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A Preliminary LCA Analysis of Snowmaking in Fiemme Valley

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Abstract

Modern ski resorts have been using systems of technical snow for many years: initially they were used to compensate the limits of natural snow but today it is actually the natural snow that is used as an integration to artificial snow and not vice versa. This paper aims to identify and evaluate the environmental impacts associated to the production of artificial snow, comparing two very different winter seasons in terms of snowfalls. The results of LCA analysis shows that the production of artificial snow primarily implies impacts on natural land transformation and fossil depletion, and that more snowfalls cause more onerous skiing resorts management, due to high consumption of diesel fuel for piste machines used for snow grooming.

1. Introduction

The Alps zone is particularly vulnerable to climate changes. Twentieth century temperatures in the Alps region have generally increased at higher speed compared to the global average temperatures (Böhm et al, 2001) and, although there is a lot of uncertainty over future scenarios, it is estimated that the increase will continue also in the coming years. IPCC estimates a temperature increase between 0.3 and 4.8 degrees (under different representative concentration pathway (RCP) emission scenarios) by 2100 (IPCC, 2014) indicating that this will be more prominent in the Northern hemisphere, especially during the winter season. Due to the temperature increase, the time of snow remaining on the ground has shortened, and the decrease of the global surface of Alps glaciers has already been registered. Moreover, a gradual decrease of rain in the summer and a rain increase in winter is highly predictable, but this will be accompanied by a snowfalls reduction (Guidetti, 2008). Natural snow was assured for 91% of skiing resorts in Alps at the beginning of the 21st century, but an average of 1°C temperature increase would take the percentage to 75%, and to 61% and 30% with an average increase of 2°C and 4°C respectively (Abegg et al, 2007). At present, the big challenge for skiing resorts is being able to guarantee the best possible snow conditions for winter sports lovers over a long period of time, while facing this lack of “raw material”. Skiing resorts have been using systems of artificial snow for many years: initially they were used to compensate the limits of natural snow (i.e. unpredictability), but today it is actually the natural snow that is used as an integration to technical snow and not vice versa. The reason is that artificial snow allows ski facilities not only to be less dependent from whether conditions, but also to stretch the skiing season, from late autumn until early spring. In Italy, about 40% of ski territory (9,000 hectares) is covered by technical snow (Guidetti, 2008).

The best conditions for the production of artificial snow are very dry air and cold water. When these conditions are lacking, snowing process is uneconomic and many skiing resorts use additives which impact on temperature needed for water to ice. Therefore, what is needed for the production of artificial snow are water, air and energy. Water plays a fundamental role: one water cubic meter produces between 2 and 2.5 snow cubic meters. When considering basic snow level (about 30 cm) on one hectare of sky run, at least 1 million liters of water is necessary and then much more water for further snow production (Hahn, 2004). According to a study conducted in France (Marnezy, 2008) artificial snow can require up to 4,000 cubic meters of water per hectare of slope. If these data are applied to the Alps (23,800 hectares ski area), around 95 million cubic meters of water would be necessary to produce technical snow, which is equivalent to annual water consumption in a city with 1.5 million inhabitants. There is also the problem that the water needed for technical snow is taken from creeks, rivers, basins or even drinkable water in periods of great water shortage (technical snow is done especially in November and December, a bit less in January and February). A lot of energy is also needed, although energy consumption depends on technical systems, location, water supplying and weather conditions. Another study conducted in France in the 2001/02 season (SEATM, 2002) showed that for artificial snow covering a ski area of 1 hectare, energy consumption was more than 25,000 kWh. Applying these numbers to the Alps area the global energy consumption would be no less than 600 million kWh, which is equivalent to the annual energy consumption of 130,000 families with 4 people (Hahn, 2004). This study aims to identify and evaluate the environmental impacts associated to the production of artificial snow, considering two very different winter seasons in terms of snowfalls, 2016/17 and 2017/2018. To the best of our knowledge, no study has applied the LCA methodology to evaluate the environmental impacts associated with artificial snow production except for a Norwegian study (Ragnhild, 2017), dealing with identification and quantification of the resources consumption.

2. Materials and methods

In this study a Life Cycle Assessment (LCA) approach has been applied to identify and evaluate the environmental impacts of the artificial snow production in a ski resort located in Trentino Province. The analysis refers to two different tourist seasons characterized by different weather conditions, 2016/17 characterized by a very dry winter with low snowfalls and 2017/18 with a particularly wet winter and plenty of snowfalls, allowing to highlight how the weather affects the environmental impacts associated with snow production.

