the 1980 Olympics and used 1,000 watt metal halides for illumination. Lighting wasn’t sufficient for night competition, but could be used for practice runs and maintenance. A lighting renovation plan was requested in 2016 and subsequently updated. To be sure, this is a highly specialized lighting application that is not often required since there are very few such jumps in all of North America. These include Lake Placid (ORDA), Harris Hill, Suicide Hill, Howelsen Hill, and others. Key lighting objectives include low glare, uniformity, no flicker, high color temperature, forward lighting for shadow removal.

By way of example, Lake Placid requested a competition lighting design using Snow-Bright™ magnetic induction lighting to avoid excessive glare and flicker while allowing uplighting for

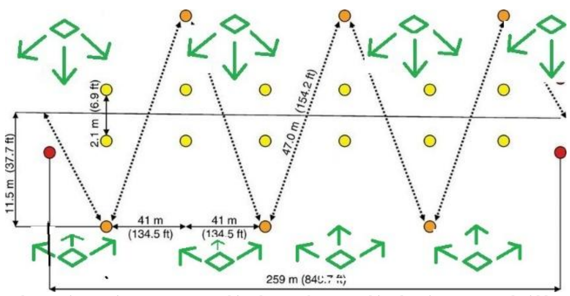
the landing area. Since one side has a catwalk, lighting was placed on the opposite side. Although 90 meter competition jumps follow the same design criteria, location dynamics must be incorporated into any design. From the judging area (perspective) to general viewing and filming locations, lighting must be properly positioned. The photometric layout calls for approximately 10 fc measured uniformly over the takeoff and landing areas. Snow-Bright™ fixtures have an S/P ratio of 2.77 which means the perceived lighting at 10 fc would be equivalent to 27.7 fc based upon "visually effective lumens" (VEL). (See visually effective lumens explanation) *As of 2025, this project was not implemented.*

An equal challenge is properly illuminating aerial ski jumps that are difficult to stage during the day due to the sun's movement and potential glare at certain angles to the approach and jump ramp. A nighttime event offers unchanging consistent light, but the angle of attack from the light source to the intended target area is critical to avoid blinding the athlete at any point in the approach, takeoff, and landing. Given the aerial height off the landing area can be 60 feet (18.28 meters) or more, fixture mounting must accommodate this distance while providing sufficient projection to the ground for visual accuracy. Most important is depth perception and timing. Obviously, this is a highly specialized application that does not pertain to many snow

sports venues. Building an aerial jump location is expensive and would probably not be open to the general public. In most cases, such areas are constructed for specific events and deconstructed when the competition is over. To be sure, there are several practice venues where athletes can hone skills.

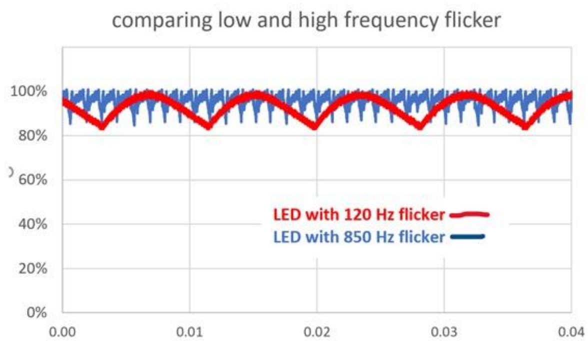
RACING – SLALOM AND SUPER G

Race events are increasingly being scheduled at night. Advantages include eliminating inconsistencies caused by changing sunlight that affects temperature, snow texture, and visual perception. The challenge has been to create lighting that fully illuminates the course while not interfering with visual perception. (See "Technical Elements for Event Lighting") Since high intensity lighting can blind a skier, courses have been *downlit*, meaning lamps are faced downhill at the racers back. Obviously, this can cause shadowing in front of the skier's progress down the course. A review of FIS guidelines specifies that athletes should not be blinded by lighting, but downhill shadowing should also be eliminated. Lighting physics forecloses this combination of objectives. The only way to eliminate forward shadowing is to up-light; face lighting uphill.

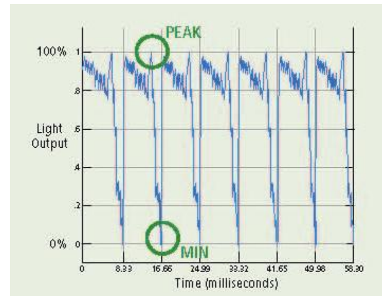


Achieving the desired result requires a plan that alternates lighting infrastructure along the slalom track. This "zig-zag" should focus at the centerline from both sides going across the course, uphill, and downhill. Alternatively, light can be projected from high-mast poles that can provide uniform illumination with direct top-down projection. Advantages to high-masts include removing forward shadows and smooth light distribution. Disadvantages are a propensity to "flatten" the course appearance, much like flat sunlight, and over-projection, causing light pollution. High-mast infrastructure is more expensive than conventional 25 to 40-foot (7.62 to 12.19m) poles. If the resort already has high-mast lighting using metal halide fixtures, greater energy efficiency can be achieved by upgrading to high-intensity LEDs or Snow-Bright™ magnetic induction floods. High-masts are typically 60 feet (18.28M) or higher. Some important considerations include making sure fixtures are suitable for snow and ice, the LED drivers should minimize high-frequency flicker, ballasts (drivers) should not generate high-pitch harmonics that can disturb bats and canines. Research whether the LED uses Pulse Width Modulation (PWM) for controlling intensity. This is specifically linked to the flicker rate.

