# TECHNICAL SNOW 101: Truths and Myths

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The Chartreuse Mountains stretch across southeastern France, spanning from Grenoble in the south to Lac du Bourget in the north. This region, known for its dramatic limestone cliffs and rich wildlife, becomes a hotspot for skiers each winter. However, according to a 2023 report by Euronews, snowfall in the area has decreased by 40% over the past 30 years due to climate change.

These changes reflect a broader natural phenomenon impacting the ski industry worldwide. For instance, an unseasonably warm winter in 2022 led to 7,500 ski slopes across France closing. Beyond Europe, resorts in India faced similar challenges in 2024, resulting in widespread cancellations as tourists were unable to ski due to a lack of snow.

To address diminishing snowfall, many resorts are beginning to use technical snow production and snow farming to ensure suitable skiing conditions throughout the year. However, this transition has raised concerns about whether technical snow production could harm the very natural environments that skiers value. How much truth is there to these concerns? Is the media being too harsh in its criticism of these practices?

This discussion engages with this ongoing debate by exploring the effects of technical snow production and snow farming on the environment. The goal is to provide a balanced argument that clarifies common misunderstandings about these practices, while also addressing the main environmental challenges that need to be resolved.

# THE PROBLEM:
# Climate change threatens the future of skiing

> Of course, there are shifts and changes year on year, but the long-term trend (for snow) is declining. Over the past four decades, human-caused global warming has led to reduced snow across much of the Northern Hemisphere, a recent study shows.
>
> ***Madeleine Orr,*** *Sports Ecologist and Assistant Professor at the University of Toronto, New Artificial Snowmaking Technology Could Offer a Lifeline to Struggling Ski Resorts*

The Intergovernmental Panel on Climate Change (IPCC) reports that human activity has caused the Earth's temperature to rise by 1°C (1.8°F) since 1850. If the Earth continues to warm at this rate, the IPCC predicts that by 2040, the world could be 1.5°C (2.7°F) hotter than it was before industrialization.

Expanding on this point, a more recent report from 2023 suggests that there's a 50% chance that temperatures will exceed this 1.5°C (2.7°F) threshold between 2021 and 2040. If this happens, around 53% of ski resorts in Europe will be at a "very high" risk of not having enough snow. This risk could increase to 98% if global temperatures rise by 4°C (7.2°F), which represents the worst-case scenario. The level of risk each resort faces depends on its geographic location and elevation, with resorts at lower altitudes or near the coast being the most affected.

These challenges facing ski resorts are significant, but the impact goes beyond the resorts themselves. Diminishing ski tourism will have a substantial effect on local communities and the broader economy. For example, the Alps are the most popular destination for skiing in the world, attracting over 40% of all ski tourists each year. The snow sports industry in this region is worth about € 30 billion.

**Exploring the data country by country:**

- In France, ski tourism provided 120,000 jobs and contributed € 2 billion to the country's exports in 2020.
- In Austria, winter sports tourism generated €12.6 billion in sales in 2022, adding €6.7 billion to the economy, which makes up 6.2% of Austria's total economic activity. The industry supported 250,000 jobs, or about 7.8% of all jobs in the country.
- In Germany, people spend €16.4 billion each year on winter sports (according to data from 2010). This amount is about 20% of the €83.4 billion spent on all active sports in the country. Skiing is the most important sport for the economy, making up 13% of all spending.

> We don't want all the ski resorts to be closed in five years or ten years, and not have had time to really think something through for the economy of the regions.
>
> ***Albert Verdaguer*** *Scientist at ICMAB-CSIC,*
> *New Artificial Snowmaking Technology Could Offer a Lifeline to Struggling Ski Resorts*

In addition to these economic benefits, skiing also fosters community spirit, promotes a love for the outdoors, and is often linked to local traditions and festivals. Preserving skiing helps maintain this cultural heritage. The sport also provides physical and mental health benefits.

Taking these points into account requires a holistic view when considering sustainability in skiing – one that balances the health of people, communities, and the environment, alongside the economy. With this in mind, finding a way to continue snow sports within a warming climate is extremely valuable. So, what can be done?

