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Climate Change in the Spanish Ski Resorts

Final Project

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1. Introduction

Tourism is one of the most important sectors of the Spanish economy, it represents the 14.9% of total GDP, so it's important to study the factors that make it vary. One of these factors is climate change, very present in today's society.

In this research we study the close relationship between climate change and tourism in the ski resorts, how affects these increased temperatures to the most important features of these sites.

Due to increased Earth temperatures, more and more obvious changes that are experiencing snowfall in the mountains, especially the ski resorts. It's therefore important to study what its causes are and what solutions could be to mitigate these consequences.

This increase in temperature is due to the greenhouse effect, which causes the earth temperature increases, decreasing the amount of snow and reduces its duration on the ground.

For these reasons, the ski resorts should be renewed and use clean energies, to don't help increase climate change, so several mitigation measures for ski resorts are proposed.

It's important for them because if they don't cooperate, are the primarily affected, because if it lowers the snow level and its duration, directly affects the season, lowering the number of tourists, who seek alternatives to ski, even if it costs them more money. Not only could lose tourists if they could not stand to lose the entire season, because if the snow level of the ski resort is not very high, it could be the case that there was not enough snow even using the known snowmakers.

For these reasons, the objective of the research is to publicize this problem, aware that climate change does affect tourism, and knowing that it's one of the main drivers of income of our country, it should have more importance than it has actually.

To capture all these problems, we have divided the work into the following parts, dividing it into four sections to differentiate it, and therefore are easier to locate when we're reading it.

In the first part, the theoretical framework, we begin framing the field, we talked about theoretical considerations, so we explain what are tourism, winter tourism, and climate change, in which we explained the current situation of this, the greenhouse effect, and measures taken to prevent internationally.

Once we have assimilated the concepts of the previous section, we go to the second part. Here we analyze the current situation of Spanish ski resorts, contemplating the changes that have suffered due to climate change, and the consequences of this, such as reducing the snow thickness, the height that we found snow, the consequences for some of the ski stations, and artificial methods to preserve the snow.

Now that we have seen how the panorama of the ski resorts is, we turn to the third part, where we propose some solutions to try to stop this climate change. Some measures are proposed, such as the use of renewable energy, reduce the visual impact, and explain the fourth generation ski resorts.

In the fourth and last part, now that we have all the analysis and proposals, we've given way to conclusions, where we reflect the realized study.

2. Methodology

The methodology that we used for the realization of this work, is based on heuristics methodology based on empirical rules to reach a solution.

Once I had clear the reasons that I would address issue of climate change on ski resorts, I began the first phase, which consisted of search for and documentation on the subject that would treat both tourism and climate change. The first sources that I used to address the issue were books from the Library of the University Jaume I. These helped me to document myself on climate change and tourism, but tourism centred on the ski resorts had to expressly consult the online literature, so books, documents, newspaper articles, specialized pages...

After reading the bibliographic resources I had, I began to study the way of work, which points are interesting for me and which points don't interest me. This does not mean that only seek library resources in the first phase, if not I have been seeking and using the bibliographic resources throughout the investigation.

Taking clear the work organization, I started with theoretical issues concerning the theoretical framework, the basic part for understanding what is spoken during work. In this part we frame the issues that we will try, being a basic resource to continue the investigation. Once clear this part, I started with the analysis.

In the analysis, as I said before, I continued documenting especially online, that is where I get much more updated information. After reading several articles and scientific papers, I began to write it, using quotes to make comparisons and to supplement the written texts. The quotations in the text are important because they reinforce the ideas shown and provide knowledge to work.

After I've completed the analysis, we pass to the search for viable alternatives to combat climate change in the ski resorts. Here, starting of the existing renewable energy, we proposed some existing ideas but applied to ski sustainable, and also proposals that are being carried out in other countries and in Spain haven't yet been implemented in any of the ski resorts.

At all times, in every part I've supplemented the text with images, graphs and tables, some taken from the Internet and other own elaboration with data from various external sources. Both the graphic resources and every one of the appointments resources has been cited at the end of these, and added to the final bibliography, where the location of these is collected.

Finally, in the last part of the research, we have completed the investigation with the conclusions, which is a short and simple objective reflection of the entire investigation.

3. Theoretical Framework

3.1. Tourism

Tourism is one of the most important sectors and not only in Spain but worldwide. Tourism generates 9.8% of the world economy, 7.6 billion dollars (in 2015), both directly and indirectly, directly generating throughout 2015 a total of 2.4 billion dollars, which represents a 3'1 world GDP (Xavier Canalis, 2015).

With regard to Spain, the tourism sector is the fastest growing each year, and that generates more employment. At the close of 2015, the Spanish GDP accounted for 11'2% of total Spanish. It's estimated that in 2016 it rises a 3'7%, generating a profit of more than 124,000 million euros.

We have seen the importance of tourism both globally and Spanish level, but what is tourism? WTO (1994) defines tourism as:

"Tourism is a collection of activities, services and industries which deliver a travel experience comprising transportation, accommodation, eating and drinking establishments, retail shops, entertainment businesses and other hospitality services provided for individuals or groups traveling away from home." (World Tourism Organization, 1994)

Although our research is focused on tourism snow, Jorge Olcina Cantos makes a definition of tourism and climate change that is necessary to know:

"El turismo es una actividad especialmente expuesta a los efectos del cambio climático. Alguna de las modalidades de turismo (sol y playa, de nieve, de grandes ciudades) presenta una alta vulnerabilidad ante el calentamiento térmico planetario y sus procesos asociados. Aumento de temperaturas y reducción de precipitaciones son los procesos que han tenido preferencia en la transmisión de los efectos del cambio climático en latitudes medias y, con especial incidencia, en el ámbito mediterráneo. Sin embargo, otras consecuencias del cambio climático son menos conocidas y pueden afectar en especial a la actividad turística en las modalidades señaladas: el incremento de extremos atmosféricos y la pérdida del confort climático. El turismo debe aproximarse al problema del cambio climático con la necesidad de transmitir la realidad de un fenómeno complejo y con la responsabilidad de evitar posturas extremas (cambio drástico de destinos, desaparición del modelo de "sol y playa", etc.) que pueden crear descreimientos o afianzar irresponsables actitudes "negacionistas" arraigadas en la falta de manifestaciones evidentes en la actualidad de un proceso que, por naturaleza, se desarrollará a medio y largo plazo. La puesta en marcha de

medidas de reducción y adaptación al cambio climático evitará la pérdida de competitividad de los destinos turísticos" (Olcina Cantos, 2012)

3.1.1. Snow Tourism

For sightseeing snow, as its name suggests, it's related to snow sports, such as skiing. This type of tourism, as discussed below, is the one that is most harmed by climate change, due to its characteristics.

This type of tourism has a great dependence on the weather, space, landscape and nature. It's the most sensitive to changes in temperature by his perishability snow, which appears or disappears depending on the temperatures.