High-frequency flicker is a fundamental LED characteristic. It generally related to the alternating current hertz which is 60 Hz in the U.S. and 50 Hz in Europe and other regions. Regarding conscious vision, a 60-cycle flicker can be perceived by most people and causes strobe effect. Doubling this to 120-cycles is incorrectly believed to exceed human perception, but can actually be more problematic for high-speed sports because strobing still impacts depth perception and timing.



The graph illustrates a dip of only 20% which assumes interpolation between strobes. When making an investment in lighting infrastructure, getting it right requires vigorous research and verification. For operations managers inclined to "test before you invest," it is easy to use a watt meter to measure in-rush current on a demo fixture. See if the vendor is willing to provide a unit for testing. If there is access to an oscilloscope, determine the actual flicker rate and intensity. You may find the actual dip is far more than 20% as the second graph depicts.



NOTE: If LEDs are already deployed, it is possible to mount up-hill magnetic induction fixtures to remove forward shadowing without altering the existing lighting plan. Such lighting can be integrated into the LED fixture array, or mounted separately.

MOGULS

One of the most technical lighting challenges encompasses mogul (bump) runs that fit into three categories; 1) recreational, 2) practice, and 3) competition. Recreational moguls usually naturally result from slope contours, snowfall, fall-lines, and ski patterns. They can also be intentionally formed by grooming. Practice moguls are machine groomed for recreation and training. Competition moguls are specified by FIS and/or the U.S. Ski & Snowboard Association. In all cases, illumination should be across, downhill, and uphill to eliminate shadowing, illuminate landings (forward progress), and provide contour visibility.

Competition course considerations include:

- **Lighting Poles**: Staggered on both sides of the run every 100 feet (~30m), alternating left and right to minimize shadow overlap.
- **Pole Heights**: Between 25 to 40 feet (7.6 – 12m), depending on terrain steepness and mogul depth.
- **Beam Spread**: Wide-angle fixtures (30°–60°) with neutral white color temperature (4000K–5000K… Snow-Bright™ magnetic induction is rated 6,500K) for optimal contrast.
- **Mogul Terrain**: Represented with contour shading to highlight troughs and peaks.
- **Emergency Lighting Zones**: Placed every 300 feet (~100m) along the centerline for backup visibility.
- **Finish Area**: Clearly marked at the base of the run with additional lighting for deceleration and safety.

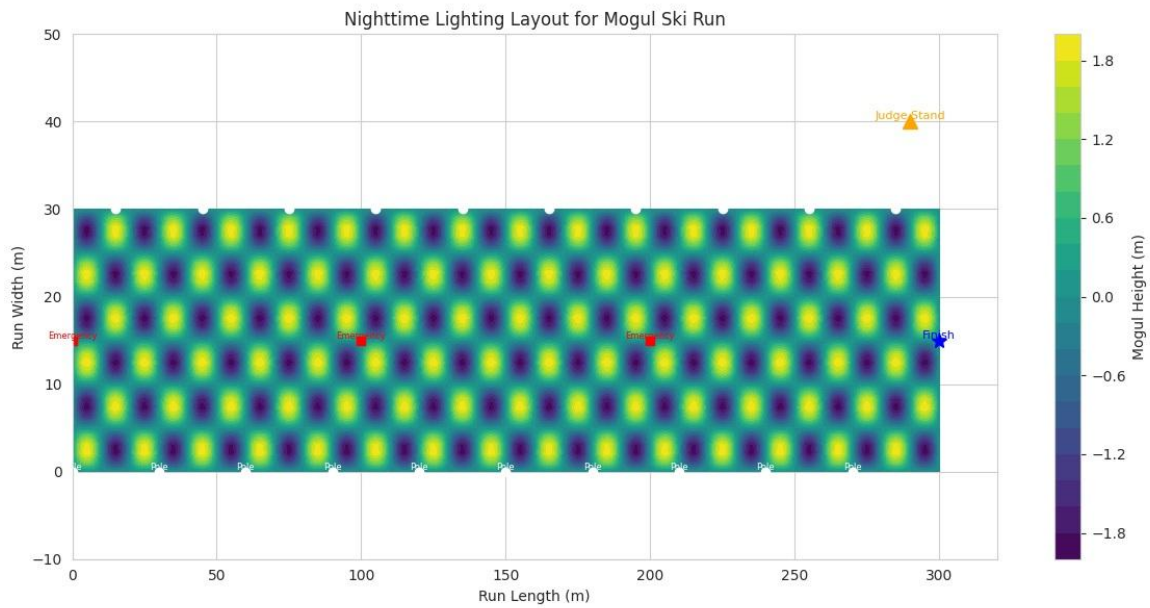
- **Judge Stand**: Positioned off to the side near the finish, with elevated lighting for unobstructed viewing.