# SNOWMAKING:
# A Way to ensure good ski conditions

In response to rising global temperatures, technical snowmaking and snow farming practices have become key strategies for ensuring there is enough snow. As a result, the number of snowmaking facilities in the Alps has grown rapidly in recent years.

In Switzerland, the percentage of ski areas with technical snow increased from less than 10 % in 2000 to 36 % by 2010. In 2021, 90 % of ski areas in Italy, 70 % in Austria, 53 % in Switzerland, 37 % in France, and 25 % in Germany used technical snow.

## Truths and myths around technical snow production

Technical snow production, like all human activities, does affect the environment, though it's hard to say exactly how much. For example, one study states, "there is limited research on the actual water and energy usage involved in snow production." With this in mind, the remainder of this article aims to provide a fuller picture of how technical snow production impacts the environment and people, dispelling common myths while highlighting key challenges.

### Myth: "Snowmaking has an extremely high carbon footprint"

Making technical snow helps ski resorts maintain good snow conditions, even when global temperatures are rising. However, this practice has been criticized for contributing to the very problem it aims to solve. A warmer climate increases the need for technical snow, but making that snow contributes to climate change, creating a negative feedback cycle.

Snow cannons and guns create snow by using high-pressure water, compressed air, and nozzles. This process typically requires 0.6–0.7 kWh/$m^3$ for lances and 1–2 kWh/$m^3$ for fan guns. For perspective, powering a 100-watt light bulb for 10 hours uses 1 kWh. In Canada, creating around 42 million cubic meters of machine-made snow in a typical winter uses as much energy as nearly 17,000 homes do in a year (130,000 metric tons of $CO_2$ per year).

However, looking at the bigger picture, a recent study from 2023 found that snowmaking only makes up a small part – about 2–4 % – of the total carbon footprint at ski resorts. Most of the emissions come from things like transportation (for example, flying) and accommodations.

This study shows how important it is to consider the whole picture when thinking about the environmental impact of technical snow. Expanding on this point, Marit Gjerland, Venue Advisor for the Norwegian Ski Federation, explains that it is necessary to compare the energy used in making snow to that of other public places, like swimming pools, ice rinks, and sports tracks, which also produce carbon emissions.

> These other recreational venues are rarely scrutinized for their environmental impact in the way ski facilities are. It would be beneficial to examine and compare the $CO_2$ footprints of these amenities alongside those of ski areas to gain a more balanced understanding.
>
> *Marit Gjerland, Venue Advisor for the Norwegian Ski Federation, interview by the International Ski Federation*

Additionally, countries with extensive renewable energy systems in place will have a smaller carbon footprint from snow machines. This is because a larger portion of the electricity used by these machines comes from renewable sources that supply the country's power.

For example, in 2022, Norway generated 95.6% of its electricity from renewable energy, while renewable energy accounted for 23.1% of the European Union's total energy consumption in 2022. These details are important to consider when calculating the carbon footprint of making technical snow.

"In Norway, for example, ski tracks of up to 10 km are accessible to the public free of charge, benefiting many while utilizing predominantly green energy sources, such as hydropower. Given our reliance on renewable energy, it's worth noting that the emissions from snow production may be relatively modest, especially compared to the broad social and economic benefits that ski areas provide. However, further documentation and precise data are needed to quantify these impacts more effectively", says Gjerland.

Another important factor to consider when looking at the carbon footprint of making technical snow is the albedo effect. The albedo effect refers to how well a surface can reflect sunlight, and snow is particularly good at reflecting light compared to other surfaces. When technical snow is made in areas where there is no longer any natural snow due to a warming climate, it helps increase the albedo effect in those regions.

One study shows that making snow can raise the albedo of a region compared to areas without snow. What's important to know is that this helps cool the local environment. However, this cooling effect mostly occurs in March and April and can vary depending on the landscape of the area. The study concludes that a complete life cycle assessment is needed to measure the environmental impact of making technical snow. This means considering the entire process, including the energy used for making snow and maintaining the ski areas.

## Truth: "It is important to lower the carbon footprint of snowmaking"

Even though it is not completely clear what the climate impact of making technical snow is, the ski industry is working hard to reduce emissions, acknowledging that there is still a carbon footprint to minimize.