According to the Tourism Institute of Spain, winter tourism is:

"Corresponde al viaje vacacional cuya motivación principal es la práctica del esquí en alguna de sus diversas modalidades: alpino, nórdico, snowboard, de travesía, etc.

El esquí es un producto altamente estacional. Su consumo se centra entre los meses de diciembre a abril y, principalmente, en los fines de semana, puentes y épocas vacacionales (navidades y pascuas)." (Instituto de Turismo de España, 2008).

3.2. Climate change

Climate change is defined by the Spanish Environment Ministry as follows:

"Se llama cambio climático a la variación global del clima de la Tierra. Esta variación se debe a causas naturales y a la acción del hombre y se produce sobre todos los parámetros climáticos: temperatura, precipitaciones, nubosidad, etc, a muy diversas escalas de tiempo." (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2016)

We also find the following definition, older but no less valid, of the United Nations Framework Convention on Climate Change 1992:

"Por "cambio climático" se entiende un cambio de clima atribuido directa o indirectamente a la actividad humana que altera la composición de la atmósfera mundial y que se suma a la variabilidad natural del clima observada durante períodos de tiempo comparables." (United Nations, 1995)

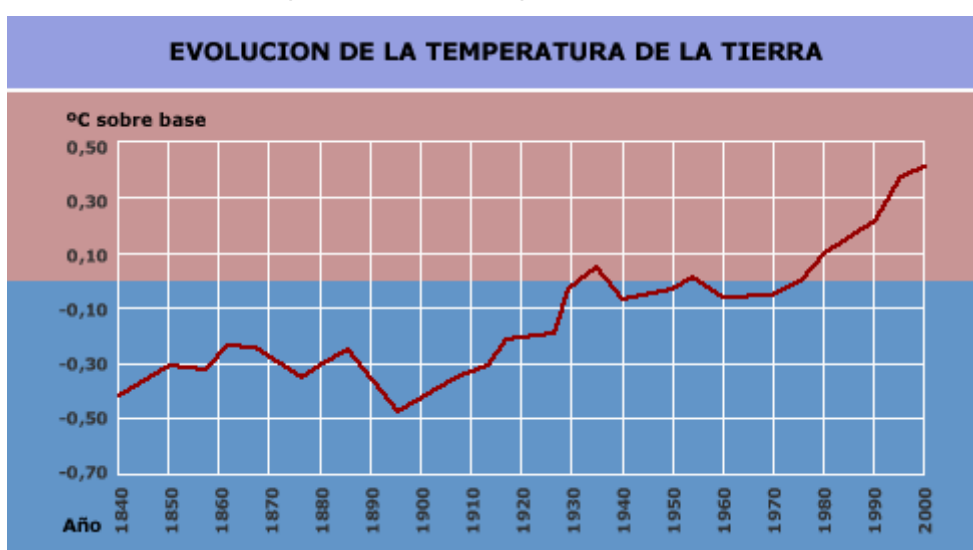
3.2.1. Climate Change currently

The Spanish Institute for Strategic Studies defines the current situation of climate change:

“El cambio climático se empezó a manifestar hace escasas décadas y desde el cuarto informe del IPCC solamente tiene explicación mediante modelos que tienen en cuenta la emisión de CO2 a la atmósfera por el hombre. La concentración de este gas es hoy muy superior a su intervalo natural desde hace 650.000 años y aumenta rápidamente. Las consecuencias pueden ser muy graves. La ciencia económica proporciona conceptos y teorías muy valiosas para explicar los orígenes del problema –un consumo desenfrenado de recursos y un mal funcionamiento del mercado-, para cuantificar los daños y para combatirlo: imponer un “coste social” a las emisiones de CO2, establecer un mecanismo de “comercio de emisiones” y ayudando al diseño de políticas económicas apropiadas. Todo ello debe hacerse con un enfoque “sistémico” del problema, para lo que debería aprobarse urgentemente un Acuerdo “Kioto II”, de carácter vinculante.” (Instituto español de estudios estratégicos, 2011)

Currently the climate change situation is quite alarming. It's clear that the climate is cyclical, and now we come from a glaciation, so the temperature tends to rise, but this does not mean that human action hasn't an impact on climate change. Since the industrial revolution (200 years ago), this increase in temperature has been increased significantly, due to the emergence of industries, and its great capacity for pollution, with an increase in global temperature of 0'6°C for average.

Graphic 1: Earth Temperature Evolution



Source: <http://www.ambientum.com/>

As we can see in the chart, since 1895 it is when pollution has increased more. This is due to the foregoing, apart from some countries didn't comply of the measures taken to reduce this increasing temperature, largely due to the greenhouse gases that throw into the atmosphere, and that cause global warming.

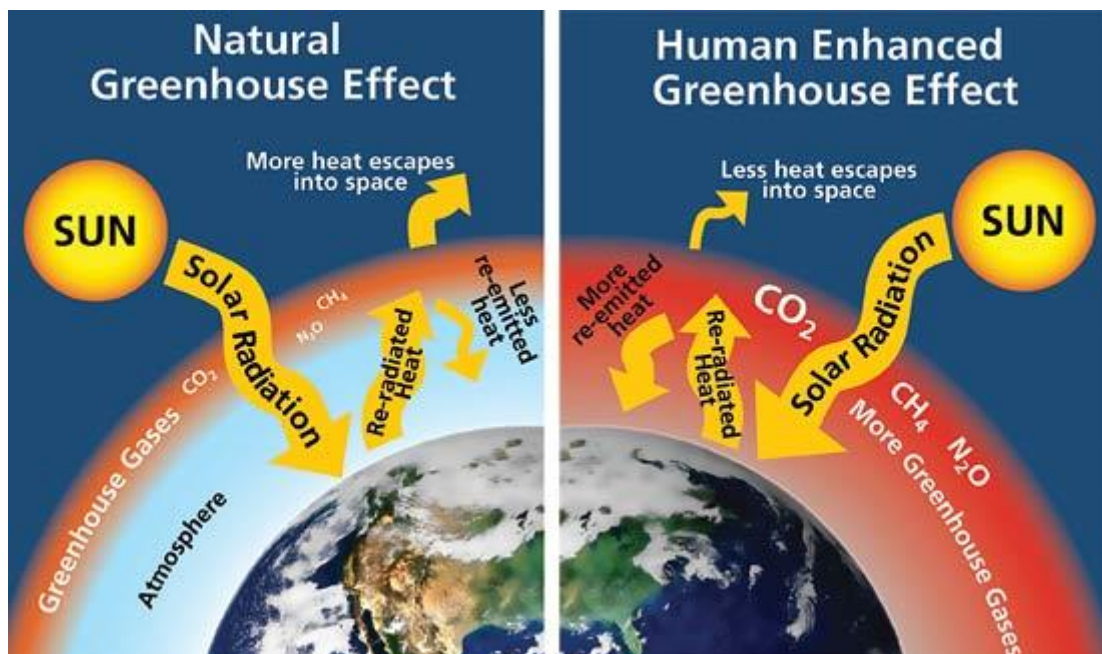
Another reason of global warming is produced by the ozone layer depletion, also produced by harmful gases to the atmosphere, such as CFCs (chlorofluorocarbons) gases used in aerosols and cleaning products, but which you are avoiding use, to prevent the hole is made larger.