System boundaries. A “cradle to gate” analysis for the snow production system has been designed including the different activities considered in snowmaking (Figure 1). At the facility examined the process is divided in two parts depending on the place of water supply: water coming from the valley floor or water coming from the mountain. The former requires purification (by ozone), filtration and cooling; while the latter requires only the cooling phase, if needed. Afterwards, all the water is collected in a single basin and pumped to the snow guns for the artificial snow production. Finally, snow grooming and auxiliary services required are taken in account. The phases of use by ski tourists and snow disposal are not taken into consideration because of the difficulty in identifying the inputs and collecting the data.

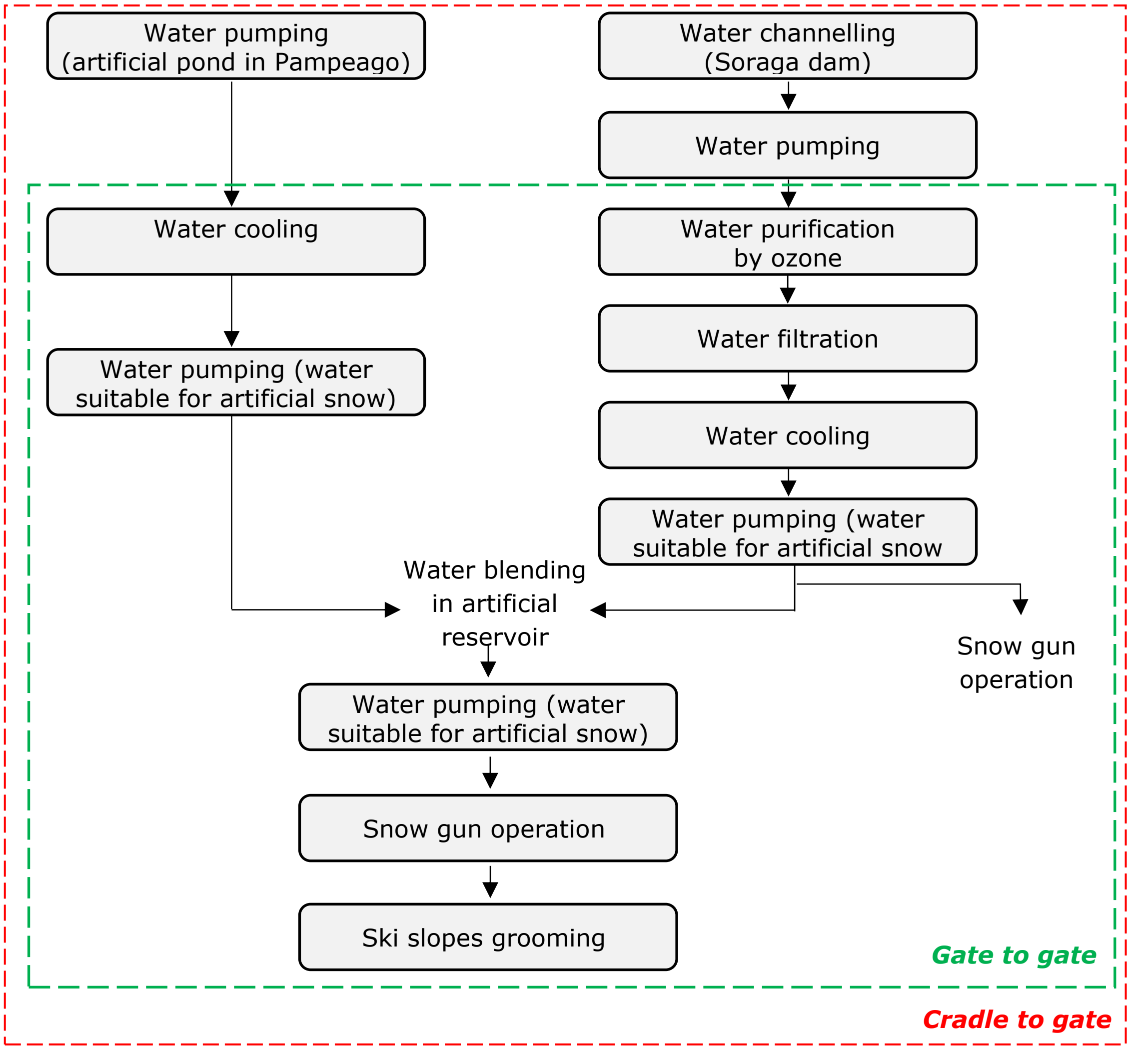

Figure 1: System boundaries and process chain of artificial snow production under assessment

Functional Unit (FU). The FU chosen is 1 m³ of artificial snow (corresponding at 0,4 m³ of water) and refers to the artificial snow used to cover approximately 3 m² of ski slope with a snow height of 30 cm.