As technology improves, new systems are being developed to lower the emissions from making technical snow. One example is SnowRESolution, funded by the EU, which is designing a snow cannon that runs on solar energy. This snow cannon is currently in the testing phase to determine if it functions effectively.

Other snowmaking systems use weather forecasting and monitoring to optimize the timing and quantity of snow production. For instance, some snow groomers are now equipped with GPS systems that measure snow depth. This information is sent to the snow machines to control snow production. The LEVI project at Levi Ski Resort in Finland utilizes such automatic snow machines with smart weather sensors that only produce snow when conditions are ideal.

Major snow producers are focusing on improving the efficiency of their snowmaking technologies. For example:

- TechnoAlpin has been enhancing cooling systems and pipelines, while also developing software to help manage snow production more efficiently. The company has also created a forecasting tool that provides clients with 5- to 10-day temperature and weather predictions, allowing them to plan snow production carefully and use less water and energy based on the weather, explains Wolfgang Hanni, Area Manager at TechnoAlpin.

- DemacLenko's Snowvisual 4.0 system is a high-tech tool that helps ski resorts make snow more efficiently. It tracks important data in real time, such as how much water and energy is being used, and provides detailed reports to optimize the snowmaking process. By carefully managing resources, the aim of Snowvisual 4.0 is to help resorts use less water and energy and reduce waste.

* MND's SUFAG division is advancing snowmaking technology with the Makalu model, a system that uses the latest technology to produce high-quality snow with much lower energy consumption.

Snow farming is another method that helps reduce the energy needed for snow production. Storing snow complements – not competes with – technical snowmaking. A balanced approach is recommended for ski resorts: produce enough technical snow to meet seasonal demands while ensuring that any excess stored snow maintains its quality throughout the summer. Like temperature-independent snowmaking (discussed below), snow farming can be used in warmer conditions.

> "At Snow Secure Tech, we offer a unique solution for snow storage that performs exceptionally well even in warm climates. Our technology includes advanced temperature monitoring both above and below the snow storage area (or 'snow farm'). Temperatures on the surface can reach up to 45°C (113°F), but directly beneath, the temperature stays stable below 2°C (35.6°F). This setup essentially acts as a 'freezer box,' where rain cannot penetrate the storage area, preserving the snow effectively."
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> ***Antti Lauslahti,*** *Chief Executive Office of Snow Secure, interview by the International Ski Federation*

Antti Lauslahti further explains: "Our snow storage technology offers significant benefits in terms of energy savings, sustainability, and ecosystem management. By storing snow during colder months, energy savings for snowmaking can reach up to 80%, as we can produce and store snow when energy demands are lower. Stored snow also allows us to create thicker snow bases on trails, and we can access this snow pile whenever needed, providing reliable snow coverage for our clients. For instance, one client now stores up to 250,000 cubic meters of snow, enabling them to use less energy while producing most of their technical snow during cold weather. Snow storage harnesses 'cold energy,' preserving snow in its natural form and reducing the energy needed to recreate it each season."

However, Fabian Wolfsperger, a sports engineer at the Institute of Snow and Avalanche Research SLF, explains that snow farming can use two to three times more energy than traditional snowmaking when transporting snow from farmed piles to ski runs. This is because snow groomers running on fossil fuels are often used. However, using grooming machines powered by renewable diesel would cut the carbon footprint of this process by 90%.

## Myth: “A warming climate will halt the production of technical snow”

Making technical snow requires both cold temperatures and low humidity. Usually, snow can only be made when the temperature is below about 3° C (37.4° F), and the air has to be dry, with humidity around 20 %. As temperatures rise, it becomes harder to rely on such cold conditions, making traditional snowmaking methods less effective.

To solve this problem, there is a method for making what’s called temperature-independent snow. This approach allows snow to be produced without the need for cold temperatures outside.

However, this method is expensive to set up and uses a lot of energy. About 20 to 40 kWh/m³ of energy is needed to make one cubic meter of snow, compared to the 0.5 to 2 kWh/m³ of energy used for traditional snowmaking methods. To tackle these challenges, the Snow for the Future Project in Norway is working with experts from various industries to create temperature-independent snow that requires less energy. In the upcoming third phase of this project, FIS will join the effort as a key partner.