3.2.2. The greenhouse effect

The greenhouse effect is defined by National Geographic as:

“El “efecto invernadero” es el calentamiento que se produce cuando ciertos gases de la atmósfera de la Tierra retienen el calor. Estos gases dejan pasar la luz, pero mantienen el calor como las paredes de cristal de un invernadero.” (National Geographic, 2016)

Image 1: Greenhouse



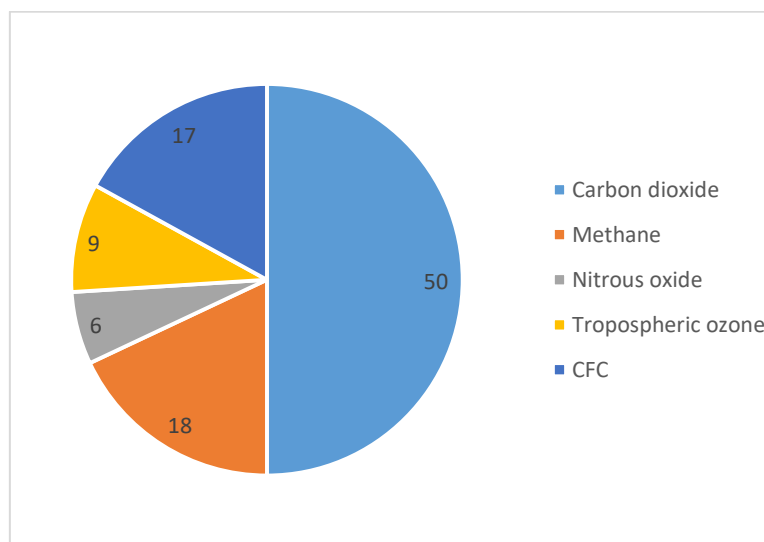
Source: <http://climatechange.lta.org/>

As we can see in the image (image 1), the function of the natural effect of greenhouse gases is to preserve a small part of the solar radiation entering the atmosphere, preventing this small part goes out of the atmosphere and returns to earth in order to maintain the normal temperature of the earth.

In the second part of the image (Image 1), we see the accumulation of greenhouse gases makes this solar radiation that should leave the atmosphere and not return to Earth, is trapped in the atmosphere, letting out just a small percentage, and causing the Earth's temperature increases.

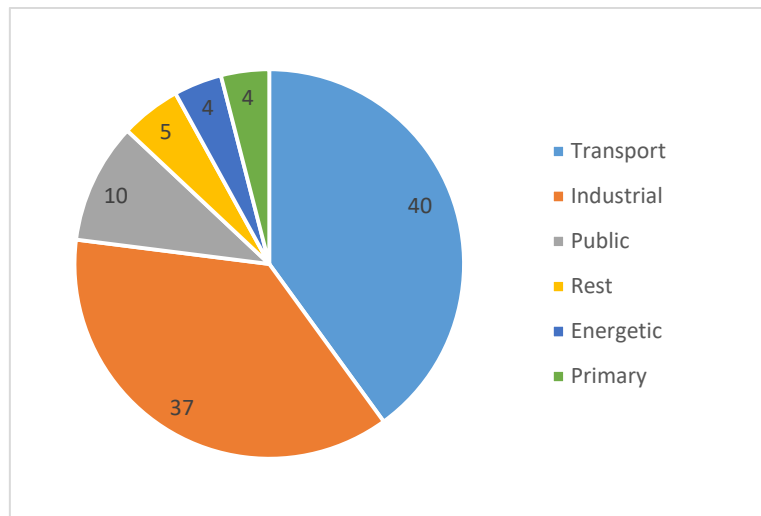
In the following graph (graphic 2) we can see the greenhouse gases and what amount of these gases causes the greenhouse effect, and produce this excessive global warming. In the graphic 3, we show which sectors produce more greenhouse gases.

Graphic 2: Greenhouse Gases Percentage 2009



Source: www.fotosintesiscalentamientoglobal.wordpress.com

Graphic 3: Greenhouse Gases number by sector 2009



Source: <http://www.ambientum.com/>

The greenhouse effect is caused by natural causes and by human action both. Natural causes would like that the sun irradiation, the volcanic eruptions... But undoubtedly the most significant is the action of man, as more and sheds more polluting gases into the atmosphere, especially the CO₂ gases. Also, apart from throwing these gases it's due to the loss of forests due to logging, since these are responsible for storing and transform CO₂ so abundant in the atmosphere. In the Graphic 3 we can see how it contributes and how much each sector to the emission of these gases.

The following section will speak of Montreal Protocol and the Kyoto Protocol, which are agreements to reduce these harmful gases in the atmosphere.

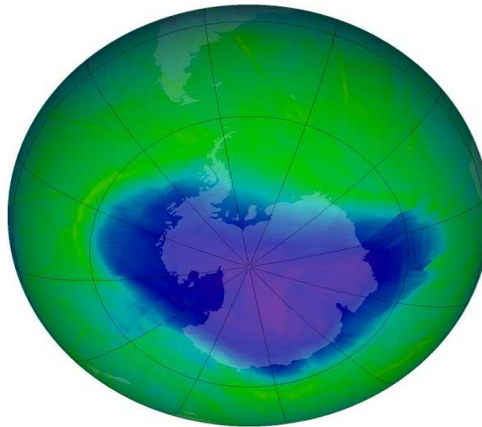
3.2.3. Montreal Protocol

The Montreal Protocol is based on the emission of gases CFCs (chlorofluorocarbons). These gases are used mainly in cooling equipment and aerosols around the world. Because these gases were thrown directly into the atmosphere, in 1975 was discharged into the atmosphere 150,000 tons, which was very harmful to this.

These gases, to throw them directly into the atmosphere, and because of its high pollution, formed the known ozone hole in Antarctica. Once the contaminant power these gases was discovered, we preceded to regulation both use as recycling. In

Image 2, we see the current situation of ozone depletion in Antarctica. As we see, it is not a small thing, since its size is considerable.

Image 2: Ozone Layer Hole 2016



Source: <http://www.eluniversobajoelmicroscopio.blogspot.com.es/>

The regulation of these gases came with the Montreal Protocol, in which 46 countries met in 1987 and signed this agreement, finally ratified by 167 countries around the world. The Montreal Protocol is an agreement between these countries, which it was agreed the production control and consumption of gases harmful to the ozone layer agreed. That control should be evaluated every four years, and adjusted to reduce their emissions increasingly, coming to the eradication of use.