Data collection. The primary data were gathered through personal interviews with the technicians of ITAP S.p.A. (the company that manages the ski resort of Pampeago, in Fiemme Valley) and were referred to activities carried out in 2016/17 and 2017/18 winter seasons. The data concern water consumption (referring to freshwater taken from the artificial lakes of Pampeago and Soraga), the energy consumption of all the machinery involved in snowmaking processes (including the phases of water purification, filtration, cooling and pumping) the number of snow groomers and their diesel fuel consumption, the wastewater treatment process etc., no chemical additives are used in this plant. Secondary data derive from EcoInvent 3.3 database included in the SimaPro 8.3 software (PRè, 2016). The inventory table (Table 1), obtained from the data collected at the Pampeago facility, highlights all the inputs and outputs associated with the analyzed process. The input factors considered in the study were: hydroelectric energy (for pumping, ozonization, filter washing, cooling, cannon use, auxiliary services); water (for the washing of the filters and total water for snow production); diesel fuel (for snowcats operations). The output factors were: 1 m³ of artificial snow (functional unit of the analysis) and waste water (from water purification and filtration processes).

Table 1: Summary of inputs and outputs of 1 m³ artificial snow production in the 2016/17 and 2017/18 seasons

INPUT				OUTPUT			
	Units	**2016/17**	**2017/18**		**Units**	**2016/17**	**2017/18**
Electric Energy pumps	kWh	2.0635	2.7288	Waste Water	m³	0.0404	0.0694
Electric energy ozonization	kWh	0.0179	0.0148	Artificial snow	m³	1	1
Electric energy filters washing	kWh	0.0002	0.0003				
Electric energy cooling	kWh	0.0888	0,1022				
Electric energy snow guns	kWh	1.5123	1.6160				
Electric energy auxiliary services	kWh	0.1157	0.1542				
Water for filters washing	m³	0.0021	0.0017				
Water pumped	m³	0.4404	0.4694				
Diesel fuel	L	0.1549	0.2635				

3. Results and discussion

Data regarding 2016/17 season were taken into consideration, in order to correctly assess the environmental impacts related to 1 m³ artificial snow production. In fact, that season was really unusual, since there was no snowfall at all, therefore all the data are entirely ascribable to this specific production. Table 2 shows the contribution values of each activity to the impact categories. Figure 2 shows the relative contribution (in percentage) of the different inputs to the environmental impact categories. The processes that contribute most to the various impact categories are: diesel fuel consumption and waste water treatment which mainly affect 16 out of the 18 impact categories.

Table 2: Data of the processes contribution to the impact categories for the artificial snow production in the 2016/17 seasons

Impact Categories	**Unit**	**Water**	**Waste water**	**Filter washing water**	**Electric Energy**	**Diesel Fuel**	**Total**
Climate change	kg CO_2 eq	0	0.010444	0	0.001354	0.048628	0.060427
Ozone depletion	kg CFC-11 eq	0	6.99E-10	0	2.68E-11	9.36E-08	9.43E-08
Terrestrial acidification	kg SO_2 eq	0	0.000128	0	2.17E-07	0.000448	0.000576
Freshwater eutrophication	kg P eq	0	4.26E-05	0	8.48E-09	1.47E-06	4.41E-05
Marine eutrophication	kg N eq	0	0.00083	0	5.1E-09	9.51E-06	0.00084
Human toxicity	kg 1.4-DB eq	0	0.005695	0	5.04E-06	0.005079	0.010779
Photochemical oxidant formation	kg NMVOC	0	5.37E-05	0	9.6E-07	0.000365	0.000419
Particulate matter formation	kg PM10 eq	0	4.47E-05	0	7.17E-08	0.000122	0.000167
Terrestrial Eco toxicity	kg 1.4-DB eq	0	5.29E-06	0	2.29E-09	4.7E-06	9.99E-06
Freshwater Eco toxicity	kg 1.4-DB eq	0	0.000251	0	1.7E-07	0.000243	0.000494
Marine Eco toxicity	kg 1.4-DB eq	0	0.000223	0	1.29E-07	0.000113	0.000336
Ionising radiation	kBq U235 eq	0	0.001131	0	1.06E-05	0.033783	0.034925
Agricultural land occupation	m^2a	0	0.000394	0	5.37E-07	0.000354	0.000749
Urban land occupation	m^2a	0	4.29E-05	0	7.9E-08	5.32E-05	9.62E-05
Natural land transformation	m^2	0	3.35E-07	0	3.49E-05	1.16E-07	3.54E-05
Water depletion	m^3	0.4404	-0.03628	0.0021	0.110996	0.0007	0.517912
Metal depletion	kg Fe eq	0	4.2E-05	0	5.6E-08	4.09E-05	8.3E-05
Fossil depletion	kg oil eq	0	0.002107	0	5.1E-05	0.172687	0.174845