The project has found that most methods for making temperature-independent snow (flake ice, plate ice, and scraped ice slurry machines) aren’t very energy-efficient. In particular, flake ice machines are the least efficient. (Flake ice machines work by freezing water on a very cold surface, causing the ice to form into thin, flat flakes. These flakes are easy to collect for making snow.)

The Snow for the Future Project suggests that increasing the size of the evaporator in flake ice machines by 50 % would reduce energy use by 40 %. Additionally, lowering the condenser temperature by just 5° C could cut energy use by 50 %.

The Snow for the Future Project also suggests connecting snow factories to new housing and condo developments. This way, the leftover heat from snowmaking processes can be used to warm buildings. Plus, linking snow factories to other industrial processes can utilize waste heat from these operations to make snow. This idea supports the concept of smart, green cities by using energy more efficiently throughout urban areas as a whole, rather than considering key industries in isolation. It also supports local communities by encouraging sports and recreational activities through the development of ski parks in urban areas – another primary objective of the Snow for the Future Project, which is discussed further below.

## Truth: "Producing technical snow to sustain skiing in a warming climate is crucial for conservation involvement and well-being"

In the third phase of the Snow for the Future Project (which includes FIS as a key partner), the goal is to create "neighbourhood snow" for smaller ski areas, especially in places that usually don't get a lot of snow. As mentioned before, skiing is an important cultural activity that provides both physical and mental health benefits. Furthermore, research shows that outdoor sports like skiing can help reduce crime, encourage people to be more active in their communities, and strengthen their connection with nature. Studies indicate that this connection can lead to pro-environmental behavior (actions taken by individuals or groups that protect and improve the environment).

The above highlights the need for a holistic approach to sustainability, which means looking beyond just carbon emissions and considering the social, cultural, and economic effects of means looking beyond just carbon emissions and considering the social, cultural, and economic effects of initiatives.

## Truth: "Making technical snow uses a lot of water and is a key challenge to address"

Making technical snow uses a lot of water. For instance, a ski run that is 3 km long, 40 meters wide, and 30 cm deep would need about 33.3 liters of water every second for 10 nights. In total, this adds up to around 20 million liters of water, which is enough to fill 8 Olympic-sized swimming pools. In Davos, Switzerland, snowmaking used 21.5% of the town's total drinking water, and in Scuol, it used 36.2%.

The Beijing Olympics, the first Winter Olympics to rely entirely on technical snow, used 49 million gallons of water for snow creation, which is equivalent to filling 19.6 Olympic-sized swimming pools.

However, when considering the impact of water use during snowmaking processes, it's important to understand:

> When it comes to water usage, this is one of the most strictly regulated aspects of snow production. Ski resorts are required to obtain water from permitted sources like rivers, creeks, or lakes under strict oversight, ensuring no harm to aquatic ecosystems. All water use is monitored and reported to authorities, guaranteeing that wildlife and fisheries remain protected. Importantly, we don't alter or add anything to the water [when making snow] – it's simply pressurized air and natural water, returned to nature as the snow melts.
>
> ***Wolfgang Hanni,*** *Area Manager at TechnoAlpin*

Despite these high levels of regulation, creating snow still demands a large amount of water, which the industry is working to reduce. Snow farming can be an effective way to lower water demand by reducing how much technical snow needs to be made each season. For instance, Antti Lauslahti states that by covering the stored snow pile, snowmelt can be reduced by up to 90% under Snow Secure insulation mats.

Additionally, some ski resorts are starting to use recycled water to make snow. For example, Salzburg Snow Space collects melted snow in ponds and cleans it with UVB light to ensure it's as pure as drinking water.

In another example, Bridger Bowl Ski Resort is working with the Montana Department of Civil Engineering to test a special system that cleans wastewater using technical wetlands. Wastewater is sent through trenches filled with gravel, sand, and plants. Microbes in the plant roots break down chemicals and waste, making the water clean enough to reuse.

Technological advances in snow machines are also helping to reduce water demand. For example, at Levi Ski Resort in Finland, a project called the LEVI Project uses automated snow machines that save water and energy. These machines adjust to the weather and only make snow when conditions are ideal.