Thanks to this regulation, in 2015 the hole has been reduced by 4 million square kilometers, as we see in the article published by the newspaper La Vanguardia on July 1, 2016:

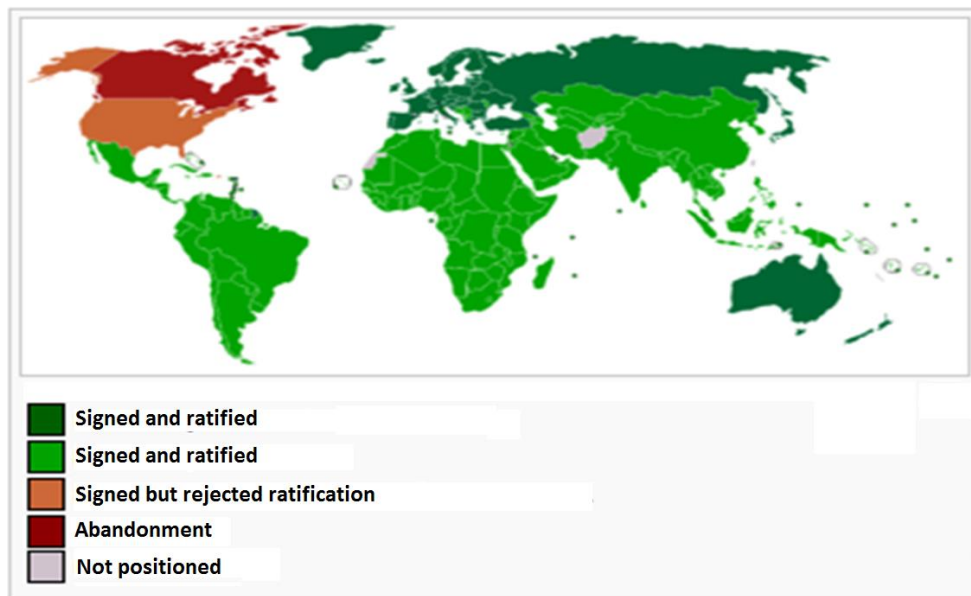
“El planeta Tierra empieza a cicatrizar la herida producida por los humanos en la capa de ozono. Casi tres décadas después de que el acuerdo internacional conocido como Protocolo de Montreal prohibiera la emisión de los gases que destruyen esta capa que protege a los seres vivos de los rayos solares más peligrosos [...] Los datos analizados por el equipo que encabeza la profesora Susan Solomon, del Massachusetts Institute of Technology, en Cambridge (EE.UU), indican que en septiembre de 2015, el agujero en la capa de ozono sobre la Antártida era 4 millones de kilómetros cuadrados más pequeño en relación con las dimensiones del mismo mes del año 2000.” (La Vanguardia, 2016)

3.2.4. Kyoto Protocol

The Kyoto Protocol is an international treaty that emerged years after the Montreal Protocol due to concerns about the emission of harmful gases to the environment and its impact on this.

In 1997 they met in Kyoto more than a hundred countries to reach an agreement on controlling greenhouse gas emissions, of which only 39 countries signed the treaty. The agreement was to reduce its greenhouse gas emissions in a 5.2% in the period 2005 to 2012 compared to emissions in 1990. Because it needed at least 55% of countries ratify the agreement, it was not until 2005 when it came into effect.

Image 3: Countries position in 2011 with to the Kyoto Protocol



Source: <http://undecimoempresarial.blogspot.com.es/>

Currently it's in effect the second period, from 2013 to 2020, in which some countries have refused to renew their adherence to the treaty. In this second period the gases included in the list of harmful gases were revised, amendments to several articles of the protocol and new commitments to be met by the countries that have agreed to comply the second period. Due to the low commitment of some signatory countries and those not renewed, the emission of harmful gases to the environment has increased compared to 1990 by 40%, so the protocol is currently serving little.

There have been several attempts to revive the Kyoto Protocol, and the summits in Copenhagen and Cancun, but without reaching any binding agreement.

4. Current status of the main Spanish ski resorts

Currently, in Spain we have 31 ski resorts, which all have an excellent infrastructure, good communication and good location. In these 31 ski resorts we can find 1141 ski slopes, with a total of over 1180Km of skiable surface. Spain is currently the 8th country with more days of skiing in the European ranking.

Here we can see a list of Spanish ski resorts, detailed with his number of ski slopes and his total kilometers that each have:

Catalan Pyrenees:

- Baqueira Beret (106 ski slopes; 155Km)
- Boí Taüll (51 ski slopes; 48Km)
- Espot Esquí (22 ski slopes ; 25Km)
- La Molina (61 ski slopes; 67Km)
- Masella (65 ski slopes; 74'5Km)
- Port Ainé (25 ski slopes; 26'7Km)
- Port del Comte (39 ski slopes; 50Km)
- Tavascán (7 ski slopes; 6Km)
- Vall de Nuria (11 ski slopes; 7'6Km)
- Vallter 2000 (13 ski slopes; 18'73Km)

Aragon Pyrenees:

- Astún (60 ski slopes; 50Km)
- Candanchú (51 ski slopes; 50'6Km)
- Cerler (68 ski slopes; 79Km)
- Formigal (101 ski slopes; 137Km)
- Panticosa (46 ski slopes; 39Km)

Cantabrian Mountain Chain:

- Alto Campoo (22 ski slopes; 27'7Km)
- Fuentes de Invierno (15 ski slopes; 8'76Km)
- Leitariegos (11 ski slopes; 7'17Km)
- Lunada (9 ski slopes; 8Km)
- Manzaneda (23 ski slopes; 16'75Km)
- San Isidro (31 ski slopes; 27'41Km)
- Valgrande-Pajares (32 ski slopes; 21'58Km)

Iberian Chain:

- Javalambre (18 ski slopes; 15Km)
- Santa Inés (2 ski slopes; 1'8Km)
- Valdelinares (13 ski slopes; 14Km)
- Valdezcaray (26 ski slopes; 22'35Km)

Central Chain:

- La Pinilla (23 ski slopes; 15'57Km)
- Puerto de Navacerrada (16 ski slopes; 11'15Km)
- Sierra de Béjar (24 ski slopes; 20'29Km)
- Valdesquí (26 ski slopes; 22'24Km)

Penibetic Chain:

- Sierra Nevada (124 ski slopes; 106'7Km)

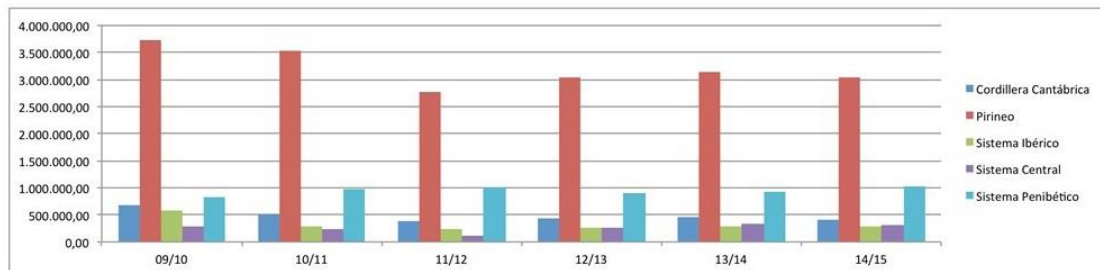
Snow tourism is a very important national tourism subsector as it attracts a lot of tourists, and relocates seasonally adjusted tourism in Spain, which has always been faithful to sun and beach tourism.