Mogul Course Dimensions & Layout

General course specifications:

Feature	Meters (m)	Feet (ft)
Course Length	235 ± 35 m	771 ± 115 ft
Course Width	≥ 18 m	≥ 59 ft
Track Width	10 ± 2 m	33 ± 6.5 ft
Course Angle (CA)	28° ± 4°	28° ± 4°
Vertical Drop	110 ± 30 m	361 ± 98 ft
Horizontal Distance	175m ± 35m	575 ± 115 ft
Finish Area Length	35 ± 5 m	115 ± 16 ft
Finish Area Slope	5° ± 5°	5° ± 5

Using these dimensions, a layout would appear as follows:

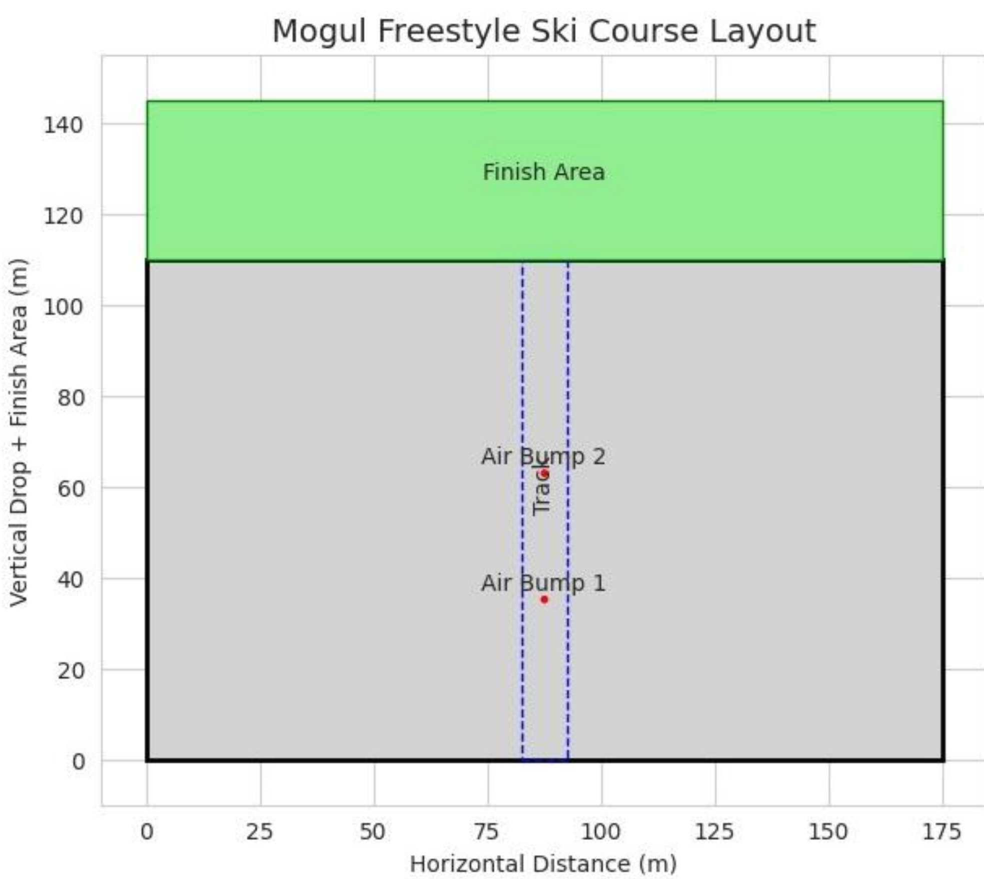


This assumes the following placements:

Feature	Specification (metric)
Start to 1st Air Bump (A1)	15% of course length (CL)
2nd Air Bump to Finish (A2)	20% of course length (CL)
Air Bump Height (AH)	50–60 cm
Air Bump Width (AW)	≥ 120 cm
Takeoff Angle (TA)	26°–30°
Landing Zone Angle (LA)	> 26°
Distance: Last Bump to Takeoff	4.0–5.0m
Distance: Takeoff to Landing End	15.0m

There are ten offset pole locations (white dots) on each side to create a multi-angled light field with even distribution. For moguls, contrast is the most significant feature. Additional mounting brackets can be added halfway up the poles at safety exit locations for supplemental lighting. Even daytime conditions use debris to create visual contour differentiation. A double-sided competition run could be designed as follows:

- The **gray rectangle** represents the full course area, with a vertical drop of ~110 meters and horizontal span of ~175 meters.
- The **blue dashed rectangle** marks the central track (about 10 meters wide), where skiers perform their runs.
- Two **red circles** indicate the **air bumps**—strategically placed at 15% and 80% of the course length to challenge aerial skills.
- The **green zone** at the top is the **finish area**, sloped gently for safe deceleration.
- Labels show key zones like the track, air bumps, and finish area for easy reference.