## Myth: "Water from technical snow is not lost but retained locally to be reused when it melts"

To make technical snow, water is taken from nearby natural lakes, streams, or technical reservoirs. Some claim that this is a form of water storage and that when the snow melts, the water is released back into the natural environment.

However, one key issue is that a percentage of this water is lost from the local environment into the air through evaporation. The extent of this effect is still unknown. For instance, some field studies indicate that between 3–10% of the water is lost in this way. Other studies model water loss at 3–13% due to evaporation, while further studies indicate a higher loss of 15–40%.

To counter these effects, snow farming offers a promising solution. Antti Lauslahti states that covering stored snow piles before the main evaporation process begins helps slow water loss from spring evaporation, saving around 10–18% of the water.

However, there's still the problem of the water being locked in the snow from one season to the next. To address these effects, ski resorts have turned to innovative technology to reduce initial water demand, as mentioned above.

## Myth: "Technical snow creation uses harmful chemicals"

Many people are concerned about the chemicals used to make technical snow. However, the idea that most ski resorts, especially in Europe, rely on chemicals for snow production is a common misunderstanding. Technical snow can be, and often is, made without using any chemicals at all.

When considering the use of additives in snowmaking, one approach that has sparked attention involves adding proteins derived from bacteria to water, helping the water freeze more quickly, even in warmer temperatures. However, due to concerns about the environmental effects of using this bacteria on ski resorts, most ski areas don't use this technology. It's banned in Austria and Germany, and only Switzerland still uses it in Europe. For example, the German Ski Federation states that chemicals can only be used on ski racing tracks to keep the competition fair.

Other chemicals, like antifreeze and salt, can be used to harden the snow on slopes, but they also raise environmental concerns. According to Marit Gjerland, in Europe, most places don't use antifreeze for making snow. However, salt is commonly used in countries hosting alpine competitions during the late season to ensure consistent snow conditions.

Furthermore, the European Union is considering stricter regulations on PFAS (per- and polyfluoroalkyl substances), which are chemicals used in ski wax. The problem with PFAS substances is that they don't break down and enter water and food systems when the snow from ski slopes melts. One study found 14 different types of PFAS in the environment at ski resorts in Austria. To address this issue, in 2019, the FIS announced it would outlaw fluorinated ski waxes, a type of PFAS. By March 2023, the ban was fully enforced for the 2023/2024 season. FIS developed a reliable testing system using Fourier Transform Infrared (FTIR) Spectroscopy to detect traces of fluor on skis during competitions. This testing will expand to include lower levels of competition. The ultimate goal is a future free of fluorinated waxes.

## Myth: "Snow machines are entirely harmful to local wildlife"

Research shows that snowmaking can have negative effects on local wildlife. Still, to fully understand the scope of these impacts, both direct and indirect effects, as well as the year-round operations of the ski industry, must be considered.

One concern is the noise from snow machines and how it disturbs wildlife. Other studies show the ski areas themselves harm birds, mammals, and insects. By keeping ski resorts open, this is an indirect consequence of snowmaking.

However, in the summer, some animals actually use ski runs for breeding, hunting, and grazing, which adds a layer of complexity to the issue.

With the above in mind, being closely connected to natural areas, ski resorts have a special opportunity to work on projects that protect and restore the habitats and wildlife around them. And many resorts across the world are doing this. For instance, Alta Ski Area in the U.S. runs the Alta Environmental Center (AEC). The center has planted native trees to help reduce deforestation and has restored wetlands to balance out the effects of the ski lifts. These actions help protect the environment and also offer new activities for visitors. Alta runs special programs like "Birding on Skis" and "Snowshoe with a Naturalist" to engage people with the natural world. By extending the operational season of ski resorts, technical snowmaking supports both the resorts and their restoration efforts in an industry intrinsically connected to nature. Without this extension, other industries may take over, which may not engage in similar restorative practices.

## Truth: "Snowmaking harms soil health and plant life presenting a key challenge to address"

Research indicates that increased snow cover from creating technical snow leads to a predominance of cold-loving plants and delays soil activity. This means natural plant growth and other biological processes start later in the season on ski slopes compared to other areas. However, the overall impact of these changes is complex.