Thanks to this large number of tourists, which has increased by more than 30% over the last 10 years, from 2014/2015 season beating the 5 million visitors (5,076,185), slightly lower than the previous season, but that does not clash within the average, as this number is increasing every year. With this large number of visitors, the Spanish ski stations earned a total of 114 million euros, higher than the previous season, which received more tourists (one 0.73% more tourists), which It suggests that even fewer tourists coming, they spent more money on his vacations.

In the graph (graphic 4) we can see the evolution of the visitors separated by spanish mountains ranges, from the 2009/2010 season until the 2015/2016 season. And in the next graph (Graphic 5), we see the evolution of revenues from the 2007/2008 season until the 2015/2016 season. Both graphs are taken from ATUDEM Press Dossier (Tourist Association of Ski and Mountain) of 18 November 2015.

Graphic 4: Evolution of mountain visitors

España Cordilleras	09/10	10/11	11/12	12/13	13/14	14/15	% Δ
Cordillera Cantábrica	673.383,00	496.427,00	376.844,00	424.275,00	448.810,00	407.658,00	-9,17%
Pirineo	3.724.945,00	3.533.066,00	2.761.370,00	3.043.071,00	3.137.786,00	3.029.605,00	-3,45%
Sistema Ibérico	580.413,00	277.878,00	247.506,00	260.935,00	283.362,00	284.418,00	0,37%
Sistema Central	298.106,00	235.551,00	124.286,00	266.979,00	325.179,00	320.920,00	-1,31%
Sistema Penibético	827.971,00	984.635,00	995.709,00	910.212,00	918.288,00	1.033.584,00	12,56%
	6.104.818,00	5.527.557,00	4.505.715,00	4.905.472,00	5.113.425,00	5.076.185,00	-0,73%



Source: ATUDEM, 2015

Graphic 5: Income evolution (excluding VAT)

Millones	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
España	101,88	126,52	111,57	111,48	91,75	100,28	106,94	114,40



Source: ATUDEM, 2015

As Antonio Llano, ex-president of ATUDEM and Francisco Leno, Retired ex-coordinator of ATUDEM, at the World Congress of Tourism of Snow and Winter Sports 1998 said:

“La evolución de la oferta española de esquí, el crecimiento de las instalaciones y la diversificación de sus productos no es más que una respuesta a la evolución de la demanda de turismo de nieve en España. El esquí ha conocido en los últimos años un proceso de popularización, pasando de ser una actividad en cierto modo elitista en décadas pasadas a ser una actividad cada vez más popular y con un crecimiento estable y acelerado durante los últimos años.” (Llano Falcón & Leno Cerro, 1998)

This evolution has been possible thanks to the adaptation of the ski to the supply and demand of population. It has been able to keep customers, promoting winter sports, improving its hotels, and improving communications. Well truth is that, in recent years and accentuated by the crisis, people have lost purchasing power, but seen by the above data, this has not been an impediment to visit ski resorts.

4.1. Changes and consequences suffered in snow tourism

In the following section we will analyze how it has affected climate change to snow tourism, analyzing different factors, such as the duration of the snow or the minimum altitude at which we can find it.

Over the years it has been to go innovating to keep amateur clientele snow tourism, so they have had to introduce new production techniques and conservation of the snow, which will be analyzed in a section below.

4.1.1. Snow duration

The duration of the snow on the mountain is also a factor that is very directly affected by climate change, because as temperatures rise, this tends to last less. Therefore, as already mentioned in the previous section, the ski resorts have had to modernize their facilities, making large investments of money and infrastructure to install production methods and conservation of snow, such as snowmakers and snow groomers, which we'll talk later.

In the following table (Table 1) we can see the amount of snow on the different ski resorts in the seasons 2009/2010, 2011/2012, 2013/2014, 2015/2016. We analyzed the data every two seasons, with reference to the latter, since it is the one that currently affects us.

Table 1: Seasonal Snow Depth

	2009/2010 (minimum – maxim)	2011/2012 (minimum – maxim)	2013/2014 (minimum – maxim)	2015/2016 (minimum – maxim)
Baqueira Beret	50 - 200	100 - 300	170 - 350	60 - 250
Boí Taüll	30 - 310	25 - 120	50 - 310	25 - 180
Espot Esquí	25 - 150	25 - 110	100 - 240	50 - 160
La Molina	25 - 225	20 - 120	50 - 210	25 - 130
Masella	25 - 225	25 - 150	60 - 225	50 - 140
Port Ainé	20 - 150	30 - 110	120 - 240	50 - 180
Port del Comte	25 - 250	25 - 120	50 - 170	40 - 185
Tavascán	35 - 200	35 - 125	125 - 400	25 - 160
Valle de Nuria	20 - 180	15 - 110	50 - 130	30 - 80
Vallter 2000	20 - 220	50 - 140	50 - 160	15 - 100
Astún	80 - 210	100 - 140	50 - 270	25 - 220
Candanchú	40 - 275	60 - 180	70 - 350	50 - 250
Cerler	60 - 220	60 - 135	40 - 260	40 - 250
Formigal	80 - 245	50 - 120	70 - 325	40 - 260
Panticosa	60 - 220	40 - 110	120 - 300	40 - 250
Alto Campoo	40 - 210	35 - 150	50 - 110	35 - 200
Fuentes de Invierno	20 - 235	10 - 200	50 - 210	10 - 315
Leitariegos	50 - 225	25 - 120	25 - 170	20 - 150
Lunada	110 - 140	50 - 100	-	-
Manzaneda	20 - 80	20 - 50	50 - 120	30 - 70
San Isidro	50 - 230	25 - 175	50 - 210	20 - 300
Valgrande-Pajares	50 - 245	10 - 260	50 - 250	50 - 250
Javalambre	40 - 150	50 - 140	70 - 120	30 - 80
Santa Inés	-	20 - 200	50 - 220	10 - 195
Valdelinares	30 - 170	50 - 140	70 - 145	20 - 125
Valdezcaray	50 - 220	30 - 170	80 - 130	30 - 250
La Pinilla	25 - 145	20 - 100	30 - 130	30 - 150
Puerto de Navacerrada	25 - 170	25 - 100	25 - 200	40 - 300
Sierra de Béjar	30 - 210	50 - 100	60 - 330	25 - 155
Valdesquí	60 - 225	35 - 170	20 - 170	80 - 120
Sierra Nevada	40 - 600	100 - 150	50 - 250	50 - 200

Source: www.infonieve.es and own elaboration

Before analyzing Table 1, it is necessary to clarify that all data portrayed have been obtained from the website www.infonieve.es, specializing in ski page. In each cell we can see two digits, the lowest corresponds to the minimum thickness recorded and the highest the maximum thickness recorded, all reflected in centimeters.