Additional lighting can be added to Air Bump positions for better judging. This can also involve higher poles when the course position on the slope is permanent, meaning it will always be set in the same area with the same dimensions. These recommendations are for competition areas. It is always advisable to have a photometric layout for any project, even if it is a retrofit from one technology, like metal halide, to another like magnetic induction.

Consider that LEDs may not be appropriate for mogul illumination due to high glare and flicker. As mentioned, high-frequency flicker can cause strobe effect that may alter depth perception and associated timing. Glare… even daytime sun glare will flatten the snow surface appearance. This represents a dangerous condition for mogul skiers.

Installation Considerations

Infrastructure –

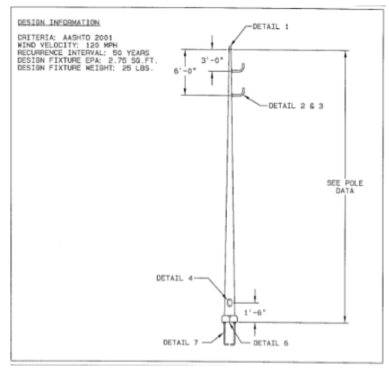
Mountainside construction and installation is challenging and expensive. As any mountain manager can say, pouring concrete on a 45-degree slope is a difficult and costly process. Some projects have required pours from helicopters because trucks cannot negotiate such extreme angles. This is one reason why many steep-sloped venues have chosen not to install night lighting. Simply pouring casings for pole mounting can cost more than the fixtures. Hogadon Basin in Casper, Wyoming was quoted $1.3 million to install new lighting on two slopes. The majority of the cost was for pole infrastructure. At the same time, the company quoting the project warned that it would take up to eight weeks to pour the casings for light poles. Another four to six weeks would be required to allow the concrete to cure.

Hogadon Basin was able to reduce the project from $1.3 million to $420,000.00 by using *helical piles* instead of concrete casings for pole mounting. Helical piles are essentially large screws that drive into the ground like piles. The design is specific to the type of soil or rock. Such piles are able to support skyscrapers and bridges as well as chair lift towers and lighting poles. They are used for building foundations and other structures. The project manager contacted the TorcSill® Foundation company to build appropriate helical piles that matched the mountain's soil profile. The TorcSill® engineering department created a helical pile with a mounting plate that aligned with the lighting pole bolt pattern. A total of 78 poles were used. The entire installation was completed in two days, saving more than two months and eliminating risks associated with curing concrete. Other helical pile companies include Conte Company, Hubbell, and more that can be found on the internet.

Environmental and planning advantages include the ability to remove the piles by unscrewing from the soil medium. Thus, slope topology can be reconfigured without removing infrastructure that is semi-permanent like concrete casings. This is considered more environmentally friendly and sustainable. Understand that helical piles can be used for ski lift towers, buildings, cell towers, wind turbines, and more.

Metal – Wood – Concrete – Composite

For new installations or when supplementing existing infrastructure, there are four choices for pole material. Much depends upon budget and particular environments. For example, metal poles are made from steel or aluminum. Steel is less expensive, but can oxidize more than aluminum. In all cases, poles must be designed for the specific environment. Steamboat Ski Resort can see sustained winds exceeding 100 mph while Mount Peter may see maximum winds of only 60 mph. Wooden utility poles are the least expensive and have the added advantage of being available from many utilities that may help with installation. Two new materials are concrete and composites. These are usually priced between metal and wood. There are not many concrete poles used at ski areas. Concerns include potential spalling (crumbling) concrete and snow chemical incompatibility. Many composite designs incorporate "breakaway" technology because they are mostly used on roads. Breakaway poles are designed to snap if impacted by a vehicle. A skier wouldn't impact this sufficiently, but high winds can inadvertently cause these to fail. Always get a *warranty of use* as well as a guarantee on the function. When ordering poles, be aware of the grade and size. *Wooden utility poles have different diameters for different loads*. Make sure the source for poles is aware of the load requirements.



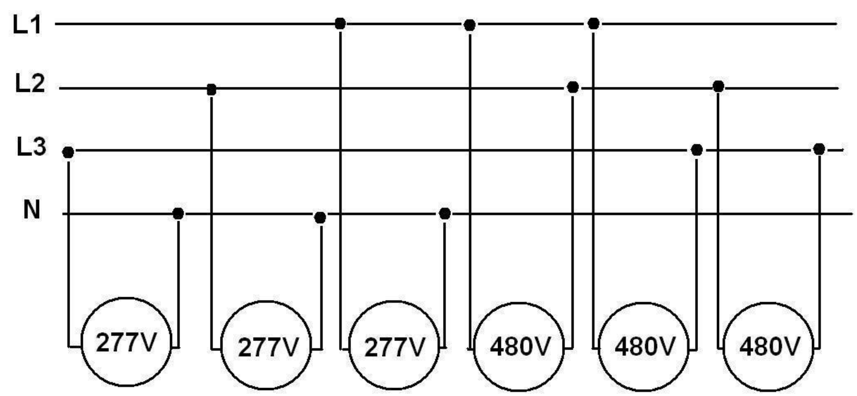
Electrical

Many slope lighting systems share electricity with snow-making. This usually involves tapping off of 480V 3-wire, 4-wire, and even 5-wire. These are described in layman's terms as:

a. Two 277V hots and a ground
b. Two 277V hots, a ground, and a neutral
c. Two 277 hots, a 277V "wild leg," a ground, and a neutral.