Diesel fuel consumption for snowcats operations contributes, as expected, almost entirely to fossil depletion, ozone depletion and ionising radiation (respectively 98%, 99% and 97%) and partially to photochemical oxidant formation (87%), climate change (80%), terrestrial acidification (78%) and particulate matter formation (73%). All these impact categories are related to atmospheric emission from fossil fuels combustion. Likewise, wastewater treatment contributes mainly to freshwater and marine eutrophication (respectively 97% and 99%) as well as to marine toxicity (66%). Conversely, it negatively contributes to water depletion impact category (-7%) corresponding to an avoided impact in terms of water withdrawal from nature.

Another important process to be considered is the electric energy production. In the specific case studied, electrical energy comes wholly from the hydroelectric power plants of the Trentino Province. It contributes almost entirely to the natural land transformation (99%) due to the construction of the water accumulation basins that determines a long term modification of the territory. In addition, hydroelectric production contributes for 20% to the water depletion, whereas remaining percentage is obviously attributable to water withdrawal for snowmaking.

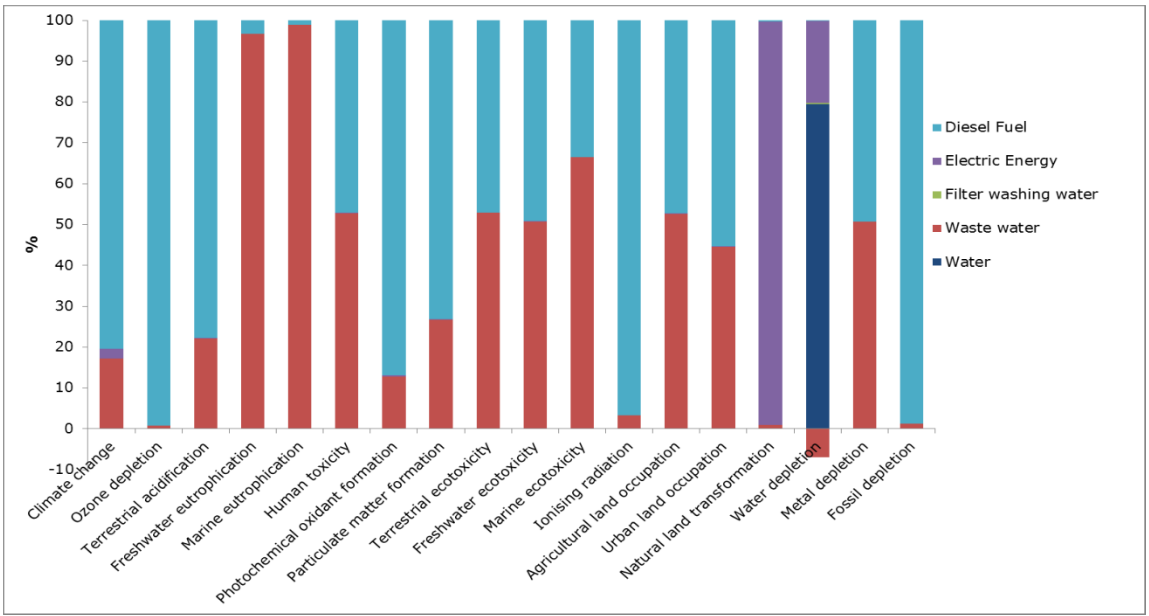

Figure 2: Relative contributions of inputs for 1 m^3 of artificial snow production to environmental impact categories in 2016/17 season. The term "water" (see the key) refers only to the amount withdrawn from the two reservoirs

Data normalization allows to evaluate the actual weight of the environmental impacts related to 1 m^3 artificial snow production.