In the table, as has already been said, we have 4 skiing seasons reflected. The minimum thickness data correspond almost entirely to the months of December and January, just after the start of the season; the maximum thickness data correspond to

the months of March and April, having a few isolated cases that also includes the month of February.

As we can see represented in the table data, regarding the 2009/2010 season, the 2010/2011 season has a level falling snow depth, all but Baqueira Beret suffered the consequences of rising temperatures, which increased by 100 cm. The following season fared better for the vast majority, since all increased their thickness. Last season, which have closer temporarily, has again suffered a major decline snow depth in most of the ski resorts.

This decrease in the snow depth, apart from that no snowed enough during the season, is due to the global warming increasing, human pollution, which causes the greenhouse effect, causing the earth average temperature raises, and has more seasons of heat and more heat waves, affecting the ski seasons.

Increasing the snow depth we observe, besides the temperature has accompanied this season, it's due with the help of snowmakers, which help a lot to extend the season and preserve the snow depth for longer. This does not mean that they are not used in seasons that we observe a decrease of snow depth, only which in these seasons the temperatures have been abnormally high, and the snowmakers cannot work normally in snow production.

This upward trend in temperature, it will become more constant, season after season snow depth will decline as long as the use of artificial measures to produce snow isn't increased, as we shall see in a later section, they are not nothing cheap, and require a large investment, which may come a time that doesn't leave profitable.

4.1.2. Rise snow level

A definition of the snow level according <http://foro.tiempo.com/> is:

“La cota de nieve es la altura respecto al nivel del mar a partir de la cual la nieve cuaja. Debemos distinguir entre diferentes tipos de nieve, principalmente en función al tamaño y la dureza (compactación). Así pues, la nieve granulada presenta una cota más baja que la nieve blanda (en torno a unos 300-400m más baja). En general la nieve llega a una cierta altura si en su recorrido la temperatura está por debajo del punto de fusión (que es en torno a 2°C a alturas de pocos kilómetros). Puede encontrarse con zonas de temperatura superior al punto de fusión y mantenerse la estructura nivosa, pero sólo si el "recorrido cálido" es corto.” (Foro de Tiempo, 2008)

According to an article in El País:

“El español Javier Corripio, profesor de Ciencias Atmosféricas de Innsbruck (Austria) y experto en glaciares explica que, aunque hay muchas incertidumbres y diferencias según el valle, la insolación, la orientación y la precipitación, cada grado de temperatura de subida supone que la nieve asciende unos 150 metros. Así que el aumento previsto en España se corresponde con subidas en la cota de nieve de 300 metros.” (Méndez, 2008)

Displaying the previous article, and knowing that the temperature of the earth is increasing due to climate change, we can see that the Spanish resorts snow levels (and not Spanish) will increasingly rising. Even with the help of snowmakers cannot get the snow level down because they do not have enough power to keep the snow without unravelling.

As we shall see now, there are ski resorts that are already being affected, and they have to resort to curious ways to keep the snow on the lower levels. An example gives us the online daily La Vanguardia:

“En la estación de Val d’Aran circulan desde hace unas noches camiones que llevan nieve cargada en Beret (a dos mil metros) para extenderla por la cota 1.500 de Baqueira. Una operación muy pocas veces vista, pero que ha resultado efectiva pues asegura el descenso de los esquiadores hasta la parte más baja de la estación por una lengua de nieve con hierba a ambos lados.” (Ricou, 2015)

With these data we can see that climate change is affecting the snow level, and to maintain these levels of snow as low as possible, the ski resorts have to manage to find viable and effective solutions, because if not do more of skiing fond people look for alternative, look for other ski resorts that they believe are better, even changing their plans at the last minute to find skiable snow. It's clear that there are seasons that snow level has lowered, but are short-lived and abnormal, since the trend is to increase this.

4.1.3. Ski resorts affected

Almost at the end of the Christmas holidays this year, half of Spanish stations were closed for lack of snow, as we have seen so thanks to an article of cerodosbé of January 4, 2016.

“La mitad de las pistas españolas permanecen cerradas a pocos días del fin de las vacaciones navideñas debido a la falta de nieve. Hasta ahora, las pistas catalanas de Lles (Lleida), Sant Joan de L'Erm (Lleida), Tuixent la Vansa (Lleida), Aransa en Lles de Cerdanya (Lleida) y Guils Fontanera (Girona) no han podido abrir por el clima cálido.

En el pirineo aragonés, las estaciones de Candanchú, Valdelinares, Lizara, La Pineta, Linza, Gabardito, Fanlo del Valle del Vío y Javalambre también permanecen cerradas, según ha informado la Asociación Turística de Estaciones de Montaña y Esquí Atudem, que representa a las pistas de esquí españolas.” (cerodosbe.com, 2016)

As we can see, the lack of snow affects many of the ski slopes in the season's most important holiday, which thing affects tourism directly, since everyone who takes holidays to go skiing on Christmas holidays, they do not and seek alternatives, seeking open stations with good snow level, though this proves them more expensive and larger displacement.

An example of an alternative to these stations would Formigal-Panticosa and Baqueira Beret, which could open and function normally.

Climate change isn't laughing matter, as it directly affects snow tourism. They're changing seasons, shortening them, and consequently reducing the time tourists spend in the ski resorts (and businesses that complement the offer of skiing). Many of these stations, instead of opening in November or December, had to open in late January, losing, as we have indicated, one of the most important period of holidays.

In the next image (Image 4) we can see the ski resort of Lunada, belonging to the Cantabrian Mountains, where snow is scarce in this 2016 season during the Christmas holidays.

Image 4: Lunada January 2016



Source: <http://www.diariodeburgos.es/>

4.1.4. Snowmakers and snow groomers

The snowmakers were invented in the 50s in the US, but it was not until the 70s when they began marketing for ski resorts. In Spain, the first station purchased was in La Molina in 1983, and since then all ski resorts have been buying them to satisfy the lack of snow in his snow resorts.

These snowmakers are responsible for the production of artificial snow to supplement natural snow at times when snow level doesn't get a minimum thickness to ski.

The online page solonieve, which is specialized in ski tourism, describes its operation as follows:

“Las estaciones de esquí extraen el agua de ríos, embalses, depósitos artificiales o lagos cercanos mediante bombas extractoras y un complejo entramado de tuberías. El agua se distribuye por todos los cañones de la estación y es allí donde se mezcla con el aire presurizado. En una sala de bombas, el aire se comprime, se enfría y se le retira la humedad. Por tuberías paralelas a las del agua, corre el aire hasta los cañones, donde confluyen. El cañón los expulsa por separado y al juntarse el resultado son microgotas de agua pulverizada a presión, que al exponerse al frío se convierten en bolitas de hielo. Éstas mientras caen, se van convirtiendo en un grano redondo de entre 1 mm y un 1,5mm.” (Solonieve.es, 2013)

Image 5: Snowmaker



Source: www.solonieve.es

In Spain, there are about 3,700 snowmakers counting the total of all the ski resorts, of which more than 2000 of them are in the Catalan Pyrenees.