Modern lighting ballasts (drivers) can be auto-sensing on the input side to range from 110V/120V to 277V. If 480V is available from snow-making circuits with two 277V hots, a ground and a neutral, 277V fixtures can be configured to use *one* 277V hot, the ground, **and the neutral**. **Warning: Do not install fixtures requiring a hot, neutral, and ground with only the hot and ground. Although it will operate, abandoning the neutral is dangerous.** If the ballast is *not auto-sensing*, care must be taken to keep wire runs (lengths) within voltage operating parameters to avoid *undervoltage* that can overheat the ballast. Check voltages every 100 feet (30.48 meters) to ensure proper voltage is available. Long runs may require a transformer.

If the circuit is 480V with no neutral, select fixtures that are designed for 480V using two 277V hot legs and the ground. There are auto-sensing ballasts that range from 300V to 600V and accommodate 50hZ and 60hZ to adhere to Canadian, European, and other electrical infrastructures. Here are typical wiring option diagrams for U.S. installations:



Canadian high voltage is 600V that breaks down into two legs of 347V. This requires lighting with Canadian specifications unless using a stepdown transformer. It is best to consult a licensed electrician or an electrical engineer to be sure about purchasing the right fixtures.

In-Rush current is also an important consideration. Make sure to check on in-rush current to ensure against overvoltage when turning lights on. Since MIL like Snow-Bright™ does not have in-rush, it is not a concern; however, LEDs that do not incorporate capacitor start-up components will spike current demand.

On new installations, it is usually best to keep lighting circuits *independent and separate* from other applications like snow-making or ski lifts. Lower voltage lighting ranging from 110V to 277V is usually less expensive. Keep in mind that higher voltages use less current (amperage). Fixtures that operate on standard 110V/120V can be used when mounting on buildings because they can be tied into available electricity outlets.

Risk Mitigation

Nighttime activities have associated risks. Anytime operations are expanded to include activities like night skiing/riding, terrain parks, halfpipes, jumps, moguls, and racing, there is liability. Sports lighting has been associated with accidents, environmental impacts, light pollution, and even eye damage. When faced with such exposure, it is important to consider the most common generalized accusation that those responsible “knew, or should have known” about dangers, risks, exposures, and consequences.

Accidents: The best defense is to make sure there is a lighting *plan.* It's best to get a photometric study and adjust the installation to adhere to documented standards. If there is reasonable care taken to ensure safety, accident claims based upon faulty or insufficient lighting can be successfully challenged.

Eye damage: There have been claims for alleged eye damage because light glare or intensity can be harmful to the retina. This means that fixtures with very high lumen-per-watt output can carry more risk for eye damage claims. In the May 13, 2013 edition of *Live Science,* Assistant Editor Marc Lallanilla reported on the research of Dr. Celia Sánchez-Ramos of Complutense University (Madrid, Spain) regarding potential dangers of directly viewing unshielded LED lighting. Simply put, the intense concentrated light of LEDs can permanently damage the retina, causing blind spots and color de-sensitivity. As the installed base of LEDs rapidly expands, more and more emphasis is being placed upon health risks associated with directly viewing LEDs. In fact, the problem has become sufficiently serious for CREE, one of the largest LED lighting manufacturers, to issue its own warning white paper. If you already have LEDs, check to see if you can look directly at the fixtures without discomfort. If not, consider getting diffusion lenses.

Environmental Impact: Increasingly, environmental advocacy groups are becoming litigation activists. If lighting is considered environmentally harmful, the ski area could face litigation. Exposure can be reduced if it is shown that environmental impacts were considered and the lighting brand has *documentation regarding environmental effects*. This is not only related to light intensity or quality. A company was forced to *cease and desist* operating LED fixtures because a bat advocacy group alleged the ballasts produced a high-frequency harmonic that interfered with bat navigation. *It was less expensive to replace the lighting than to defend the litigation.* Try to get environmental impact representations from the lighting vendor to show a "reasonable effort" to minimize negative environmental consequences. If litigation is filed, ask legal counsel if the lighting vendor or manufacturer can be joined in the action.

Light pollution or intrusion: Venues that have communities in and around the mountain area often face complaints from residents about light intrusion. On new projects, this exposure can be minimized by holding demonstrations and approval meetings with affected residents. Such meeting can often be scheduled in conjunction with local authorities like planning boards. Brands like Snow-Bright™ are designed to have limited projection and low intensity at the bulb. Regardless of claims, getting preapproval is always better than relying upon manufacturers' claims. Light pollution claims can also be made by Dark Sky advocacy groups, environmental organizations, and town boards. Check for local, state, and (eventually) Federal light pollution ordinances.