Figure 3 shows how the midpoint impact category mostly involved in the production of artificial snow is the "transformation of natural soil", caused above all by the production of hydroelectric energy. It follows the category "depletion of fossil fuels”, due to the high consumption of diesel oil for the ski slope grooming. Since SimaPro does not calculate normalization for water depletion a water footprint analysis (Simapro method: Pfister et al 2010 (ReCiPe)) was performed to evaluate the impact related to the water consumption. This analysis highlights that water withdrawal for snowmaking is the phase that generates the most important impact both for “ecosystem quality” and for “resources” damage categories contributing to each of them for 79.6%. Moreover, the consumption of water for the production of electricity contributes to the two categories of damage for 20%.

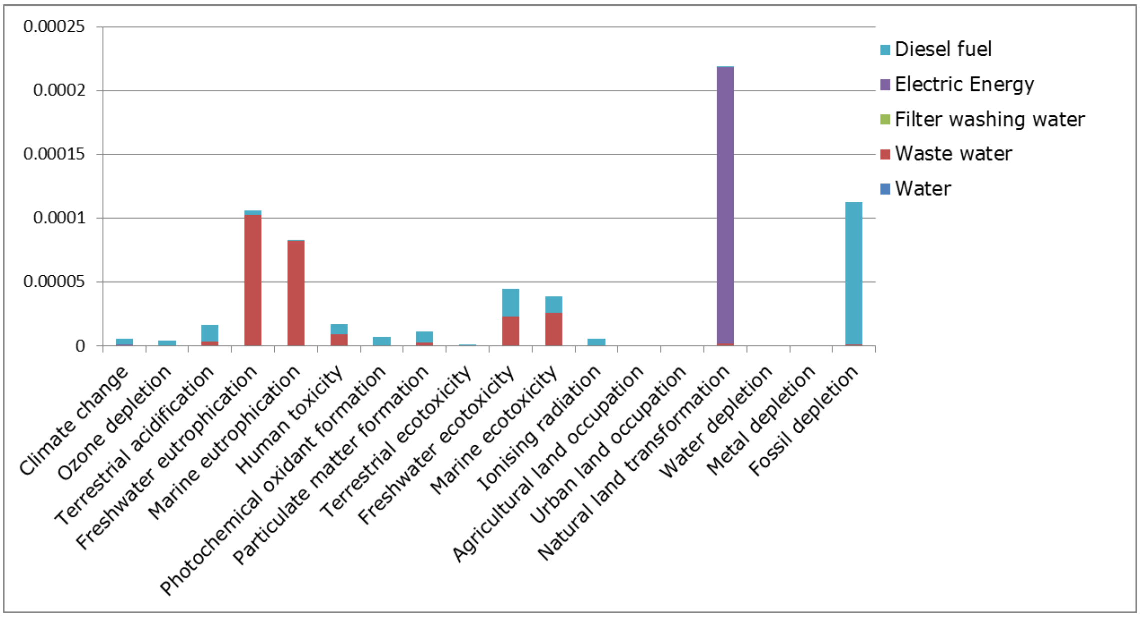

Figure 3: Normalized results for 1 m³ of artificial snow production in Fiemme Valley in 2016/17 season

The overall result of the analysis shows that energy production, both from fossil fuels and renewable sources, is the most important cause of environmental impacts to produce 1 m^3 of artificial snow in Fiemme Valley. It follows that the activities involved are the pumping for the collection and transport of water from the catchment basins to the purification plant and to the snowguns (electricity) and the use of machinery to groom the skiing slopes after snowmaking.