As climate change leads to warmer springs and shifts in natural cycles, the use of technical snow introduces colder conditions in ski areas, especially in March and April due to the previously explained albedo effect. This raises an important question: how does this colder environment on ski slopes affect local wildlife and plant life on a larger scale in the context of a warming environment? Monitoring these effects is essential to understand their full impact.

When technical snow is combined with snow farming, the impacts on plant and animal life can be aggravated further. When snow piles stay in the same place year after year, they can affect the soil below in several ways:

- Less sunlight reaches the soil, disrupting the balance between plants and microorganisms.
- Soil conditions, such as temperature, moisture, and airflow, change.
- Soil microbes become less active.
- Nutrient cycles in the soil are altered, possibly slowing plant growth.
- Cold meltwater from snow affects when plants start to grow each spring.
- Certain types of plants thrive more than others in the colder soil.
- Soil erosion might increase as snowmelt runs off.

Studies suggest that when snow piles sit for more than a year and a half, it can take up to three years for the soil and plants in that area to fully recover. When compressed snow cover remains for multiple years, it can lead to more lasting damage.

Moving snow piles to different locations can help lessen these effects, giving soil and plants time to recover. However, this approach isn't always practical, as it would require large areas and make ski maintenance more costly and inefficient.

In these cases, it's recommended to keep snow piles in the same spot each year, but in low-biodiversity areas or "wastelands." Restoration projects in other areas can help offset the broader environmental impact. For instance, Salzburg Snow Space built a service area with a "green roof" planted with native plant species to support local plant and animal life.

It is worth emphasizing here that, when assessing skiing's impact on soil, plants, and animals, it's important to compare it to other human activities for a balanced perspective. With this in mind, studies comparing ski areas with local farmland present intriguing results. Over time, the differences in plant and animal diversity between ski runs and nearby meadows become minor, with little difference in the types of species present.

## Balancing the benefits of skiing with its environmental impact

Like many industries, skiing impacts the environment, with technical snowmaking being a key process under scrutiny. However, this impact is often overstated, leading to what some view as "unfair" criticism. The goal is to clear up common misunderstandings about the environmental effects of snowmaking, while also discussing important challenges.

Dispelling common misconceptions, this article explains that the carbon footprint of snowmaking is not as large as many people think. Additionally, in Europe, the use of chemicals is not as prevalent as many assume. As for its impact on local wildlife, more research is needed to understand the indirect consequences of snowmaking in maintaining open resorts, while considering the restoration efforts ski resorts have in place to offset these effects.

Challenges remain, particularly regarding water usage and the production of snow in warmer conditions. Combining snow farming with technical snowmaking is essential for minimizing these impacts, as is the use of new technologies that create more efficient processes that generate less waste.

Taking a holistic approach to sustainability is vital. Snowmaking helps keep skiing alive, which has many benefits for the economy, local communities, and people's well-being. Additionally, skiing fosters societal awareness and action on climate change by connecting people to nature. Can this positive influence offset the industry's environmental costs?

> It's worth noting that skiing is a beloved sport, but it's only accessible in certain parts of the world. This creates a unique dynamic in environmental discussions, as people who are familiar with skiing may have a different perspective than those who don't engage in it. For the younger generation, especially those growing up in urban areas, we face a challenge in promoting winter sports in the context of environmental responsibility.
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> While skiing itself has a relatively small environmental footprint, the largest impact often comes from travel to and from ski resorts. Raising awareness about responsible travel and sustainable snow production is crucial to ensuring that skiing remains viable and environmentally conscious for future generations.
>
> ***Wolfgang Hanni,*** *Area Manager at TechnoAlpin*

The ski industry serves as a powerful reminder of the effects of climate change. As winters become milder, the industry has a unique opportunity to advocate for conservation and climate action. By collaborating with key partners, the industry can showcase green technologies in action, bringing the sport closer to nature. This article highlights several positive efforts, but the movement needs to grow worldwide. As Marit Gjerland says:

> Overall, the ski industry is relatively small on a global scale, so it's crucial for those involved in the sport to unite in developing better solutions. Bringing together a strong team and aligning resources in the same direction will be essential, prioritizing collaboration over competition. To secure the future of snow sports, we must work together and pool our efforts.
>
> ***Marit Gjerland,*** *Venue Advisor for the Norwegian Ski Federation*

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