Health: Less likely, but still a consideration are negative health risks associated with artificial lighting. An AI **ChatGPT** inquiry yields the following:

Artificial lighting, including **LEDs (light-emitting diodes)**, has revolutionized energy efficiency and longevity in lighting. However, there are **several documented and potential health concerns** when LEDs are improperly used or overexposed — especially at night.

⚠️ Health Risks Associated with LED and Artificial Lighting

1. Disruption of Circadian Rhythms

- **Cause**: Blue light wavelengths (especially ~460–480 nm) in many white LEDs.
- **Effect**: Suppresses melatonin, the sleep-regulating hormone.
- **Outcome**: Sleep disturbances, insomnia, fatigue, and increased risk of chronic conditions like obesity, depression, and cardiovascular issues.
- **Evidence**: Supported by studies from Harvard Medical School, WHO, and AMA.

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2. Increased Risk of Eye Strain and Retinal Stress

- **Cause**: High-intensity point-source light; blue light scatters more in the eye.
- **Effect**: Digital eye strain, dry eyes, headaches.
- **Long-Term Risk**: Potential contribution to **macular degeneration** (though long-term human data is limited).
- **Particularly Sensitive Populations**: Children, seniors, and those with pre-existing eye conditions.

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3. Potential Endocrine and Metabolic Effects

- **Disrupted sleep** caused by nighttime LED exposure is linked to:
  - Insulin resistance
  - Weight gain
  - Elevated cortisol levels

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4. Triggering Migraines and Seizures

- **Cause**: Flicker in low-quality or dimmed LEDs (invisible to the naked eye but neurologically detected).
- **Effect**: Headaches, migraines, and in rare cases, photosensitive epilepsy.
- **At-Risk Groups**: People with light sensitivity, epilepsy, chronic migraines.

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5. Mood and Mental Health Effects

- **Reduced melatonin** and circadian misalignment can exacerbate:
    - Depression
    - Anxiety
    - Seasonal Affective Disorder (SAD)

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6. Children and Adolescents

- **More vulnerable to blue light** due to clearer lenses and larger pupils.
- **Effects**: Greater melatonin suppression and possible developmental concerns tied to sleep deprivation.

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7. Environmental and Indirect Health Risks

- **Light pollution** from outdoor LEDs may:
    - Disrupt wildlife and ecosystems
    - Affect human sleep through ambient light intrusion
    - Alter melatonin production in entire communities

ECONOMIC CONSIDERATIONS

RESORT OPTIMIZATION THROUGH NIGHT RACING AND EVENTS

Ski area operators face the challenge of increasing revenues by maximizing the utility of a major fixed asset. The mountain is there along with the lodge, parking, snow-making, lifts, and general infrastructure. Resources are always constrained and it is difficult to balance what the mountain offers to diverse customers given available terrain and facilities. For this reason, more and more ski areas are emphasizing "event driven" revenue models. Shifting ski racing programs and special events to nighttime is leading the list.

The challenge is in the execution of profitable night activities that maximize revenue and overall customer satisfaction while minimizing additional overheads. The two most important considerations are 1) the terrain dedicated to nighttime activities, and 2) the lighting plan.

The Model

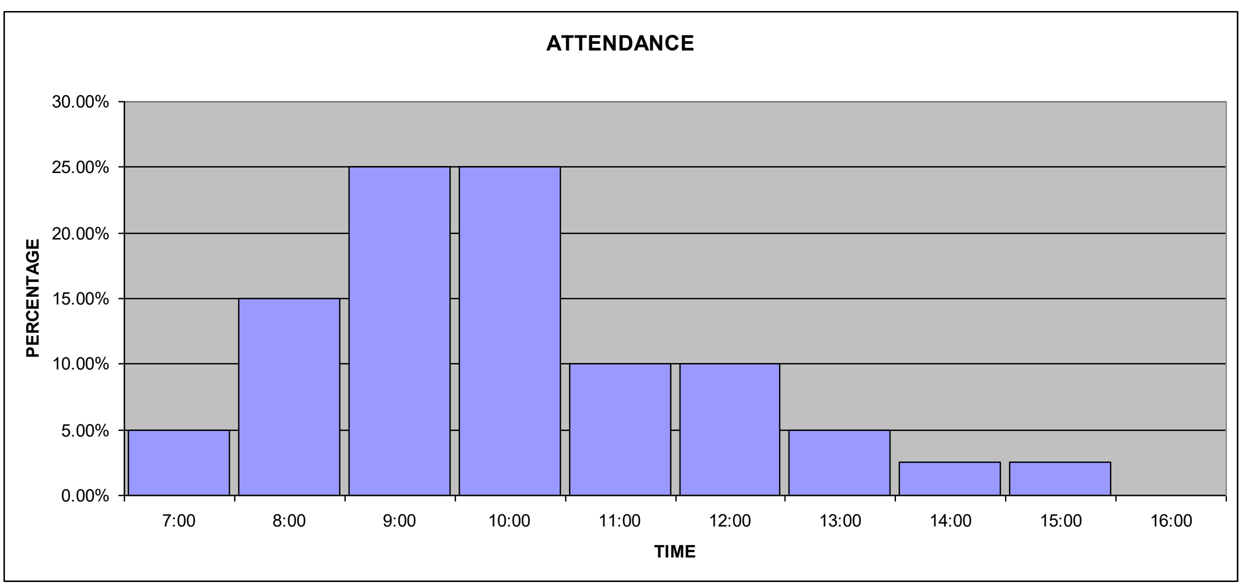
There are three main customer categories; 1) general skiing/riding public, 2) learners (beginners), 3) programs (racing, freestyle). Mountain resources must be divided among these categories to provide a wide range of general skiing/riding terrain, beginner areas, and designated training or event venues. When events or training are conducted during the day, terrain is removed from general customer access. More often than not, the restricted terrain is prime space that can limit the general customer experience and satisfaction.