Although at first glance it seems a very good measure for the fight against the falling snow depth, behind it a series of costs and environmental impacts, which greatly reduce profits and even, sometimes, cause losses.

The first drawback of these cannons would be its high cost, which each cost about € 10,000, plus installation, construction of the engine room, and the construction of the necessary transports water to these snowmakers infrastructure.

“Ello habría sido imposible sin los 2.136 cañones de nieve artificial repartidos por las nueve estaciones de esquí alpino. Los cañones son la salvación del sector turístico de montaña, pero a la vez la bestia negra de los ecologistas. Y es que las estaciones catalanas gastan en los cuatro meses de temporada tanta agua como una ciudad de 18.000 habitantes en todo un año. También consumen una ingente cantidad de energía eléctrica, alrededor de 9.000 kilovatios, la misma energía que una ciudad de 15.000 habitantes.” (Carbonell and Noguer, 2007)

As we can see, besides the high cost of installation, we have the problem of consumption, both electricity and water. An example would be Baqueira Beret, which has about 50 snow cannons, which represent about 900.000m³ every season, making a season light spending almost € 300,000. Moreover, the water consumption can get to use about 3500 cubic hectometres by season.

“Para algunos grupos conservacionistas, como Depana o Ecologistas en Acción, este despilfarro de energía y agua para la fabricación de nieve no tiene justificación. Lo que les pasa ahora a las estaciones, opinan estos ecologistas, es lo mismo que al pez que se muerde la cola. La falta de nieve en las estaciones incrementa la actividad de los cañones, eso aumenta el gasto energético y también las emisiones de CO que provocan el calentamiento del planeta, lo que, a su vez, muchos ya relacionan con la falta de precipitaciones de nieve en invierno.” (Plataformamontanas.es, 2016)

As we see in plataformamontana.es, as more snowmakers are installed in the ski resorts, the higher the energy consumption, so the emissions of CO² we throw into the atmosphere are higher, and as we have seen in the section of theoretical framework, this gas is the most damaging to the atmosphere and causes the most known greenhouse effect, for which thing, temperatures will be increases every time, and snow will dispose more and more.

Even knowing all this, the ski resorts don't stop to attend their snowmakers to meet the tourist demand, a clear example is Alto Campoo, who has installed this year, and will start to use (if necessary) this coming winter, and that has cost more than 10 million euros.

Another major expense are investments that are made for snow groomers, which leave the slopes as if no tourist has skied for them. These are a big expense for ski resorts, and each costs about 350,000 €, and consume a quantity of 22 liters per hour, which thing brings us back to business as before, more consumption equals more production of CO².

5. How to reduce pollution in the ski resorts

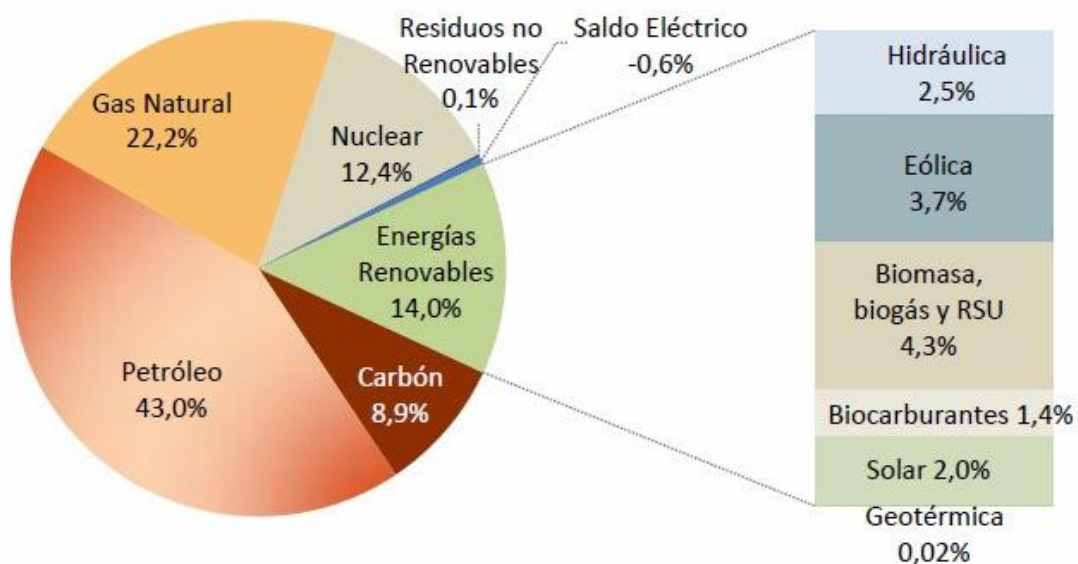
As we have seen in previous sections, pollution is very present in the ski resorts, not only caused by external agents, if not for the own normal functioning of each day.

In the following sections we will see some steps that serve to reduce these emissions, which in the long term would save them a lot of money to ski resorts, thereby also reducing the percentage of pollution and therefore not contribute to global warming and the effect greenhouse, very present in the changes suffered in the ski resorts.

5.1. Use of renewable energy

As is known, to produce electricity we need a primary source, which, mostly obtained from non-renewable energy, which produce all polluting gases to the atmosphere and causing major greenhouse. In the following graph, realized by the Center of Studies Renewable Energy we can see the percentage by energy used in the world as of 2013.

Graphic 6: Percentage of primary energy used to generate energy



Source: Studies Center of Renewable Energy

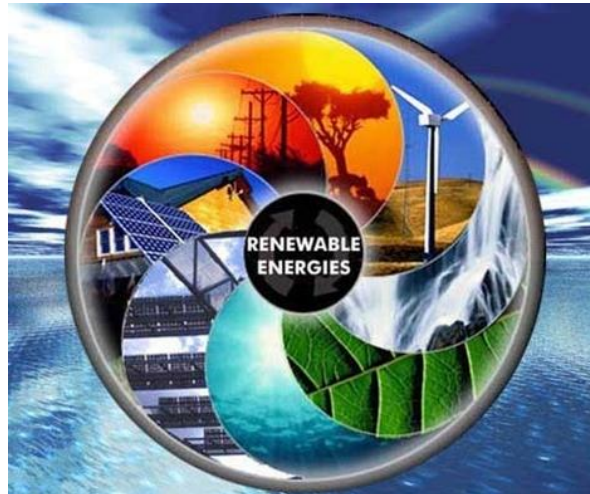
As we can see, only 14% of raw materials to generate electricity are renewable, being all the rest non-renewable.