Finally, the environmental impacts associated with the total snow production in the two different seasons, characterized by different weather conditions, were compared in order to highlight how the weather conditions can affect the environmental impacts. In fact, total snowfalls for the 2017/18 season were abundant. Therefore, only 460,040 m^3 of technical snow were produced with respect to 776,910 m^3 produced for the 2016/17 season. The different types of impacts generated are shown in the graph of Figure 4. It clearly emerges from the analysis carried out that the impacts are very similar for all the categories considered but for “water depletion” and “natural land transformation”: for these categories the values regarding the 2016/17 season are definitely higher due to greater water and electric energy consumption. On the contrary, the impact categories related to diesel consumption do not show significant differences because the heavy snowfalls of the 2017/18 season required an intense activity of ski-slope grooming. Therefore, the different weather conditions in the two seasons on one hand has allowed savings in terms of water and electricity consumption but, on the other hand, has not helped to reduce the consumption of energy from fossil fuels.

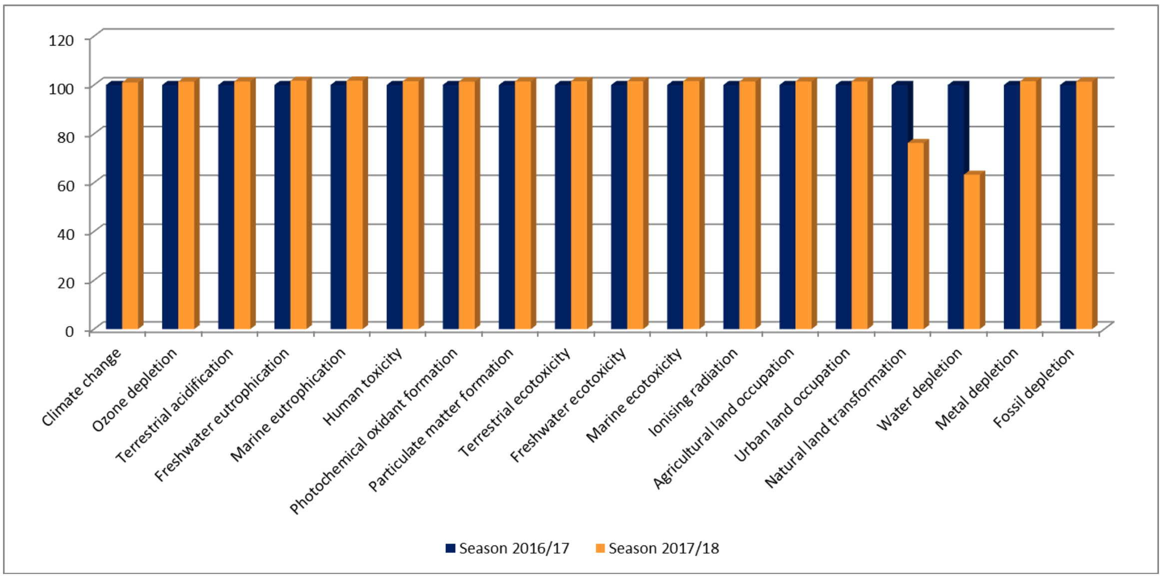

Figure 4: Comparison of the midpoint impact categories analysis of the 2016/17 and the 2017/18 winter seasons

4. Conclusions

On the basis of this study's results (which refer to a specific Alps area and therefore not necessarily applicable to other winter resorts), it is possible to state that the environmental impact associated to the production of 1 cubic meter of artificial snow is primarily attributable to two categories: fossil depletion caused by the use of diesel fuel for machinery to groom the skiing slopes and natural land transformation. In reference to the last category, the reason lies on the fact that the energy used for the production of artificial snow comes from certified renewable source, specifically hydroelectric. Therefore, the result is definitely a lower environmental impact related to energy consumption, compared to the use of non-renewable sources, but nevertheless the impact is not negligible because of the water basins exploitation for energy production. Moreover, it is quite interesting to see, when comparing the two winter seasons 2016/17 and 2017/18 very different in terms of snowfalls, how the environmental impact is overall almost unvaried, even a bit higher in the 2017/18 season with more snowfalls. This can be explained by considering that some cubic meters of artificial snow were produced before the natural snowfalls (between October and November). In addition, in the 2017/18 winter season,

skiing runs were groomed many times as a consequence of plentiful snowfalls, which caused an increase in diesel fuel consumption. This increase partially diminished the environmental benefits of a lower quantity of artificial snow. However, as expected, the two impact categories “water depletion” and “natural land transformation” show higher values for the 2016/17 season due to greater water consumption (see above in “Result and discussion” section).
Therefore, in terms of global managing of skiing resorts, it is possible to paradoxically conclude that winter seasons with favourable snowfalls do not necessarily involve a lower environmental impact.

5. References

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