Although competitions and training for racing and freestyle are important sources of income, many ski areas suffer the negative comments expressed by the general skiing and riding public over the loss of prime terrain. The solution for daytime-only ski areas may be to invest in slope lighting and shift more events and training activities to non-peak evening hours (dusk to closing)!

Northern hemisphere winter daylight runs from approximately 8:00am to 4:00pm. This provides only 8 operational hours. Logically, any incremental increase in operational hours can extend revenue.

The typical daytime ski area begins receiving customers from 7:00am for "First Tracks" until lift closings at around 4:00pm The bulk of attendance comes between 8:00am and 10:00am; approximately 70%.

During that time, as much as 30% of terrain can be dedicated to ski race training and/or events. Terrain parks may account for only 5% to 15% of the ski area. Obviously, every area is different, but based upon participation, numbers generally fall along the same breakpoints. Ski areas that service local towns or nearby cities may place an emphasis upon school programs that would provide weekday attendance. Adding nighttime hours to such programs can increase scheduling flexibility since the school day encompasses most of the daylight time during the winter.



Adolescent race programs are usually the most popular, accounting for 70% of youth program participation. The remaining formal training may be categorized as freestyle. It should be noted that freestyle popularity is increasing and is directly associated with the program philosophy of individual mountains as well as dedicated terrain (i.e. terrain parks, moguls, etc.).

With the exception of certain "destination resorts," up to 85% of attendance occurs on weekends and holidays. This includes program participation. Invariably, weekends and holidays are viewed by customers as "overcrowded." To relieve this situation, adding or enhancing a nighttime schedule for controlled attendance (i.e. programs and events) can reduce the need for dedicated terrain while lowering daytime congestion.

From the revenue side, some ski areas rent terrain (lanes) to schools, colleges, and ski clubs for training. Rental fees can be substantial, ranging from $150/hr during mid-winter at a small ski area, to $2,000/hr for early or pre-season periods at a large resort. Obviously, the venue and demand dictate the value proposition. Providing nighttime access increases revenue potential while reducing the population burden. Events and training at areas that might be restricted during the day can be reallocated to nighttime hours.

Adding skiing from 4:00pm (16:00) to 8:00pm (20:00) increases access by 40%. Unfortunately, many mountains *do not* realize commensurate revenues because they do not allocate resources specifically to the evening schedule. Certainly, 100% of program participation cannot be directed to the evening schedule. Further, the most successful nighttime operations are "additive." This means that there is purposeful overlap between daytime and evening program schedules. The "lunchtime lull" is an example. There is a propensity toward setting up training or event courses in the morning and running through the heaviest portion of the attendance schedule; between 9:00am and 12:00pm. By approximately 10:30am, there is competition between the general customer base and programs to use terrain.

By midday, general customers and program participants head to the lodge to eat. Mountain utilization precipitously declines for 45 minutes to more than an hour. Some program directors stagger lunch to maximize practice area utilization. This may relieve afternoon congestion, but does little to avoid the conflict of terrain interest during the morning. Managers know that race events can increase top line revenue, but there is a cost. Race participants often arrange for meals to save money at the expense of the mountain's food concession. Human resources and infrastructure resources (parking, security, common area space, snow-making, and terrain) can significantly diminish bottom line results.

Questions to consider are:

- How much will it cost to keep lifts open to service evening operations?
- How much will it cost to keep food service open during evening hours?
- What is the revenue expectation (tickets, area (lane) rentals, entrance fees)?
- What are the additional gross management costs? Insurance?

It should be noted that there are two aspects to the proposed model. First are the regular program participants where the objective is to relieve the mountain of congestion due to terrain reservations. Second are events that attract outside one-time participation like races, rallies, and special events that can include training and certifications… PSIA. In the latter case, event revenues must be measured against top line costs. Do the incremental ticket and food & beverage sales justify the cost of hosting the event?

Ancillary considerations include customer satisfaction, safety, and resource allocation. In the case of relieving congestion, it is important to measure the customer satisfaction against the possible requirement to perform interim grooming between the day and night sessions. Certain risks may be mitigated by relieving daytime congestion, but the night venue must be appropriately safe. Until proven by actual experience, benefits of relieving congestion are speculative and amorphous. Managers need a baseline to measure improvements in attendance by the general public customer. There are subtle considerations, too:

- Does allocating training and events to night sessions allow more freedom to recreationally (socially) ski during the day?
- Do families want time to ski together, or are they looking for separation?
- Will nighttime training and events be viewed as disruptive to the program?
- Is the quality of nighttime training and events better, equal to, or worse than daytime training?
- How will nighttime training and events be received by staff?