Thus, the ski resorts should take a position more in favour of environmental conservation, and to reduce impacts to the environment as maximum as possible. One way would be to change its energy sources by renewable energies. Install clean production systems electrical energy, as could be solar panels, which use photovoltaic solar energy. This would be a measure of an expensive investment, but long term would save money on electricity and reduce emissions of polluting gases.

Besides, when we use this type of energy, reduce the environmental impact produced by the high tension towers that conduct electricity.

Another alternative would be wind power, that meets the requirement of being clean, but this would affect the environmental impact as deteriorate the mountainous landscape of the ski resorts. The best option would be to have photovoltaic panels, for the above reasons.

Image 7: Renewable Energies



Source: <http://erenovable.com/>

Regarding the use of energy, we should add the renewable energies in the snowmakers and the snow groomers. The snowmakers should supply themselves with photovoltaic solar panels, because they have a very high cost of electricity. Perhaps with this energy was not enough, it could help with conventional power, but always using a small part, so that the environmental impact as low as possible.

These measures with renewable energies, wouldn't need to be physically installed in stations, a good way to help them is to invest in these energies, to help reduce the use of polluting energies.

In the snow groomers, aside from being able also use photovoltaic energy, they should convert to electric vehicles, as fuel consumption is very high, so contamination is very high, and is thrown directly into the ski resorts.

An example of a ski resort that is betting on renewable energy, although not in the Spanish state, is the city of Aspen, in Colorado. According to the Nevasport magazine, in 2006, they acquired seven hybrid buses to transport skiers that go every day from the city of Aspen to the ski resort. These buses run on biodiesel made by a renewable agricultural fuel, so don't depend on oil and its emissions are reduced by up to 90%, in part to reduce their sound levels similar to passenger cars.

In this way, they are helping to protect a natural area (Maroon Bells Wilderness), which was already prohibited the movement of vehicles, reduce the negative impact on this area, and encourages the use of renewable energies.

5.2. Fourth Generation of Ski Resorts

As we can see, the ski resorts can be divided into four distinct generations. Nevasport through RestNeige (specializing in ski tourism company), defines the four generations as follows:

“- 1ª Generación: aparecidas a principios del siglo pasado. Los remontes salían de los mismos pueblos.

- 2ª Generación: los remontes suben cada vez más alto. De esta manera aseguran más días de esquí y se van incorporando servicios. Antes de la II Guerra Mundial ya encontramos en los Alpes este tipo de estaciones.

- 3ª Generación: se construyen núcleos artificiales en cotas altas y consecuentemente carreteras, grandes aparcamientos, apartamentos para alojar a los esquiadores, etc.

Se desarrollan a partir de la década de los 50 y 60, siendo Francia su máximo exponente.

- 4ª Generación: la estación vuelve a la población originaria, se acerca el dominio esquiable mediante grandes inversiones a través de remontes de gran capacidad y nieve producida. Existe un mayor respeto hacia el medio ambiente.” (Nevasport.com, 2015)

The called third generation stations are increasingly concerned, as customers increasingly seek more those of the fourth generation. This is a positive fact for the environment, as the third generation have produced a major environmental impact on the ground, building all in the same natural environment, while the fourth generation, have more care for the natural environment.

The growing awareness of the tourists on the environment has led them to find forms of tourism more sustainable, and the fourth generation is the one that most closely through actions such as: the construction of apartments and hotels are prohibited within stations, investing in local businesses at the foot of the mountain; there will be a limitation to build parking lots, and bus lines to transport will be provided to the ski slopes; on the ski slopes will have huts only minimum services; They cannot be installed infrastructure further than turrets, chairs and essential for the normal operation; areas for ecological reserves were limited; and foment a responsible snow tourism.

Every time we have more consideration for environmental care, and this makes these stations can differ from the rest by promoting sustainable tourism, resulting in less directly or indirectly pollution.

5.3. Reduce the visual impact

As we have seen in the preceding paragraph, third generation ski stations are the most affected, as they are the most visual impact have caused to the natural environment, building large infrastructures in high snow levels, where only should have ski slopes.

To reduce the visual impact on ski resorts, which erodes the ground, alter the landscape, modifying the water cycle and pollute the environment, we must to transform these in fourth generation ski stations. If this could not be because of the infrastructure already built, it should proceed to improve these facilities, respecting the environment, as been discussed in the preceding paragraphs, such as the use of

renewable energies, such as the adequacy of its facilities and which are in tune with the landscape.

All this is related to climate change because if the infrastructures are reduced near the ski resorts, pollution from construction is reduced due to the high percentage of contamination of materials used (such as cement).

Image 8: Visual impact. Sierra de Bejar, September 2008



Source: <http://www.nevasport.com/>

6. Conclusions

As we have seen in the investigation, we conclude that snow tourism depends to a large extent of climate change, and if we don't do something to reduce it, the effects will be devastating, because it directly affects their raw material, the snow.

In the last few years, the temperature of the earth has increased considerably due to the greenhouse effect and his consequent global warming, caused by the greenhouse gases. Disregarding the naturally occurring gases that cause global warming, it has been seen that the great majority of these are caused by humans, due to the industry and the automotive industry, main causes of carbon dioxide.

For years now it has been tried to reduce these greenhouse gases, with measures such as the Montreal Protocol or the Kyoto Protocol, which initially were working well, but they no longer have any effect. As we have seen, was intended to reduce by 5.2% the greenhouse gases in 7 years but at the end of this period the gases have increased, generating a 40% more than in 1990, due to the refusal of certain countries to meet the new conditions.

As we see, for some countries the effect of climate change is not important, but for countries like Spain, tourism is very important, as it represents a 11'2% of the Spanish GDP.

If pollution continues increasing, one of the main sectors of tourism, snow tourism, will be affected, which as we have seen, it is directly concerned. The thinning of the snow and the rise of the snow level are the main problems that are already having, and try to resolve through the artificial snow systems, snowmakers, very expensive alternative, due to the high investment needs to be done, and high maintenance costs. Furthermore, this alternative is not always effective, because if the temperatures are very high, the snow thaws equally.

For this we have proposed alternatives, such as using renewable energies, which would reduce both electricity costs and the emission of greenhouse gases that are produced when this energy is made. Another alternative proposal is to reduce the visual impact, by reducing infrastructure on top of the ski slopes, which in addition to altering the visual field of the environment, produce pollution from construction, in addition to further contamination produced by future tourists.

A part of these measures, tourists must be sensitized about the environment, about the impact of their actions about this, and if you want to continue to maintain this type of tourism, that is the type of tourism that he consumes, he has to take responsibility for their actions, and contribute to the maintenance of these, which is equal to not pollute to stop climate change.

To conclude, we have seen that tourism is very sensitive to climate change, especially the type of tourism we have studied, snow tourism. If we want to keep one of the main sources of income for our country, we must conserve the environment, and this starts with the reduction of pollutants, which is so common used.

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