There are two ways to answer some of these questions. Some managers may resort to surveys. The most effective way to determine reality for your mountain is to perform a test. Some families like to ski together while other parents view programs for their children as opportunities to take a break and enjoy their own skiing/riding. Thus, the way any change to program scheduling will be received depends upon the subjectivity of participants. Objectively, if freeing up mountain terrain brings in more general customers, the results are easily measured. Can you invite more busses? Will customers see the difference and appreciate the added terrain flexibility?

Events are more easily quantified. An example might be a club race expected to draw 50 participants. If the total ticket package is $80, the gross would be $4,000. Shared fees and other expenses would be deducted from the $4,000 to arrive at the bottom line enhancement. Additional revenues can be generated from food service, equipment rentals/sales, and parking fees (if such applies). This same approach applies to freestyle events like rail jams, bump competitions, and big air competitions. It is straight-line math. This same math applies to lane rentals and exclusivity privileges. How much rent must you receive for a night training slope or lane in order to cover the cost of maintenance, operations and clear a profit?

Hundreds of ski areas provide night skiing, *but many do not truly plan and execute a nighttime revenue generating strategy*. There are areas that successfully promote night skiing/riding while other areas are passive; taking the approach of "if we have it, they will come." To be sure, aggressively adding and promoting nighttime skiing/riding can enhance the revenue model of almost any ski area. Unfortunately, too many managers simplify their cost/benefit analysis by neglecting to consider resource allocation and the potential revenue drivers coming from releasing terrain to the general public or gaining scheduling flexibility. Many USSA race organizers are looking toward night events on weekend nights, as a way to mitigate the demand during the day – which makes management happy!

In reality, nighttime skiing can provide a more consistent visual experience under the correct lighting because the snow surface is not subject to varying lighting conditions. At night, clouds and the changing angle of the sun are not factors in determining visibility. Thus, every participant experiences the same lighting on the course. With the correct lighting, the experience can actually be better than coping with inconsistencies of daytime events.

Resorts that currently offer night skiing, racing and events should seriously look at their lighting plan and ask themselves: Are we doing the best we can for our customers? Are we providing the best lighting technology possible? If we improved our lighting plan, would that result in a dramatic increase in night skiing demand?

Resorts that are considering night operations should carefully investigate the new lighting technologies that are now available. For Steamboat Springs Ski Resort the important considerations were: visual acuity with the best spectrum, dark sky compliancy, energy efficiency and fixture longevity*. As a result, they were able to satisfy highly stringent U.S. Forest Service, zoning, and HOA requirements. The end result was racers at Steamboat being clocked better than 80 mph at night under new energy-efficient lighting specifically designed for ski slopes. The technology to provide exceptional nighttime skiing/riding is available.

The key to success is in the nighttime plan and execution. Should you run more training and events at night? In all probability, the answer is "yes!"

Nighttime Targeted Programs

Consider an event for "singles" where gents enter the lift-line on the right and ladies from the left. They meet on the ride up, exchange information (or not), and have the opportunity to get acquainted. It's called "ski dating," and was featured in the *Denver Post*. Obviously, this would be disruptive during daytime hours unless a specific day was designated "Singles Day." The program could be very effective and popular at night. If there is sufficient local, or near-local population to support ski dating, it could significantly add revenue. Some organizations that include vacation destinations and even hotels and restaurants are teaming up with online dating services to increase marketing reach.

When customers over 55 were asked what they didn't like about skiing/riding, a significant percentage objected to youthful behavior. Not recalling that they were young once, there is a fear of being injured, a dislike for rowdy behavior, and an overall jealously, perhaps. A survey conducted at Windham Mountain, New York revealed that seniors are very open to Seniors-Only days or nights. If sacrificing an entire day to seniors is too disruptive to general customers, an evening schedule can make more sense. Seniors tend to spend more, and are more easily managed.

School programs can lend themselves to evening hours. Grade school and high school students can join in evening athletic ski/ride programs that enhance revenues. In some cases, there are budgets for "off-campus" activities.

The objective is to be proactive with nighttime programs. As long as cost-benefits are demonstrably positive, implementation requires lighting infrastructure.

SUMMARY

Choosing **sustainable slope lighting** requires a holistic approach that goes well beyond energy efficiency and carbon footprint. Ski areas must be concerned with the original pollution targeted by Earth Day; soil, water, air, noise and light. Environmental considerations include impact on wildlife, neighborhoods, health, risks, and the customer experience. Economics play a paramount role on the decision to have nighttime event and install lighting infrastructure.

Two types of technology are reviewed in depth; 1) LEDs, and 2) magnetic induction lighting. AI inquiries are encouraged. Consulting a vertically integrated lighting vendor is recommended.

NOTES: