WP T3 Smart Altitude Toolkit

A.T3.2 Territorial implementation plan

D.T3.2.1 Territorial Maximization report

Project acronym:	**Smart Altitude**
Project name:	Alpine winter tourism territories demonstrating an integrated framework for a low-carbon, high-impact and resilient future
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Programme specific objective:	SO2.1 - Establish transnationally integrated low carbon policy instruments

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0.1	Draft	07/08/2020	FBK, UMIL, Les Orres, EDF, S2i, CREM, RTC Krvavec
0.2	Final	19/08/2020	FBK, UMIL, Les Orres, EDF, S2i, CREM, RTC Krvavec
Notes:			

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1. Introduction

This deliverable describes:

- Five Implementation Models to maximize climate adaptation, GHG reduction, economic impact and stakeholder benefits:
  - Climate Adaptation & Mitigation
  - Renewable energy & Sustainable mobility
  - Energy Management System
  - Smart Grid
  - Value Creation through low-carbon innovation
- Five Webinars to discuss these models with the stakeholders of the Smart Altitude project, including potential replicators:
  - 17/6/2020: About the Smart Altitude Project (including a presentation of Climate Adaptation & Mitigation)
  - 24/6/2020: Renewable energy & Sustainable mobility
  - 1/7/2020: Energy Management System
  - 8/7/2020: Smart Grid
  - 15/7/2020: Value Creation through low-carbon innovation

In the new Smart Altitude Online Toolkit an entire section is dedicated to the PLAN theme (https://smartaltitude.eu/tools/plan/) with the 5 downloadable Implementation Models and the 5 viewable Webinars (YouTube channel, with also the downloadable presentations).

The Implementation Models and the Webinars have been widely promoted through the News section on the Smart Altitude website (https://www.alpine-space.eu/projects/smart-altitude/en/news-events/news/news-overview), the Smart Altitude Newsletter of the first half of 2020, the project brochure, the project flyer for replicators and the Smart Altitude Webinar Series.

2. Implementation Model: Climate Adaptation & Mitigation

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2.1. Climate Change in Alpine Winter Tourism Territories

With its strong reliance on specific climatic and natural conditions, the ski industry is regarded as the tourism market most directly and more rapidly affected by climate change. As the Interreg ClimAlpTour Project highlighted in its last report, since the 1980s, the average winter temperature (December–February) in the Alps has increased by 1 °C and inter-year variability has also become more pronounced, with winters with minimal snow falls, such as in 2006-2007, alternating with winters with high snowfall, such as in 2008-2009. The impacts of climate change on the winter season are far from linear but important changes are already observed in snow cover, with a rise in the rain-snow limit and the rapid melting of the snow cover in anti-cyclonic weather or at the beginning and end of winter (ClimAlpTour, 2011).

In terms of economic and market impacts, a critical review of 119 academic publications carried out in 2019 (Steiger, Scott, Abegg, Pons, & Aall, 2019), that examined the climate change risk on ski tourism in 27 countries, highlighted the following general pattern: decreased reliability of ski slopes on natural snow, increased snowmaking requirements, shortened and more variable ski seasons, a contraction in the number of operating ski areas, altered competitiveness among and within regional ski markets, implications for ski tourism employment, change in real estate values. Extent and timing of these consequences depend on the rate of climate change and the types of adaptive responses by skiers as well as ski tourism destinations and their competitors (Steiger, Scott, Abegg, Pons, & Aall, 2019). The same study reports the demand changes observed during recent warm winters, concluding that the impact of snow-poor winter seasons differs greatly between individual ski areas, with higher elevation ski areas and large ski areas found to be less sensitive. Table 1 shows these data for South Tyrol (Italy) and Tyrol (Austria). The South Tyrol region, in particular, provides evidence for the economic benefit of investment in snowmaking adaptation. In fact, the massive investments in snowmaking facilities put in place in the 1990s and 2000s allowed to reduce significantly the losses in demand (number of skiers), although the temperature anomalies in the 1988–1989 and 2006–2007 seasons were almost identical.

Table 1: Impacts of extraordinary warm winter seasons on supply-side and demand side indicators (Steiger, Scott, Abegg, Pons, & Aall, 2019; Segnaposto1)

Authors	Region	Season	Temperature anomaly (temperature difference from current climate normals 1961-1990 or 1981-2010)	Analogue for future climate change	Demand change (skiers visits)	Supply change (operating days)
Steiger (2011a)	South Tyrol (Italy)	1988-1989	+2.6°C	A1B 2050s, B1 2070s	-33%	
Steiger (2011a)	South Tyrol (Italy)	2006-2007	+2.9°C	A1B 2050s, B1 2070s	-2%	
Steiger (2011b)	Tyrol (Austria)	2006-2007	+3°C	A1B 2060s, B1 2080s	-11%	-10%

Climate change is considered as a source of opportunities and threats. While it could potentially benefit summer mountain tourism, it is providing increasing challenges for winter tourism destinations. According to the ClimAlpTour project, 57 of the 666 main ski resorts of the Alps are already considered not to be snow-reliable, with obvious consequences for the competitiveness. The same project analysed 22 pilot areas with diverse environmental, social and economic conditions in order to provide a global perspective on the Alpine tourism. The results confirm the lack of a single simple strategy to cope with the issue at stake throughout the Alps (ClimAlpTour, 2011). The project concluded that future socioeconomic scenarios are as crucial as climate conditions, such as trends in tourism demand, maturity of many destinations and market saturation, globalization with exponential increase in the number of competitors and changed travellers' behaviour, increasing energy costs, reduced water availability affecting also snow making. For these reasons, the traditional development model of the ski resorts is more and more challenged, with the increasing need for more innovative, flexible and sustainable business models (ClimAlpTour, 2011).

ClimAlpTour drew interesting conclusions on the further steps to be taken, based on lessons learnt from the project. We list them in Figure 1, as they are strictly related to Smart Altitude project and should be taken into consideration as an introductory framework by any ski resort approaching the Smart Altitude Decision-Making Tree.

Interreg Alpine Space Project ClimAlpTour, Final project report (2011)
Conclusions: Further steps to be taken

1) Differentiating development strategies to reduce seasonality: Alpine resorts should move away from traditional winter and summer experiences; that is, based only on skiing and hiking. Instead, they should integrate investments in developing wine and food tourism, marketing local products and tasting tours, wellness activities, and hosting sports and cultural events, to mention just a few. All of these products are greatly appreciated at those Alpine resorts that promote them, which are increasingly becoming more popular than those where only traditional activities are promoted.

2) Coordinating locally tailored development strategies under Alpine Convention objectives, in line with sustainable development principles. Not every destination can offer the entire range of activities outlined above. ClimAlpTour results demonstrate that it is strongly advised to develop specific trademarks that make the destination unique by exploiting its specific potential. In turn, this will limit the risks resulting from fierce global competition in tourism. Cases of best practices should be communicated to promote exchange of experience within the Alpine area.

3) Concerted efforts towards long-term adaptation schemes, at both the regional and local levels, should become a priority and last beyond the term of a single political administration. Public investments should be utilized for long-term planning. These must pay particular attention to environmental protection and climate projections. It is necessary to build on and exploit local stakeholders' interest in climate-change issues to create dynamism for exploring potential development options.

Figure 1: Conclusions from Interreg ClimAlpTour Final Project report (2011)

2.2. Climate Adaptation

In the climate change literature, adaptation is referred to a change in response to environmental conditions that maintains or enhances the viability of a system (Bicknell & McManus, 2006). The European Commission (EC) refers to adaptation as "anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause or taking advantage of opportunities that may arise". Moreover, EC points out that adaptation strategies are needed at all levels of administration, from local to the international level; however, "due to the varying severity and nature of climate impacts between regions in Europe, most adaptation initiatives will be taken at the regional or local levels" (EU Commission official Website[1]).

Adaptation is therefore a necessary strategy also for mountain regions and winter tourism areas, even if this entails a number of challenges.

Climate variability across regions means it is difficult to understand the regional climate implications at one specific ski area. The expected scenario foresees a contraction of viable ski resorts that favours climatically advantaged regions. However, although these regions and associated communities are likely to benefit from increased or stable tourism revenue, they will still need to adapt to changing climate conditions and prepare for the possibility of increased development pressures, crowding, and infrastructure deficiencies (Dawson & Scott, 2013). In turn, communities loosing ski tourism operations will need to develop economic diversification strategies, due to lost winter tourism revenues and related jobs, and could also see increased pressure on social services and unemployment as well as a drop in real-estate value (Hamilton, Brown, & Keim, 2007); (Scott & McBoyle, Climate change adaptation in the ski industry, 2007).

The more vulnerable ski areas will, at varying points, need to determine if they should invest heavily in adaptations that will aid in the continuation of a snow-based business at least in the short to medium term (i.e. high efficiency snowmaking), if they should invest in adapting and evolving into a multi-season destination (i.e. four-season resort, spa, conference centre), or if they ultimately need to terminate their business altogether (Dawson & Scott, 2013). In order to take these decisions, it is very important that ski area managers consider both supply-side and demand-side implications of a changing climate.

Figure 2 shows an inventory of climate adaptation practices used by ski industry stakeholders around the world, where adaptation options are organized by type of actor in order to reflect the importance of engaging the different stakeholders who are motivated by different factors (Scott & McBoyle, Climate change adaptation in the ski industry, 2007). If we look at ski area operators, the range of adaptation practices are organized into two main types: technological (snowmaking systems, slope development and operational practices) and business practices (ski conglomerates, revenue diversification, marketing, indoor ski areas). However, the importance of other actors for successful adaptation should not be underestimated, including the government and public administrations, the financial sector and the final users.

[1] https://ec.europa.eu/clima/policies/adaptation_en

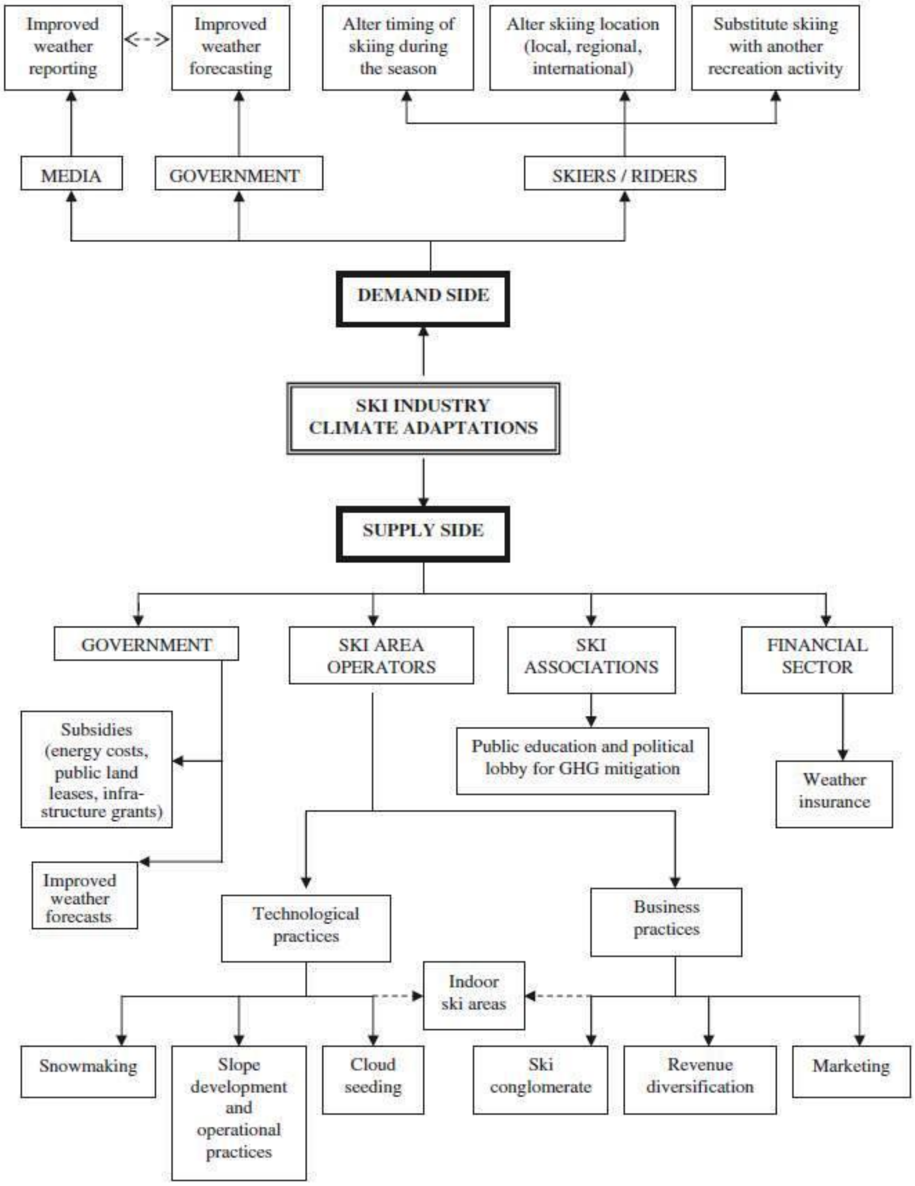

Figure 2: Inventory of Adaptation options in ski resorts around the world (Scott & McBoyle 2007)

Also, the results of the Interreg Alpine Space project ClimChAlp summarise the possible adaptation strategies for ski resorts in accordance with the figure above. Besides snow making, **technological strategies** include shifting slopes to higher altitudes, avoid south facing slopes, increase snow shading (through tree cover along slope margins), build artificial slopes and enhance weather forecasting to support programming of the ski season.

Besides technological practices, also **business practices** should not be overlooked (Figure 2).

The conglomerate business model (joining several ski resorts) may prove to be one of the most effective adaptations to future climate change, as it provides greater access to capital

and marketing resources, thus enhancing adaptive capacity, but also reduces the vulnerability of the conglomerate to the effects of climate variability and future climatic change, through regional diversification in business operations (Scott & McBoyle, Climate change adaptation in the ski industry, 2007).
Cooperation between lower and higher-elevation resorts lead to mutual advantages: the first, acting on wide market segments, could offer activities and services that complement skiing and cheaper accommodation facilities, whereas the second, thanks to cooperation with less well-known resorts (that are, however, often characterized by a richer cultural identity), can expand and differentiate what they offer (ClimAlpTour, 2011).

Revenue diversification is also necessary, especially for most vulnerable ski areas, but not only. Diversify the winter tourist offer and/or the whole year-round offer is now an essential strategy to adapt. It is necessary to identify potential resources for tourism, such as cultural and natural heritage or the wellness segment, and to make them viable. In a number of destinations, there is a demand to focus more on valuable local resources (local products and traditions, natural resources, etc.) for both tourists and local stakeholders (ClimAlpTour, 2011).

Finally, **marketing strategies** should be primarily focused on that particular differentiating element characterizing the resort/conglomerate. Furthermore, ski companies have already begun to experiment with incentives or guarantees to overcome skiers' reluctance to book a ski holiday because of uncertain snow conditions (Scott, McBoyle, & Minogue, 2007), or to reduce the costs of short holidays.

Of course, each strategy has limits and consequences, which should be carefully assessed at the planning stage. Figure 3 summarises the limits for each main adaptation strategy discussed above, based both on a literature review and as a result of interviewing stakeholders in the Australian Alps (Morrison & Pickering, 2013).

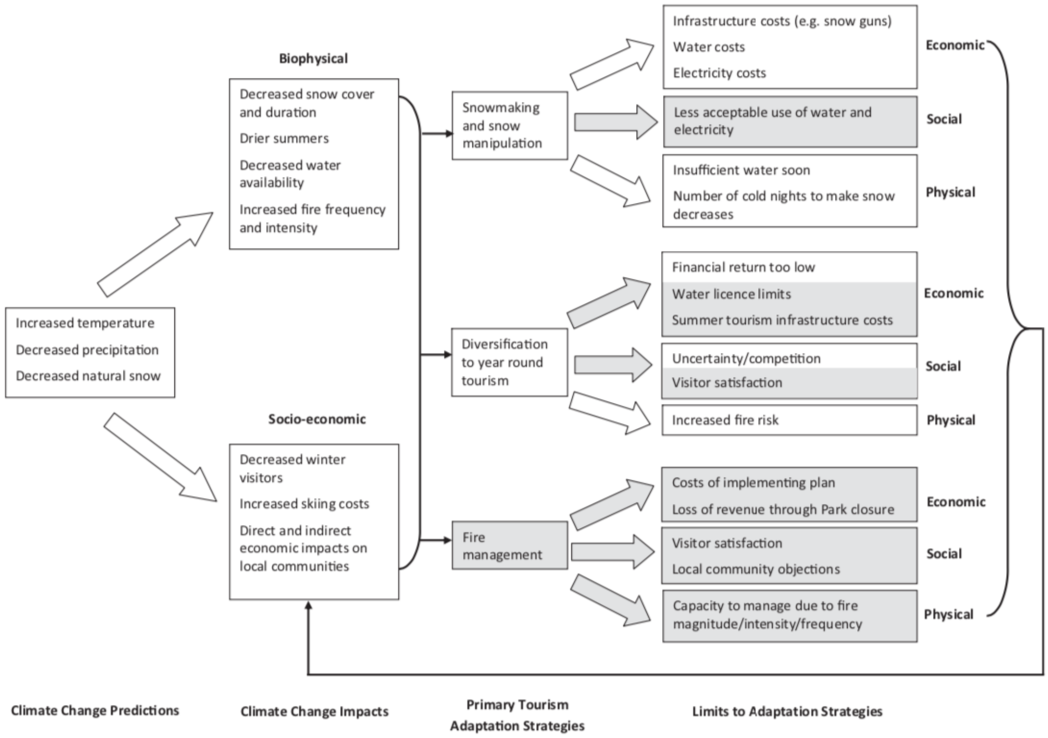

Figure 3: Adaptation strategies and their potential limits (Morrison and Pickering 2013)

Conclusions from the ClimALp project final report are again useful to close this overview of adaptation strategies for ski resorts in the Alps.

The report highlights that **climate change** will not only have negative impacts on winter tourism in the medium to long term but **can also be seen as an opportunity to more rapidly implement the structural change** necessary for dealing with the current crisis that the tourism sector is experiencing. The survival of the ski industry is not in question, but the "one-way exploitation" of mountain areas is.

A second important conclusion is that **adaptation should be mainstreamed into long-term tourism planning** and should not be considered in isolation, as reported below:
"Climate change is just another pressure being placed on already stressed tourism systems, which have specific strengths and weaknesses. Although tourism demand is very adaptive and tourists' behaviour is constantly and rapidly evolving, the tourism supply (referring to Alpine destinations as a whole) needs more time to plan activities in order to respect social, economic and environmental constraints. There certainly are autonomous activities (e.g., artificial snow, ski slope design, etc.) that tourism suppliers can engage in, but the most crucial part of the adaptation effort will be played by "planned adaptation." Climate change is merely an opportunity to involve the most appropriate set of local stakeholders in the

process of defining activities to improve the sustainability of tourism within each Alpine resort" (ClimAlpTour, 2011).

Another important point we wish to report from ClimAlpTour is that in the participatory workshops, that have been taking place over the length of the project, the local stakeholders have proven to be the sentinels of climate changes as they are already deeply interested in this issue and aware of it, expressing the desire for a higher degree of inclusivity and participation. Thus, **engaging local stakeholders** is essential, including the local population and businesses. What is still missing in many areas is the capacity to have the stakeholders sit together and agree on how to proceed to improve the situation, but ClimAlpTour demonstrated that, when consulted in an appropriate way, the local community might indeed have a coherent and "climate change-safe" vision of what the future of Alpine tourism could look like.

A final remark for this chapter is that **policy makers should enable effective and cost-efficient adaptation** as some strategies will require investments, long term planning decisions and amortization times (Hoffmann, Sprengel, Ziegler, Kolb, & Abegg, 2009). Examples on how policy makers could increase the scope of corporate adaptation are: influencing the level of awareness of possible climate change effects, including providing research and information such as improved climate forecasting (Scott & McBoyle, Climate change adaptation in the ski industry, 2007); provide financial support (e.g. tax breaks on adaptation investments, subsidies); provide capacity building (e.g. technical support, skills trainings). Moreover, policy makers should attempt to bring corporate adaptation in line with their desired direction of local or regional adaptation, as defined in regional and local plans (Hoffmann, Sprengel, Ziegler, Kolb, & Abegg, 2009).

2.3. Climate Mitigation

Due to the impacts that climate change will have on the Alpine Region, climate mitigation strategies are an essential element to be taken into account within the tourism sector. Mitigation measures are defined as those actions, implemented by a business and/or a policymaker, that reduce and curb carbon dioxide emissions in the atmosphere (Lucena, et al., 2018). The Smart Altitude project aims to demonstrate the potential of mitigation strategies such us energy efficiency, renewable energy, sustainable mobility, energy management and smart grid across the Alpine Region. Mitigation strategies set in place by a ski resort, as underline by Lucena, et al. (2018), will have an influence not only on the GHG emissions but also on the resilience of the business model and the energy system, which will be inevitably exposed to future impacts of climate change.

Within this chapter we will assess climate mitigation options for alpine ski resorts.

Climate mitigation in ski resorts

Natural snow reliability has an influence on tourism demand for a specific winter location (Damm, Köberl, & Prettenthaler, 2014). Energy demand in the winter tourism industry is rapidly increasing because, in addition to consumption for ski lifts and snow groomers, the implementation of snow making systems is at present the most widely utilized adaptation strategy (ClimAlpTour, 2011). However, there are some challenges in the snowmaking capacity of a ski resort, namely the increasing temperatures (with a consequent decreased efficiency of artificial snow production) and the potential increase in energy prices if the shift to renewable energy does not accelerate (Damm, Köberl, & Prettenthaler, 2014); (Steiger, 2010).
The costs and benefits of artificial snowmaking are dependent from several factors such as future climate scenario, snow pack scenario and resources availability (Hanzer, Marke, Steiger, & Strasser, 2012) (Damm, Köberl, & Prettenthaler, 2014). In the analysis carried out by Damm et al. (2014), electricity costs were found to be the main variable cost factor of snowmaking.

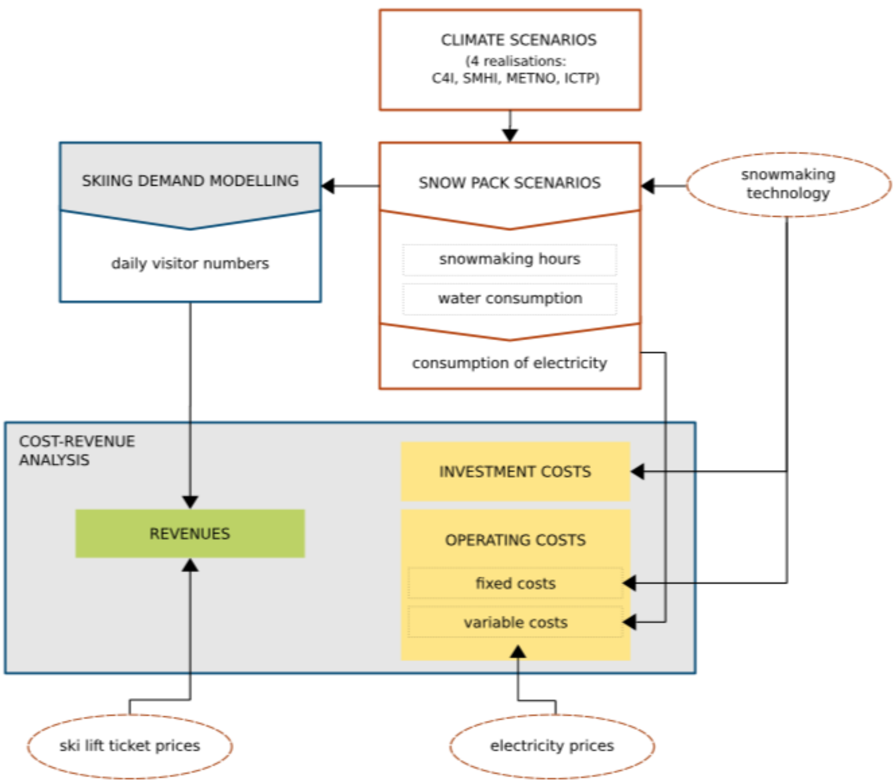

Figure 4: Causalities in determining costs and benefits of artificial snow production (Damm et al., 2014)

Taking this into account, it is of vital importance to assess energy efficiency in artificial snow making: improving energy efficiency will indeed lower the resort's running costs and make the business model more sustainable in the long run.

The strategies that could be set in place to improve the energy usage in a ski resort are: (i) Calculate the specific electricity consumption – Audit Process, (ii) Monitor the consumption data – through the implementation of an Energy Management System (EMS), (iii) Implement energy savings measures, (iv) Implement renewable energy sources (RES) (Motiva, 2008).

The implementation of an EMS, energy saving measures and RES within a ski resort will bring along several benefits, such as (i) Immediate cost savings, (ii) Long-term benefits and an increased resilience capacity towards climate change, (iii) Increased customer appeal (NSAA Association, 2006). These measures could be implemented in the whole ski resort, including ski lifting, snow making and snow grooming, as well as onto building related to the customers frequenting the ski resort.

Specifically, ski resorts operators, in order to curb their emissions, could focus on the implementation of a renewable energy mix in the whole ski area while at the same time implementing measures that will reduce their energy consumption, such as the ones reported in Table 2.

Table 2: Possible climate change mitigation measures for Ski resorts

Mitigation Measures	
Overall ski resort	Monitoring and Integrated Energy Management System (IEMS)
Ski lifting	Monitor and implement an EMS
	Assess ski lifts energy efficiency
	Implement renewable energy sources (e.g. PV)
	Implement speed control measures (e.g. based on the number of entrances)
	Replace old ski lift systems with modern technology
Snow making	Optimal water management (flow rates, height differences, main and secondary reservoirs, water concessions)
	Through the analysis of the pumps for the distribution of water and their working points, interesting ideas can be found for the reduction of unnecessary oversize, operation outside the optimum range, replacement of inefficient pumps
	Replace old snow-making systems with modern technology

	Implement an automated snow making system
	Plan which kind of snow making system is the most effective for the ski resort (Fan gun, Hybrid/tower, Hybrid/high-pressure)
	Implement renewable energy sources
Snow grooming	Verification of the systems available for the management of the snow groomers' park and for the management of the snow groomers' routes. The advantages are several: • reduction of maintenance costs; • reduction of fuel consumption through the optimization of routes; • control of the work on the slopes (thickness of the snow); • online monitoring of the machines (e.g. position, speed, with advantages for safety and consumption)
	Replace old grooming machines with newer ones
	Implement hybrid/electric snow groomers
Buildings	Assess the energy consumption of the ski resorts building and improve the heating system and ventilation
	Replace indoor and outdoor lighting with energy-efficient lightbulbs and an automated lighting control
	Improve the energy efficiency of building envelopes
	Implement heat recovery
	Implement renewable energy sources for heating and electricity

2.4. Synergies between Adaptation and Mitigation

The current phenomenon of climate change represents a new challenge for the winter tourism industry in the Alps (Michailidou, Vlachokostas, & Moussiopoulos, 2016). Elsasser and Bürki underlined that it "has to be viewed as a catalyst that will reinforce and accelerate the pace of structural change in the tourist industry and more clearly highlight the risks and opportunities inherent in tourist developments" (Elsasser & Bürki, 2002). This structural change within the tourism sector should be accompanied by the implementation of new policies and strategies, which must consider both climate mitigation and climate adaptation measures.

These synergies between adaptation and mitigation measures are evident, especially when considering a climate-dependent industry such as the winter tourism one (Figure 5). Indeed, the tourism industry is nowadays asked to adapt to new climatic conditions, compiling with environmental constraints, and at the same time have a leadership role in mitigation actions (Scott, D.; Amelung, B.; Becken, S.; Ceron, J. P.; Dubois, G.; Gössling, S.; ...Simpson, M., 2008)

(Scott, 2011). When considering ski resorts, future climate conditions will have a direct impact on their ability to operate and attract tourists. These future conditions "may threaten the implementation of artificial snow, especially in low altitude resorts with physical and economic limitations. Resorts may have to deal with an increase in water and energy consumption, and a reduction in the number of days with low temperatures that are suitable for snow production, threatening their economic viability" (Campos Rodrigues, Freire-González, Gonzalez Puig, & Puig-Ventosa).

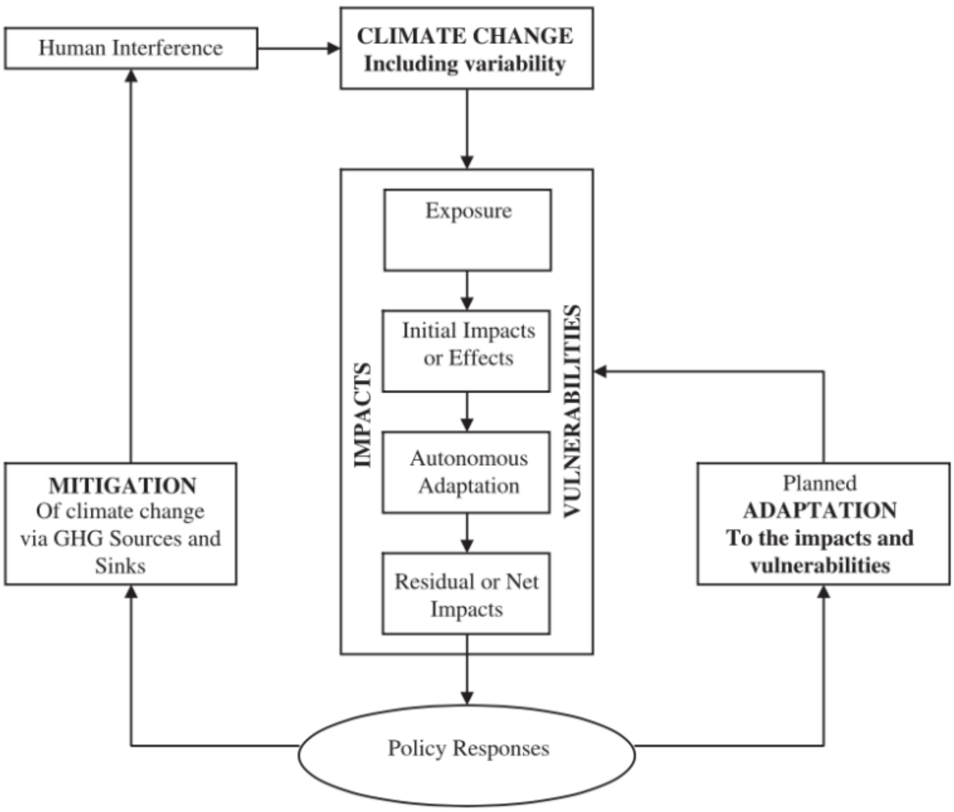

Figure 5 Climate adaptation and mitigation measures (Bicknell & McManus, 2006)

Mitigation and adaptation measures should be both integrated not only within ski resort's business plans but should also be taken into account by local, regional and national policies focusing on winter tourism. This approach could be obtained through the inclusion of different stakeholders in the decision-making process of ski resorts, among which policy makers and tourism associations, as suggested by the Smart Altitude's Decision-Making Tree. Kaján and Saarinen underlined that this process of "indirect policy involvement could assist in forming more sustainable business practices" integrating also land, water and energy consumption regulations (Kaján & Saarinen); (Scott & McBoyle, 2007). These studies underlined the need for new policy frameworks, from the local level up to the European-

International one (Kaján & Saarinen); (Scott & McBoyle, 2007); (Mochurova, Kaloyanov, & Mishev, 2010).

On top of constituting an important asset for the future resilience of ski resorts, a mix of adaptation and mitigation measures provides also the opportunity to improve the marketing strategies of an area. Tourists' attitude towards artificial snowmaking as it stands were found to be mixed because of ecological reasons and the increased use of resources that an artificial snow-covered area entail (Pütz, et al., 2011); (Saarinen & Tervo, 2006). Implementing a renewable energy mix, reducing GHG emissions and focusing on the communication of the efforts a ski resort implements could improve the stakeholder perception of the local tourism industry while at the same time reducing the impact of a changing climate (Dinca, Surugiu, Surugiu, & Frent, 2014). For this reason, marketing and communication efforts are underlined as key components within the Smart Altitude's Decision-Making Tree.

3. Implementation Model: Renewable energy & Sustainable mobility

Document: Public/Confidential
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3.1. Executive Summary

In this implementation model, “Renewable energies and sustainable mobility” there is an overview of the different topics which describe in general a wide subject such as sustainability for ski resorts. In the first part, the different renewable energy systems (RES) have been described. The working and configurations of solar (thermal and PV), wind, hydroelectric, geometric and biomass conversion methods have been described. In addition, some examples of "green" ski resorts using RES to supply their energy demand have been reported. Subsequently, alternative methods to artificial snow production were also described with the physical-biological characteristics s of the hydrological basins (artificial and natural), necessary for water supply of the snowmaking systems. In particular these alternative systems can use RES to produce snow.

In a dedicated paragraph, the fundamental role of energy storage systems (ESS) in the integration between energy demand and renewable energy production was also discussed.

Finally, in the last paragraph the optimising transport facilities, another crucial issue in the context of sustainability, was discussed. The different features of electric vehicles have been described, from the operating mechanism to the charging and refuelling mode. In particular, the main differences between battery electric vehicles (BEVs), plug in hybrid vehicles (PHEVs) and fuel cell electric vehicles (FCEVs), were seen.

Finally, the use of these special vehicles in ski resorts was reported. In particular the example of the Austrian hydrogen powered snowmobile (Hysnowmobile) and some examples of snowgroomer prototypes that are being developed, were reported.

3.2. Introduction

Changing climatic conditions and the resultant changes in the cryosphere affect the winter tourism industry. Changes in seasonal snow conditions, glacier cover, or frozen water bodies can have direct consequences that necessitate investigating technological measures to adapt to these changes. An example of one such measure is to artificially increase the mass balance of snow and ice within glacier ski resorts. [1]
With the Historical Instrumental Climatological Surface Time Series of the Greater Alpine Region (HISTALP) dataset [2] these trend patterns can be explained. It contains homogenized records and a trend analysis of temperature, pressure, precipitation, sunshine, and cloudiness for the European Alps and its wider surroundings. These results show increased winter air temperatures for all regions and decreasing precipitation in the south throughout the last century
In a world affected by climate change, experiencing an already noticeable warming effect, the reduction of snow cover in the mountains is one of the consequences, thus, winter tourism gets damaged and solutions need to be found. The production of machine made (MM) snow comes as a plausible solution for this problem, but at the end global warming will also affect the conditions for traditional snowmaking, forcing the industry to develop new technologies. One of those technologies is the temperature independent snowmaking (TIS), which is of great interest since weather conditions do not affect anymore the snow production.
Climate change represents a new challenge for tourism, and particularly for winter tourism in the Alps. [3]

3.3. Environmental sustainability aspects

The effects of climate variability and climate change are investigated in different studies based on different parameters related to the natural snow cover in the European Alps. In Switzerland, Laternser and Schneebeli [4] found a significant decrease in average snow depth, snow cover duration, and the number of snow days from the early 1980s to 1999. Christoph Marty [5] concluded that the number of days with a specific depth of snow above a certain altitude has decreased gradually and significantly until today. Both studies suggest that these observations are due to increased winter temperatures rather than to changed precipitation conditions [6]. In Austria, Jurkovic´ et al.[7] depicted region-dependent trends with negative trends of snow cover duration and snow days in the south, and no significant trend in the east and north. The data analysis of Auer et al. [2] explains the causes of the change in the European Alps. The results are characterized by a highly significant increase of air temperature in all seasons and regions. Precipitation trends have a lower statistical significance and are more complex to interpret, showing decreasing winter precipitation in all investigated subregions with greater drying in the south. A general problem of this precipitation trend analysis is the spatial and temporal heterogeneity of the statistical and of the magnitude of the observed trends. Brunetti et al. [8] applied multiple trend analyses to overlapping time periods (i.e., running trend analysis) with the HISTALP dataset and demonstrate a high impact of the choice of the time window on trend analysis. Generally, a more pronounced cold season positive temperature and negative precipitation trend in the period 1975–2000, compared with earlier times is expressed. These results, together with the expected changes in temperature and precipitation in the European Alps, underline the potential demand for increased artificial snow production as an adaptation strategy for ski resorts. However, as the potential production of artificial snow is a function of weather conditions, the artificial snowmaking industry itself may be concerned by rising air temperatures and changing humidity conditions. This is why there are snowmaking systems that are not affected by the ambient temperature as explained in the following paragraphs.

3.4. Renewable energy systems

Working towards sustainability means moving towards a massive implementation of renewable energy production, storage and management. The various renewable sources that a ski resort can generally use involve solar, wind, hydroelectric and geothermal energy.
The production of renewable energy depends on random environmental parameters such as solar radiation or the intensity and direction of the wind. For this reason, energy storage systems are required in order to achieve the most constant energy supply possible. In addition, it is necessary to design a dedicated grid to achieve an optimal integration of these renewable energy sources.
Moreover, water which is a widely used resource for the production of artificial snow, can be collected in a valley and then can be pumped to higher altitudes. This type of water storage can guarantee the snow production in winter, but can also serve as a reservoir for hydroelectric power plants to produce electricity in the summer.

3.4.1. Solar Energy

Solar energy is the cleanest and most abundant renewable energy source available, it establishes the thermal and dynamical structure of the terrestrial environment and is the primary external cause of terrestrial variability. The source of solar energy is believed to be generated from the steady conversion of four hydrogen atoms to one helium atom in fusion reactions, which take place in the deep interior of the Sun with temperatures up to many millions of degrees [9]. This energy reaches the surface of the earth in the form of electromagnetic radiation. The composition of this radiation as it travels through space towards the earth is around 56% infrared, 36% visible radiation and 7% ultraviolet with the remainder belonging to regions of the electromagnetic spectrum outside the energy ranges covered by these three [10]. Not all this radiation reaches the surface of the earth. Some is scattered by dust and molecules in the atmosphere. This scattering is a random process, sending the radiation in all directions so that much goes directly back into space. Clouds act to reflect more sunlight back into space and they play an important role in regulating the temperature on the surface of the earth. Another part of the radiation is absorbed by molecules of atmosphere such as water, carbon dioxide, ozone and oxygen. Water and carbon dioxide absorb energy from the infrared region, while oxygen and ozone absorb from the ultraviolet. All these interactions reduce the solar energy flux by around 40% while at the same time changing its composition so that the sunlight which reaches the earth's surface comprises 50% visible radiation and 47% infrared [11]. The sunlight that reaches the earth's surface is of two types, direct radiation and diffuse radiation. The latter is the result of various scattering and absorption processes that take place as the sunlight passes through the atmosphere. Furthermore, vegetation is able to absorb both types of radiation. However, a solar thermal plant requires direct radiation to operate effectively. This limits the applicability of this technology to regions where there is low average annual cloud cover. With no cloud cover in the condition of so called clear-sly, between 80% and 90% of the sunlight reaching the surface will be direct radiation. The amount of energy carried by solar radiation is normally expressed in terms of the solar constant which measures the quantity of solar energy passing through one square metre of space perpendicular to the direction of travel of the radiation at the average distance of the earth from the sun. According to the World Energy Council, the value of this constant is 1367 W/m2 and the total solar flux reaching the surface of the earth is estimated to be 1.08×10^8 GW [12]. This is between 7000 and 8000 times annual global primary energy consumption [13].

3.4.1.1. Photovoltaic system

Photovoltaic cells (PV) are semiconductor devices that convert solar energy directly into DC electric energy. The photovoltaic effect is the basic process in which a solar cell converts sunlight into electricity. Each photon, characterized by a certain wavelength, carries an even amount of energy well defined according to the relation:

$$E = \frac{h\,c}{\lambda}$$

In which E is the transported energy (eV), h is the Plank constant ($6.626\ 10^{-34}$ Js) , c is the speed of light ($299.792\ 10^{6}$ m/s) , and λ is the wavelength of the radiation considered. When an electron hits a solid there is an exchange of energy. If the energy of the photon is greater than the minimum energy to tear an electron from the solid, then the electron is free to detach itself, otherwise the energy is dissipated in the form of heat.

Experimentally we see for a certain solid and for a certain frequency of the incident radiation, the number of electrons extracted is proportional to the intensity of the incident radiation. As the intensity of solar radiation increases, the photo-generated current increases, but the potential remains constant. For each solid there is a minimum frequency (i.e. minimum energy) below which there is no electron emission. This frequency is called threshold frequency. The potential to stop electrons is proportional to the frequency of light. Semiconductors are materials in which most of the external electrons bound to atoms occupy the valence band and only a minimum amount occupies the conduction band. In insulators all electrons occlude the valence band while in metals all electrons occupy the

conduction band. In semiconductors, the valence and conduction band are separated by a well-defined energy gap of 1.12 eV.
This effect can be defined as being the appearance of a potential difference (voltage) between two layers of a semiconductor slice in which the conductivities are opposite, or between a semiconductor and a metal, under the effect of a light stream. A photovoltaic cell generates a direct current [14]. If the electrons reaching the conduction band remain stationary, they release the stored energy in the form of electromagnetic radiation. Therefore, a sort of engine is needed to set the electrons in motion. A favourable situation occurs in the junction. A junction is the union of two volumes of semiconductors, each of which has been worked separately by introducing impurities into it (doping). These impurities are such that the amount of negative charges (electrons) and positive charges (gaps) present prevails over the thermodynamic equilibrium.
Silicon, for example, is a tetravalent element, with four electrons of valence in the external orbital. By adding small amounts of a pentavalent element (such as phosphorus or arsenic), the fifth electron not engaged in a bond occupies the conduction band, resulting in an excess of electrons (n-doping). Instead, if small quantities of a tetravalent element (like boron) are added, unstable bonds are generated with the surrounding atoms that tend to trap the electrons to stabilize, releasing positive charges (p-doping). When these volumes are put in contact, the electron output of zone n tends to spread in zone p and the excess of gaps migrates from zone p to zone n. This migration causes an electrical charge imbalance that generates an electric field as is possible to see in Figure 6 [15]. The electric field is opposed to migration and draws the electrons towards zone n and the gaps towards zone p. Balance is achieved when charges that migrate due to diffusion are offset by charges that move in the opposite direction due to the electric field. At equilibrium a portion of space called the space charge region is generated, which behaves like a diode. The anode is made up of the groped region p, and the cathode of the groped region n.

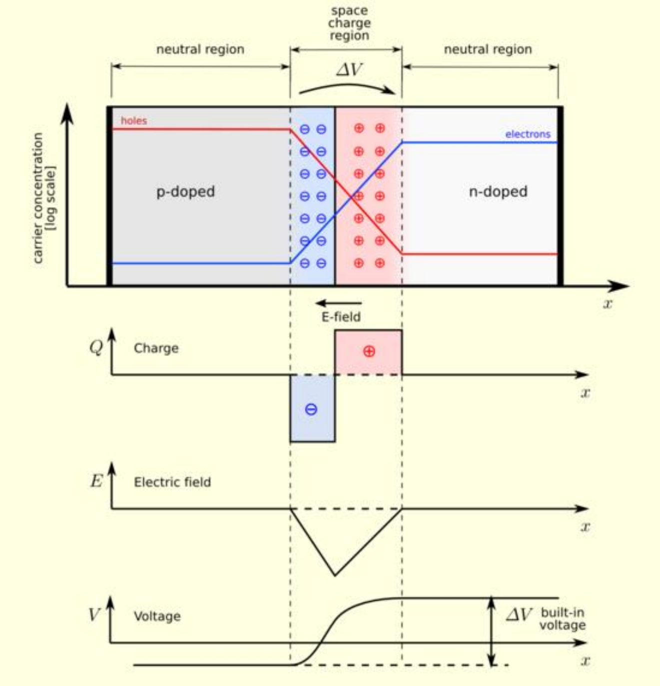


Figure 6: p-n junction

A PV cell consists of two or more thin layers of semiconducting material, most commonly silicon. When the silicon is exposed to light, electrical charges are generated; and this can be conducted away by metal contacts as direct current. The electrical output from a single cell is small, so multiple cells are connected and encapsulated (usually glass covered) to form a module (also called a panel). The PV panel is the main building block of a PV system, and any number of panels can be connected together to give the desired electrical output. This modular structure is a considerable advantage of the PV system, where further panels can be added to an existing system as required. The main photovoltaic cells on the market are: monocrystalline silicon cells, polycrystalline silicon cells, amorphous silicon cells.

The polycrystalline silicon cells have a lower degree of purity than monocrystalline having a set of crystals misaligned with each other. Amorphous silicon, on the other hand, does not have a well-defined crystalline structure. It is a disordered set of atoms and has a conversion efficiency much lower than crystalline silicon. The energy gap is 1.7 eV. While there are many environmental factors that affect the operation characteristics of a PV cell and its power generation, the two main factors are solar irradiance G, measured in W/m2, and temperature T, measured in degree Celsius (°C). An illuminated solar cell can be characterized by an I-V curve. Interconnecting several solar cells in series or in parallel merely increases the overall voltage and/or current, but does not change the shape of the I-V curve. Moreover, the MPPT (Maximum Power point Tracking) , is the maximum of the I-V curve (labelled with a star in Figure 7) and it is correlated to the technical data of the PV panel. The I-V curve is dependent on the module temperature and on the irradiance. For example, an increasing irradiance leads to an increased current and slightly increased voltage, as illustrated in Figure 7a. While, Figure 7b shows that the effect an increasing temperature has a detrimental effect on the voltage.

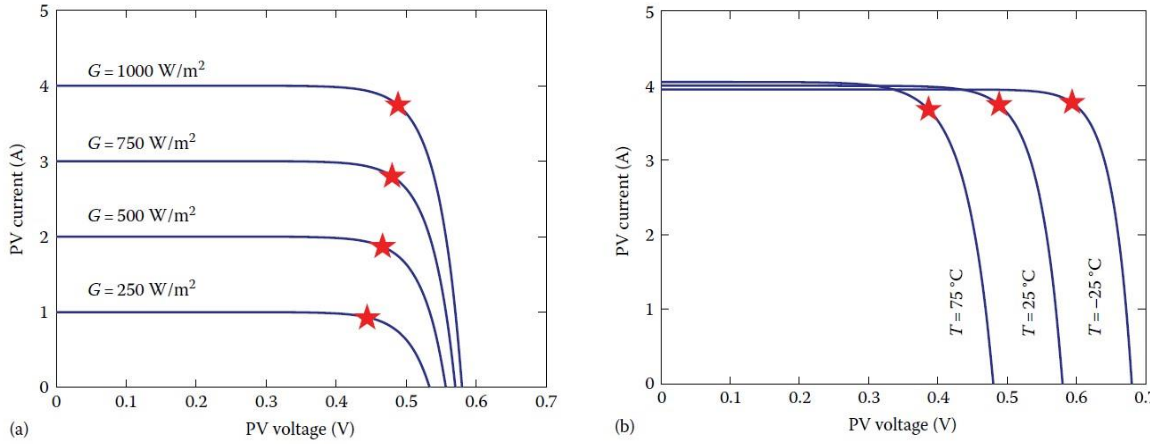


Figure 7: Effect of irradiance (a) and temperature (b) on the I-V curve

In the specific case of sky resorts, there are relatively low temperatures in the ski season and the overall efficiency of a PV system could benefit from this.
The irradiance of a PV can be expressed as the sum of three components of the solar radiation as shown in Figure 8.

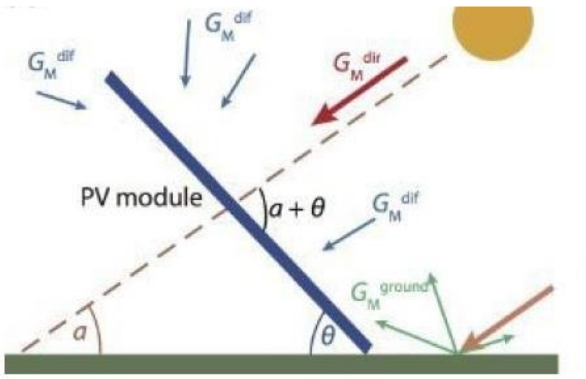


Figure 8: The three contributions to the irradiance on a PV module

$$G_M = G_M^{dir} + G_M^{dif} + G_M^{ground}$$

The solar radiation depend on several parameter such as the latitude, longitude of the place, the airmass of the atmosphere, the cloudiness index, the reflectance of the soil etc. [16][12]
In particular the G_M^{dir} is calculated as the product of Direct Normal Irradiation (DNI), that can be measured be measured in meteorological stations with a pyrheliometer, and the cosine of angle of incidence (γ):

$$G_M^{dir} = DNI\ cos(\gamma)$$

The diffuse component of solar radiation can be calculated in function of different mathematical *sky models* that express the cloudiness index and in function of Global Horizontal Irradiation (GHI) that can be measured by pyranometer [17].

Furthermore, if the PV panel is tilted there is another component of solar radiation that is the amount of radiation reflected from the ground (G_M^{ground}) that depends GHI, the tilt angle (θ) and the reflectance of the ground expressed by the albedo (α):

$$G_M^{ground} = GHI\alpha\left(\frac{1 - cos(\theta)}{2}\right)$$

Snow's albedo, or how much sunlight it reflects back into the atmosphere, is very high, reflecting 80 to 90 percent of the incoming sunlight. By contrast, trees, plants, and soil reflect only 10 to 30 percent of sunlight. Snow cover wields the largest influence during springtime (April to May) in the Northern Hemisphere, when days become longer and the amount of sunshine increases over snow-covered areas [18].
Moreover, since photovoltaic panels produce direct current, they need conversion devices, such as the one represented in Figure 9.

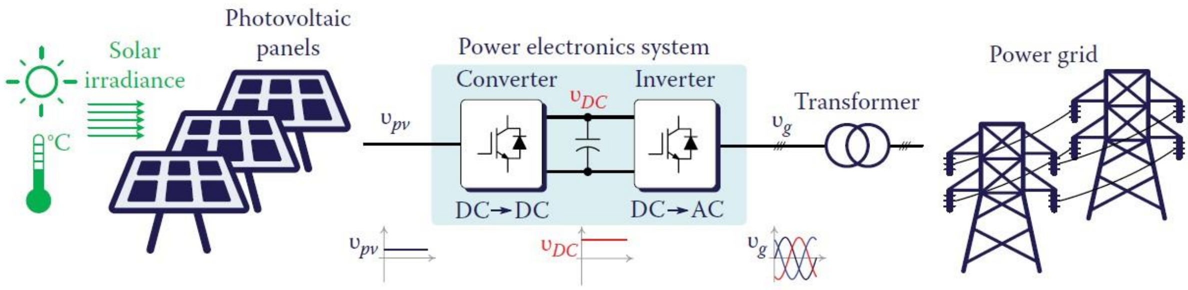


Figure 9: Conversion devices for PV panels

The Skiwelt region, one of Austria's largest, has wide-ranging initiatives to cut CO2 emissions. One of their ski lift "Sonnenlift' (sun lift) ,shown in Figure 10 is powered exclusively by solar energy thanks to a large photovoltaic system, around 12,000 kilowatt-hours are generated per year. Furthermore, it even produces a small surplus, which is fed into the electricity grid. Another similar example is the Serre Chevalier Vallée Briançon ski area in France shown in Figure 10.

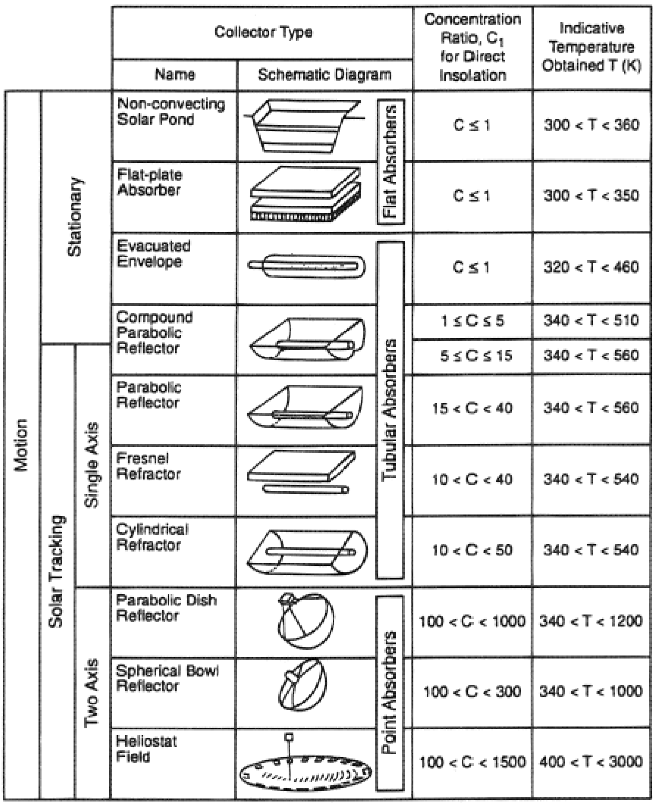
Figure 10: Solar PV installation for ski lift, Skiwelt (left), Chevalier Vallée Briançon (right)

Other applications can be the application of PV to satisfy the electrical demand of chalets or huts as in the Austrian ski resort Ischgl.


Figure 11: Solar PV installation for chalets and huts electrical demand in Austrian ski resort Ischgl [19]

3.4.1.2. Solar Thermal Energy

For solar thermal applications, solar irradiation is absorbed by a solar collector as heat which is then transferred to its heat thermal fluid (HTF). The heat carried by the working fluid can be used to either provide hot water, heating for the spaces, or to charge a thermal energy storage tank from which the heat can be drawn for use later (at night or cloudy day). In a ski resort there are different places that need heat such as the garage for snow groomers, the huts , the chalet or and the places where the control, conversion or management devices are present.
There are different technologies of solar collectors, from flat to concentrated, stationary and solar tracking systems. The different solar thermal collectors have different efficiencies and costs. In Figure 12 it is possible to see the different existing typologies in function of the concentration ratio and the indicative temperature that can obtain[20].



Motion		Collector Type: Name	Absorber	Concentration Ratio, C_1 for Direct Insolation	Indicative Temperature Obtained T (K)
Stationary		Non-convecting Solar Pond	Flat Absorbers	C ≤ 1	300 < T < 360
Stationary		Flat-plate Absorber	Flat Absorbers	C ≤ 1	300 < T < 350
Stationary		Evacuated Envelope	Tubular Absorbers	C ≤ 1	320 < T < 460
Stationary		Compound Parabolic Reflector	Tubular Absorbers	1 ≤ C ≤ 5	340 < T < 510
Solar Tracking	Single Axis	Compound Parabolic Reflector	Tubular Absorbers	5 ≤ C ≤ 15	340 < T < 560
Solar Tracking	Single Axis	Parabolic Reflector	Tubular Absorbers	15 < C < 40	340 < T < 560
Solar Tracking	Single Axis	Fresnel Refractor	Tubular Absorbers	10 < C < 40	340 < T < 540
Solar Tracking	Single Axis	Cylindrical Refractor	Tubular Absorbers	10 < C < 50	340 < T < 540
Solar Tracking	Two Axis	Parabolic Dish Reflector	Point Absorbers	100 < C < 1000	340 < T < 1200
Solar Tracking	Two Axis	Spherical Bowl Reflector	Point Absorbers	100 < C < 300	340 < T < 1000
Solar Tracking	Two Axis	Heliostat Field	Point Absorbers	100 < C < 1500	400 < T < 3000

Figure 12: Solar thermal collectors typologies [20]

The concentration ratio (C) is defined as :

$$C = \frac{A_a}{A_A}$$

where A_a is the solar radiation collection surface and A_A is the absorbing surface. The sun's rays are concentrated through the use of mirrors with different geometries and reflectance. Concentration systems have fewer thermal losses but higher optical losses than flat collectors. The latter are proportional to the concentration ratio. It is possible to notice in the diagram how flat collectors and evacuated pipes have a C value equal to 1 and how C is directly proportional to the temperature that can be obtained. In function of the output temperature of the solar field there are different technological applications. With High Temperature is possible to produce steam and then electricity with turbines, Stirling engines or through ORC (Organic Rankine Cycle) cogeneration systems. Alternatively, it is possible to associate the steam generation produced by a solar thermal system to an ice slurry generator with vacuum freezing method, which will be explained later [21]. This system uses a thermally driven steam jet ejector to feed the water vapor from the evaporator to the condenser and the steam can be generated by a solar thermal plant.

3.4.2. Wind Energy

The Alpine scenario is characterized by large mountain range where air can flow around, over or through gaps and passes. There may be several wind-related situations, these depend to a first approximation on the difference of air masses upstream and downstream of the barrier, as well as on the combination of location, static stability of the incoming air N expressed as:

$$N = \frac{g}{\theta} d\theta dz$$

Where g is the gravitational constant, θ the potential temperature and dz the height of the air mass [22]. While, the non-dimensional mountain height H_m can be expressed in function of the strength of the wind component perpendicular to the mountain U and the maximum mountain height H [23] as follow:

$$H_m = \frac{NH}{U}$$

Furthermore, flow regimes naturally depend also on the shape of the mountain. The mountain shape can be expressed through the ratio of spanwise to streamwise extension β . The combination of the shape of the mountain and the non-dimensional mountain height H_m has an influence on flow regimes. Wide mountains (β >1) form lee vortices easily and they don't necessarily need to be too high to produce windward stagnation. On the other hand, streamlined mountains (β <1) require very high mountains to produce upstream blocking. Areas above the region of upstream blocking are rather suitable for wind energy usage [22]. The air in the mountains gets warmer in the hours by day, much more than at the bottom of the valley, while at night the process is reversed. The result is during the day a breeze that rises from the bottom of the valley towards the mountain and at night a breeze in reverse.

In is possible to see an installation of wind turbines in an Austrian ski resort at Lachtal [24].

Figure 13: Wind turbine installation in Lachtal (Austria)

The maximum power extractable from wind, P_{max} [W], is given by:

$$P_{max} = \frac{1}{2} C_B \rho v^3 A$$

where v is the wind speed upstream of the turbine, A is the cross-sectional area of the turbine's propeller, and ρ is the density of air. However, the Betz factor (CB = 0.593) shows that even with a perfect wind turbine, only a fraction of the wind's power can be extracted [25]. A turbine's power depends to the first power (linearly), on density of air, to the second power on the length of the propeller r (since area $A = \pi r^2$), and to the third power on wind speed (v^3). Modern turbines fall about 10–15 % short of the Betz-factor and extract only about 45–50% instead of 59%. Their yield is further limited by a so-called cut-in speed of a low-speed (m/s) but more severely by regulating the propellers so that not more than the rated power is produced (typically from 12 m/s on to the cut-out speed of approximately 25 m/s). Air Density decreases nearly linearly with height. Alpine wind energy sites could be at an altitude of about approx. 1500 and 3500 m a.s.l . This leads to an approximately 15–30% decrease of available wind power for similar wind speeds compared to locations at sea level (graph not shown). Since wind power is proportional to the cube of wind speed, higher speeds at higher altitudes may offset the nearly linear decrease caused by the decrease of air density. The offset is so large as to cause a nearly linear increase of overall extractable power above 1.5 km (a.s.l.). The wind energy conversion has some simple foundations: the kinetic energy of the wind is converted into mechanical shaft movement with a turbine, then it is converted into electrical energy with a coupled electrical generator. Therefore, the wind propels the blades of a turbine, rotating a shaft connected to the generator rotor that produces electricity.

The simplest model of a wind turbine is the so-called actuator disc model where the turbine is replaced by a circular disc through of an area of A_t , which the airstream flows with a velocity U_t and across which there is a pressure drop from P_1 to P_2 as shown in Figure 14:

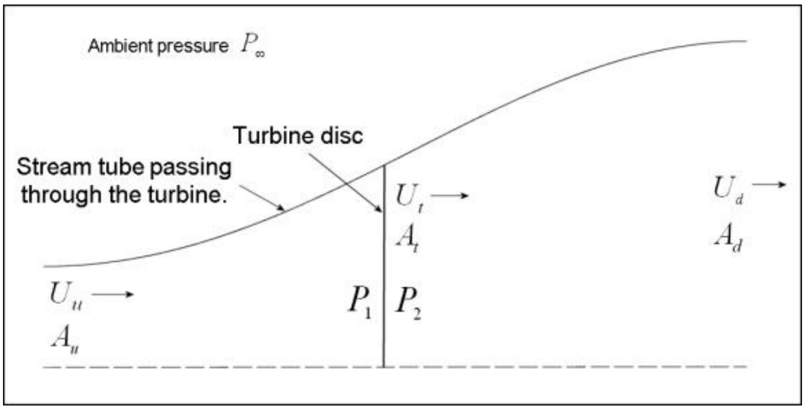


Figure 14: Model simplified of a wind turbine [26]

The power developed by the wind turbine (Pw) can be expressed by:

$$P_w = (P_1 - P_2) A_t U_t$$

While the volume flow continuity gives:

$$A_u U_u = A_t U_t = A_d U_d$$

From momentum conservation, the force exerted on the turbine is equal to the momentum change between the flow far upstream of the disc to the flow far downstream of the disc as follow:

$$(P_1 - P_2)A_t = \rho\, A_u U_u (U_u - U_d)$$

Finally, the Bernoulli's equations applied upstream and downstream of the actuator disc are the follow:

$$P_\infty + \frac{1}{2}\rho U_u^2 = P_1 + \frac{1}{2}\rho U_t^2$$
$$P_\infty + \frac{1}{2}\rho U_d^2 = P_2 + \frac{1}{2}\rho U_t^2$$

Combining all these equations results in (living force theorem) [26]:

$$U_t = \frac{1}{2}(U_u - U_d)$$
$$\eta = \frac{1}{2}\left(1 - \frac{U_d}{U_u}\right)\left(1 + \frac{U_d}{U_u}\right)^2$$

Figure 15 shows the variation of efficiency (often referred to Betz factor, C_B) with the ratio of downstream to upstream velocity. The maximum efficiency occurs when $\frac{U_d}{U_u} = 1/3$ (i.e. when Ad/Au=3). The efficiency is then η=16/27 ≈ 59%. This is the maximum achievable efficiency of a wind turbine and is known as the Betz limit - after Albert Betz who published this result in 1920 [25].

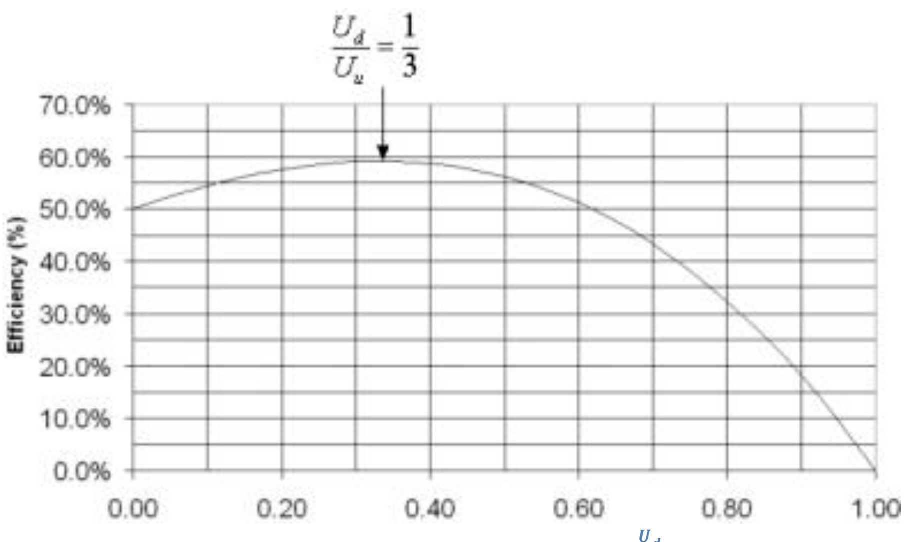


Figure 15: Effiency trend in function of $\frac{U_d}{U_u}$

The components that drive a wind turbine are represented in Figure 16 [27].

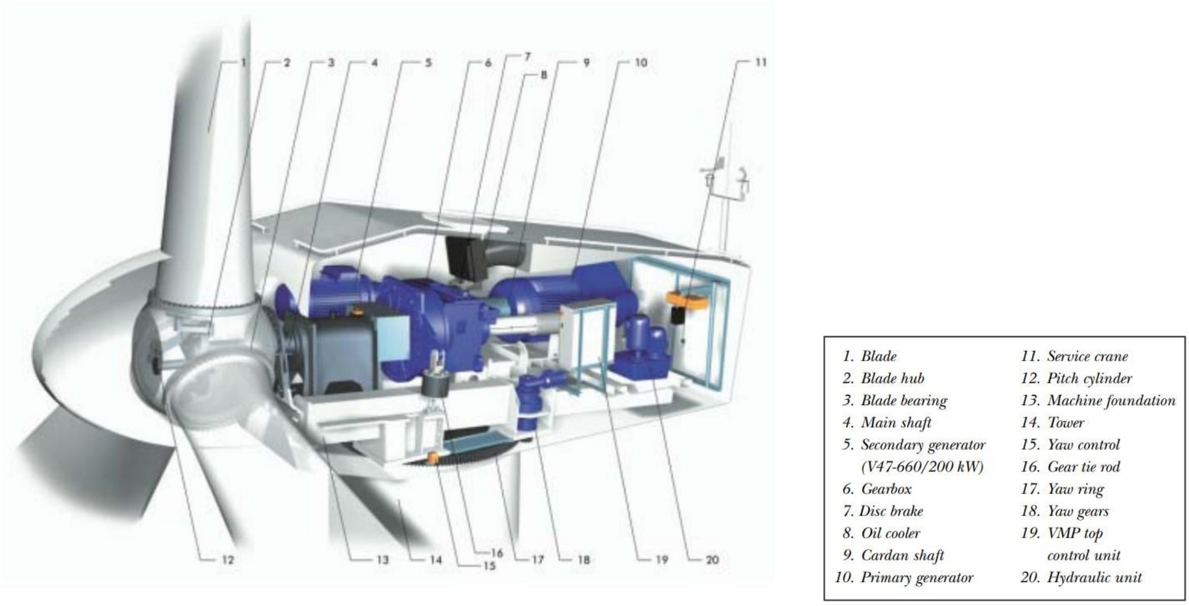


Figure 16: Components of a wind turbine [27]

3.4.3. Hydroelectric Energy

Hydroelectric power is a renewable energy source in witch electrical power is derived from the energy of water moving from higher to lower elevation. Hydropower has the best conversion efficiencies among all known energy sources (about 90 % efficiency, water to wire). Hydropower is 'fuelled' by water moving in the hydrological water cycle that is powered by solar energy. Solar radiation reaching the surface of the earth is converted into heat which in turn evaporates water. Nearly 50 % of all solar energy input to the earth is used for evaporation and converted into latent energy in water vapour. Some of the water vapour (22 %) is brought over land areas where it later condenses into clouds and rain [28]. Precipitation on land surfaces generates run-off as some of the water flows back towards the sea, under the influence of gravity. The run-off regime (amount and variability of flow) depends on the local climate: precipitation, air temperature and potential evaporation, but also on the properties of soil, topography, vegetation and land use. The theoretical output of electrical power (P) generally depends on water flow (Q), head (H) and efficiency (η) as follow:

$$P = \rho\, g\, \eta\, Q\, H$$

In witch ρ is the water density and g, is the acceleration of gravity. Hydropower plants have two basic configurations: dams with reservoirs and run-of-river plants (with no reservoirs). The dam scheme can be sub-divided into small dams with night-and-day regulation, large dams with seasonal storage and pumped storage reversible plants (for pumping and generation) for energy storage and night-and-day regulation. Small-scale hydropower is normally designed to run in-river. This is an environmentally friendlier option because it does not significantly interfere with the river's natural flow. Small-scale hydro is often used for distributed generation applications (similar to diesel generators or other small-scale power plants) to provide electricity to rural populations.

In general, hydro power plant can be classified in terms of installed power capacity as expressed in Table 3.

Table 3: Classification of Hydro power plant in function of the configuration

Large/Very Large	>100 MW/0.5 GW	Accumulation type		Reservoir with dam or surging weir
Medium	25-100 MW	Pumped Storage		Two reservoirs
		Weir Type		River regulation weir
Small	1-25 MW	Weir Type		Water level regulation weir or newly built surging weir
Mini	100KW-1MW	Pumped Type		Two reservoirs or lake and water tank with sufficient head
		Run-of-River (ROR)	No pressured derivation	Using diversion canal, side canal, adjusted river arm or river bed.
Micro	5-100 KW		Positive pressure derivation	Penstock
Pico	<5 KW		Negative pressure derivation	Siphon tube
			Combined derivation	Diversion canal and penstock/siphon

The configurations of the large and medium hydro power plants are shown in Figure 17 [29].

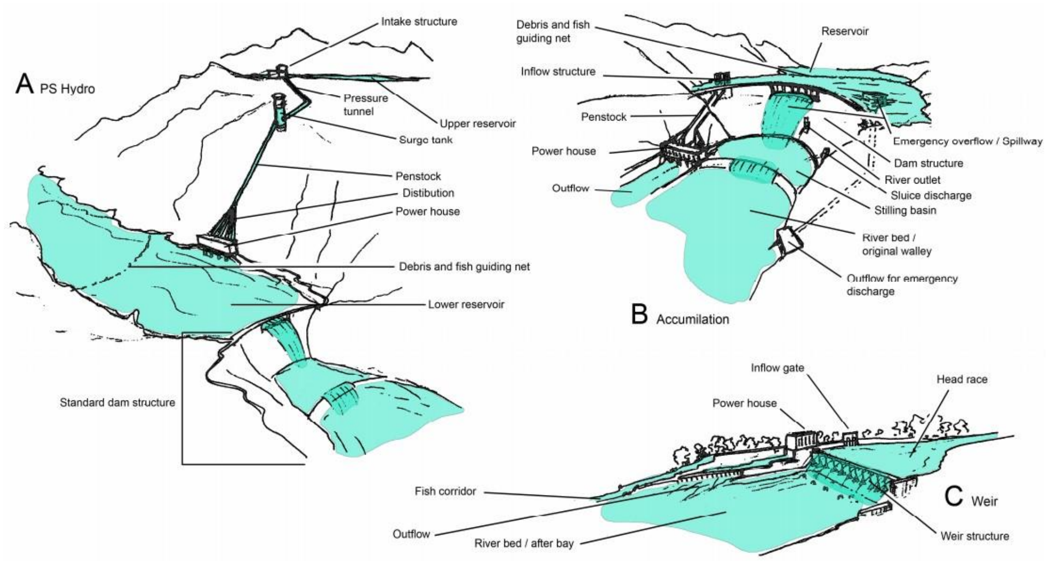


Figure 17: Large/medium hydro power plant configuration: A) Pumped Storage, B) Accumulation, C) Weir [29]

The configurations of the small, mini, micro and pico hydro power plants are shown in Figure 18 [29].

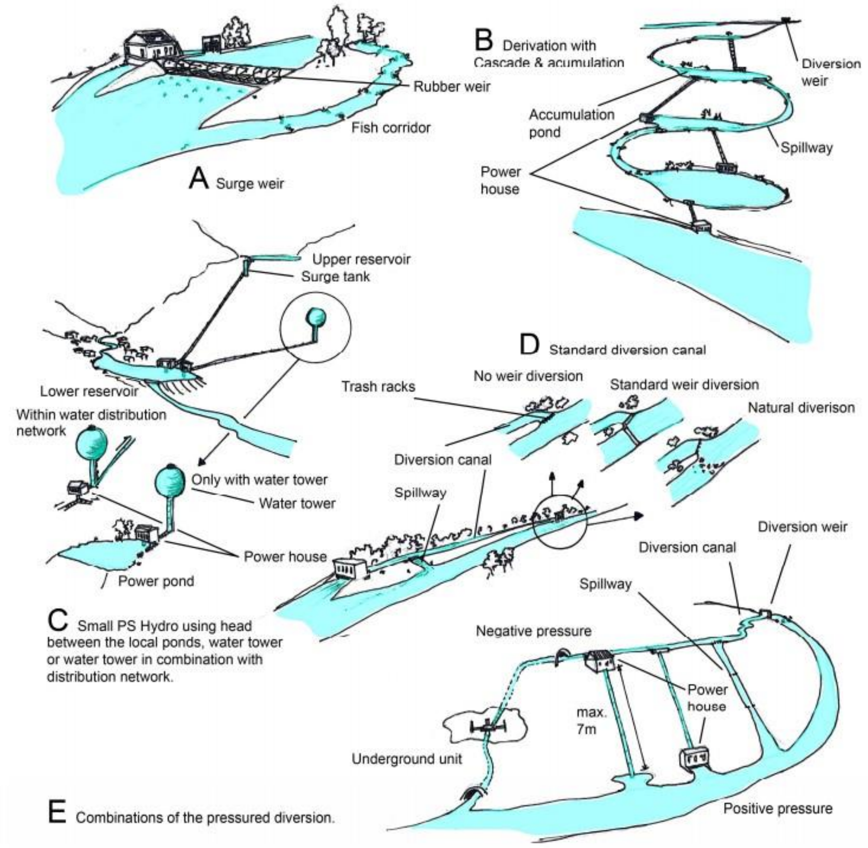


Figure 18: Small, mini, micro pico-hydro power plant configuration: A) standard weir type in rubber , B) Derivation , C) Small Pumped storage, D) Standard diversion channel, E) Combined derivation [29]

Hydro turbines are considered as a heart of hydro power plants, it almost all the time represents the highest investment in the entire project. After the electric engine hydro turbine got the highest efficiency, plus the fact that it is the most applied RES system, even slightest possibility to higher this effectiveness could make major differences. The selection of a particular turbine type for a hydropower project is mostly determined by the head and flow conditions at the site. The turbine transforms the energy of water into mechanical energy of rotation and the main function is to drive hydroelectric generators. The variation in pressure heads make use of different turbines such as the reaction or impulse turbine. They are classified into two classes:

- Impulse turbine;
- Reaction turbine.

In an impulse turbine, the driving energy is supplied by the water in kinetic form, where high pressure jets of water are directed into buckets at an angle that ensures that almost all the energy in the water is converted into rotary motion of the turbine wheel. One key to its operation is that it must rotate in the air, an example is the Pelton turbines shown in Figure 19a . On the other hand, in the reaction turbines, the driving energy is provided by the water partly in kinetic and partly in pressure form and must be completely submerged to operate efficiently. An example is the Francis turbine shown in Figure 19b , with a key feature of changing the water direction as it passes through the turbine. The transformation of hydraulic power to rotating mechanical power is based on the reaction forces that are obtained both from the pressure difference and by the change of velocity through the runner. In terms of head and flow, the Pelton turbine is a low-flow, high-head turbine as compared to the Kaplan turbine which is a high-flow, low-head turbine.

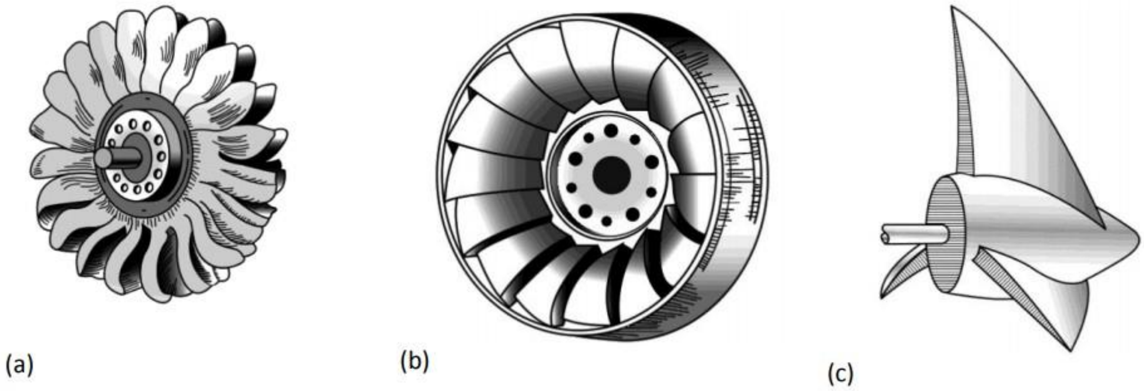


Figure 19: (a) Pelton (b) Francis and (c) Propeller turbines (EPG, u.d.)

It is possible to distinguish the existing turbines in terms of their class and the head, as shown in Table 4 :

Table 4: Classification of main turbine typologies

Turbine types	class	Head range (m)
Propeller turbines with fixed blade turbines	Reaction	10-60
Propeller turbines with adjustable blade (Kaplan)	Reaction	10-60
Diagonal flow turbines	Reaction	50-150
Francis turbine	Reaction	30-600
Pelton turbine	Impulse	<300

3.4.4. Biomass Conversion

Biomass can be classified according to its main physical and chemical characteristics. These are related to:

- moisture content,
- calorific value
- proportions of fixed carbon and volatiles
- ash/residue content, alkali metal content
- cellulose/lignin ratio.

These properties lead to requiring different biomass processing technologies conversions: thermal, biological and mechanical [30].
The thermal conversions are:

- **Pyrolysis**: thermochemical anaerobic decomposition of organic material at temperatures between 250 °C and 500 °C;

- **Gasification**: thermochemical partial oxidation process in which organic substances (e.g. biomass and coal) are converted into gas through a gasifying agent (air, steam, oxygen, CO_2 or a mixture of these). The product is syngas, a high-heating value mixture of H2, CO and other gases.
- **Combustion**: high-temperature exothermic reaction between a fuel and an oxidant whose products are CO_2 and water.

The biological conversions are:

- **Fermentation**: metabolic process that converts sugar to acids, gases or alcohol in the absence of oxygen.
- **Anaerobic digestion**: collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The product is biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases.

Finally, a mechanical conversion of biomass through **extraction of bio-oils** is also possible. Compared to gaseous energy carriers, liquid fuels are easier and safer to handle, store and transport and have greater energy density, making them ideally suited for mobile or remote applications. The main bio-oils that can be produced are: biodiesel, bioethanol, bio-methanol and dimethyl ether (DME). While, the products of gasification and anaerobic digestions are: syngas, biogas, biohydrogen.
Syngas is a mixture of H_2, CO, CO_2, N_2 and small particles of char (solid carbonaceous residue), ashes, tars and oils. Biogas is predominantly constituted of CH_4 (50–70%) and CO_2 (20–40%), but also contains traces (1-5%) of other elements, such as ammonia, nitrogen, mercaptans, indolum, skatolum, halogenated hydrocarbons, siloxanes and hydrogen sulphide.
The biogas has a LHV of about 21 MJ/Nm3 depending on its ultimate composition, which in turn depends on the biochemical composition of organic matter used and on the digestion technology and the operative conditions adopted.
Finally, Biohydrogen can also be produced directly, without resorting to a hydrocarbon intermediate (such as methane), both through thermochemical and biological methods. But, the produced hydrogen gas is usually contaminated by other constituents of the biomass source. Thus, for use in fuel cells (especially low-temperature fuel cells) the hydrogen would have to be separated and purified [31]. The different pathways leading to the final production of bio-hydrogen are shown in Figure 20.

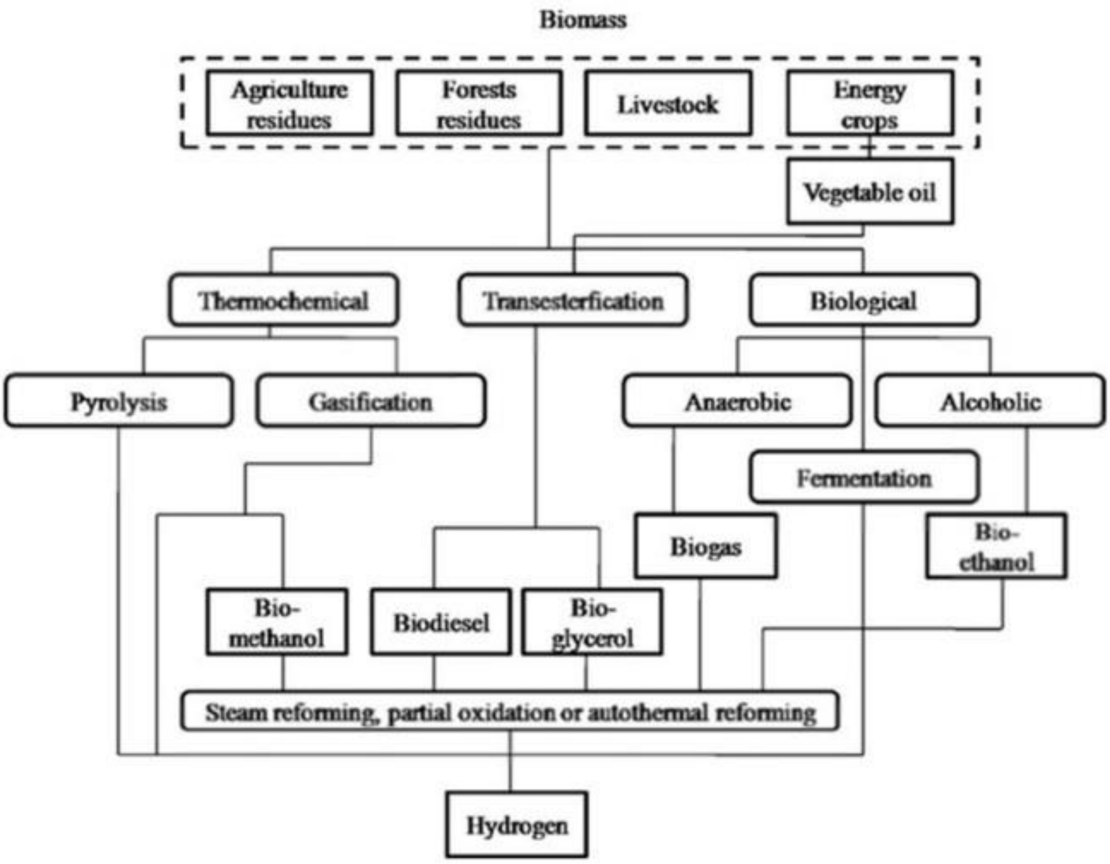


Figure 20: Hydrogen production technologies from various biomasses

3.4.5. Geothermal Energy

A geothermal resource is usually described in terms of stored thermal energy content of the rock and contained fluids underlying land masses. There is two different kind of energy contained in this storage: The first is a thermal flow produced form a volcanological or geological event while the second one is the thermal energy contended in the subsoil.

In centuries the mankind found many uses for this type of energy, just think about the terms invented more than 2000 years ago. Nowadays the main use of this energy is for the first type the production of electricity using binary cycles or steam turbines, while in the second case is exploited the exchange capacity of the ground and the capacity to conserve the temperature during all the year to air condition or warming up the buildings.

Each substance, solid or liquid, has a peculiarity called thermal capacity (S_c), this is the capacity to storage energy and it's defined by the formula:

$$S_{VC} = \rho * S_C$$

Where ρ is the density, S_{VC} is the volumetric thermal capacity and S_C is the thermal capacity. The S_{vc} for the water is particularly high (4.2 MJK^{-1}), more or less double than the anhydrous stone (1.5 MJK^{-1}), for a soil composed mainly by porous rocks the volumetric thermal capacity is 2.2-2.5MJK^{-1}.

The thermal capacity isn't enough to understand how the heat is stored in the ground and it's important to know how it move. The first parameter is the conduction trough the solid matrix and the second one is the convection operated by the underground water. The conduction is the process through which the heart is diffuse in solid, liquid or gas for a molecular interaction without mass movement. The better heat conductor are the stone with a low porosity like granite. The convection transfers the heat through the water movement through the pore or a rift. The geothermal gradient is the temperature increasing during the increase od deep in the underground. Usually is 1-3°C each 100m. Instead, the superficial soil temperature depended mainly by the average annual air temperature indeed, the Earth's surface acts like a solar collector although. The geothermal flow is minor component which influence the temperature coming from mantle and the earth core.
The geo-exchange system is composed by 4 main components: the ground heat exchanger, a heat pump, the heat storage, the distribution ring.

1 The Ground Heat Exchanger (GHE)

The GHE is the main component which allows to exchange the heat among the ground and a fluid carrier. It is usually water or a solution glycol-water. The exchange is possible thanks to a pipe positioned in the ground. There are two different solutions, which differ in price, available space and air temperature influence. The first one is a horizontal exchanger composed by a polyethylene pipe placed in a 2 meter depth trench. To increase the terminal performance for each m^3, it's possible to use the slinky pipe disposition. This technique consists in the excavation of all the zone where the exchanger is going to be built and few overlapped coils are positioned in it. This kind of GHE is the easiest despite the give an interesting heat and the low deep allows to exploit the summer reintegration of the heat storage.
The second solution is the vertical GHE. These is composed by a vertical well with a depth of 50 to 150m. Unlike the horizontal one this type needs less space for the implementation even though only a specialized company can excavate the well. That will increase costs and time needed for the works.

2 The distribution Ring

One component on which it is important to pay attention is the heat/cold diffuser. Indeed, especially during the warmth, it's important to make right choice due to the fact that a heat pump can't reach 60/70°C, temperature needed by the conventional radiators. For this reason, it's a better solution a low temperature device like the underfloor heating, which can do only heating, or a fun coil which can do booth heating and cooling.

3 The heat storage

To increase the performance of a geo-exchange system during the winter, it's possible to storage thermal energy into the ground during the summer. As we said in the previous paragraph, the ground is an excellent thermal insulating and this property can be exploited without building complex structures. This technique is particularly helpful in the cold climates, where during the winter the low temperature can influence the performance of the low deep GHE, making them effective, even in these situations.

4 The heat pump

The most important component in the geo-exchange system is the heat pump. This machine allows to transfer the heat from a colder surgent to a hotter, an impossible action without an external energy. This “Pumping” is made possible thanks to an electrical supply. The difference between the thermal energy produced (Q) and the electric energy (W) outcomes the COP (coefficient of performance) $COP = \frac{Q}{W}$. The heat pump works with difference of pressure between condenser and evaporator coil. To make it possible the system needs 2 components which can modify the pressure when the fluid passes form the cold side to the hot side; the pressure is increased with a compressor. In the same way, when the fluid goes back, the pressure must be reduced with an expansion valve. [32]

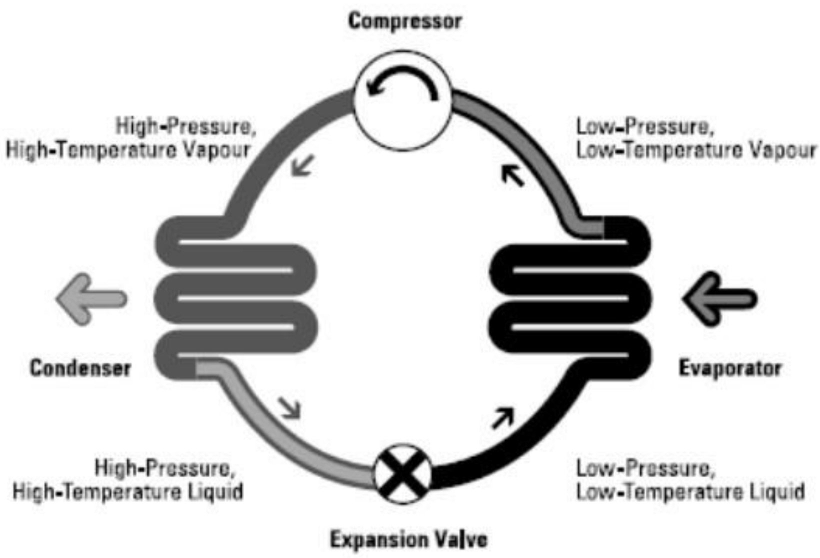


Figure 21: Diagram of a phase change heat pump: (1) condenser coil, (2) expansion valve, (3) evaporator coil and (4) compressor [33]

The inside coil type is explained in the previous paragraph whereas there are two different types of outside sources: ground (GSHP) and air (ASHP). The ASHP uses as heat surgent the atmospheric air; for this reason, the systems are easier and the implementation doesn’t request heavy work in the houses and that permits to limit the costumer’s expense. Unfortunately, the efficiency of this technology is limited by a climatic factor. Indeed, the COP is directionally correlated with the cold source temperature. In the ski resort the outside temperature must be analysed with particular attention because the period when this device will mainly be used is the coldest one of the years and the temperature usually drops below 0°C [33].

Table 5 The COP variation of two HP at different times of the year

	COP (ASHP)	COP (GSHP)
23 Aug-14 sett	4.5	4.91
1 oct-21 may	3.05	3.10
24 dec-12 jan	2.84	-
1 de-19 dec	-	3.09

The Ryerson University of Toronto took an interesting study about the COP variation between the ASHP and the GSHP in a place, the Woodbridge, Ontario, where the temperature is comparable to the alpine zone where the ski resort are built [34]. This study results show the evolution of the performance during a year. The outcome of this reserch show that the return is similar during summer for both the HP types . The main difference is during the heating phase when the temperature could drop down -19°C, especially when the device is installed more than 2000 m asl. The study shows that at this temperature the COP is lower than 1.79. For this reason, it's important to evaluate not only the medium temperature but also the lowest one. From the previous study we saw the difference in the performance for the two heat pumps. The CanmetENERG in Canada, analyzed the installation cost for 4 different heat pumps with the same power, 7,7 kW: 1 ASHP and 3 GSHP with different depth well, on 60,90,120 m. Moreover, in this study has been calculated, with a modelling software, the cost (implementation and electrical energy) after 10 years.

This analysis shows how the difference in the implementation cost was halved, using the cheap electric energy (6,10cent €/kWh) they use in Canada. We have to take into consideration two elements: the difference between the electric energy cost in Italy and the fact that the COP can arrive at 1.8 in the coldest day [35]. To sum up, the GHSP is the best one.

Table 6 The results of the tests of an ASHP and 3 GSHP with wells at different depths

Heat Pump Power=7,7 kW	ASHP	60 m	90 m	120 m
COP	2.17	2.45	2.72	2.93
Implementation cost's	$ 2.771,00	$ 5.118,00	$ 6.918,00	$ 8.718,00
Cost after 10 years	$ 9.904,00	$ 11.569,00	$ 12.431,00	$ 13.567,00
annual use of electric energy (kWh)	19.869,00	16.136,00	13.266,00	11.369,00
CO2 x electricity (Kg CO_2eq)	6.034,2	4.900,5	4.028,9	3.452,8

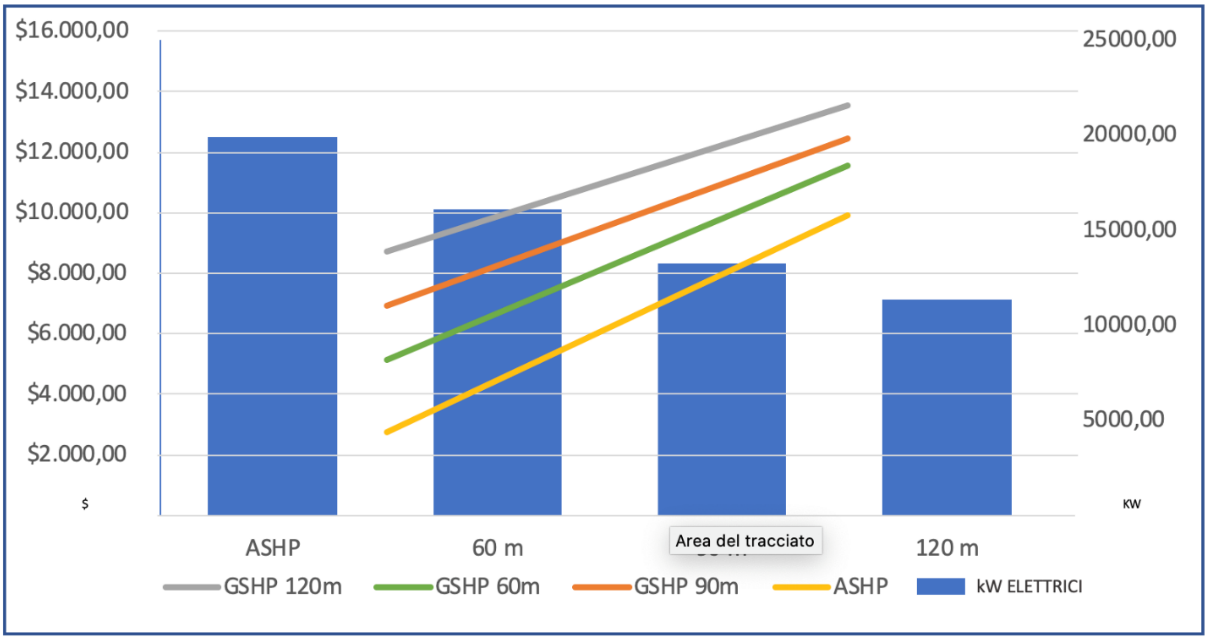


Figure 22: The four lines show the increasing in cost between installation and 10 years of use; the columns, instead, the annual electricity consumption.

3.5. All-weather snow machines

Natural and artificial snow depend both on the meteorological conditions, making the skiing industry climate sensitive. Regardless the type of snow maker considered, there are a couple of factors that are crucial for the viability of snowmaking such as the wet-bulb temperature, which takes into consideration both the ambient temperature (dry-bulb temperature), the relative humidity (RH) and the supply water temperature. The importance of the humidity conditions of the ambient air is one of the key factors of the process, since the small water droplets that are expelled from the snow gun evaporate and cool down to the wet-bulb temperature of the air [1]. The less humidity, the lower the wet-bulb temperature and, thus, the greater the evaporative cooling process, consequently improving the snowmaking conditions for the same ambient temperature. Therefore, the wet-bulb temperature is the main parameter used to study and determine snowmaking conditions as well as the quality of the snow for different weather conditions. Such is the importance of the RH, that with extremely dry conditions (RH ≤ 30 %), snowmaking is possible with temperatures of up to 3 °C [1], which means that the wet-bulb temperature (Tw) is equal or lower than -2 °C.
A recently new technology allows the production of snow regardless the weather conditions such as temperature of the ambient air or relative humidity. This can be an alternative solution to snow scarcity in ski resorts due to global warming.
The temperature independent snowmaking (TIS) systems technically do not produce snow in its normal form, but small ice particles that together act like snow. The only difference is the way they are treated once formed. There are three main types of TIS, considering the way in which the ice particles can be generated [36] [37]:

- flake ice systems;

- plate ice systems;
- ice slurry systems.

3.5.1. Flake Ice systems

The thickness of the ice particles produced by flake ice system is about 2 mm so that they are called ice flakes. The main components of a flake ice system are shown in Figure 23.

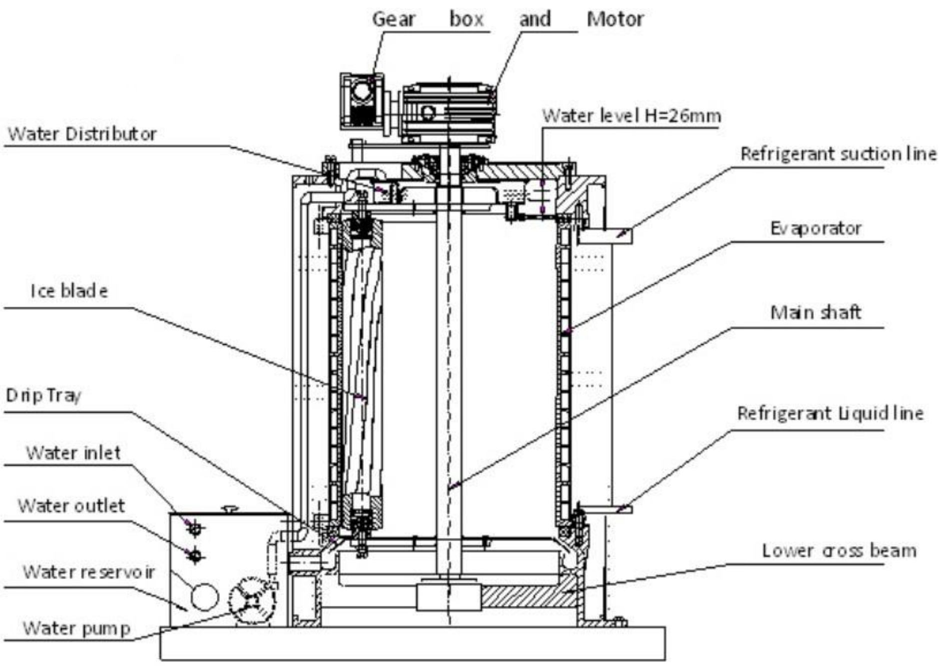


Figure 23: Flake ice components [38]

The process starts with the sprinkling of cold water flowing into the water distributive pan from the water inlet of the evaporator , and then being sprinkled evenly over the ice freezing surface through the water sprinkler, creating a water film. The water film will exchange heat through that surface with the refrigerant in the refrigerant runner, with the consequent temperature decrease that will end up in the formation of a thin layer of ice on the ice freezing surface. After that, an ice blade that is driven together with the water distribution pan, the principal axis, and the low water pan , by the decelerator will follow the ice freezing surface, removing and breaking at the same time the thin ice layer. The resulting ice flakes will then fall into the ice storage bin coming from the ice outlet . Since not all the water has been frozen, the remaining water returns to the cold-water tank through the water receiving plate from the water return pipe . The system includes a refrigeration cycle, that provides the cooling capacity needed by the ice flake generator, an ice distribution system and an ice breaking device, in order to obtain the desired particle size. Once done, the snow is distributed by either a fan that propels it through pipes, or by a conveyor belt. A schematic of the model SF200 [39] is shown in Figure 4, where the conveyor belt configuration can be seen. After, snow would be transported and distributed through the slopes.

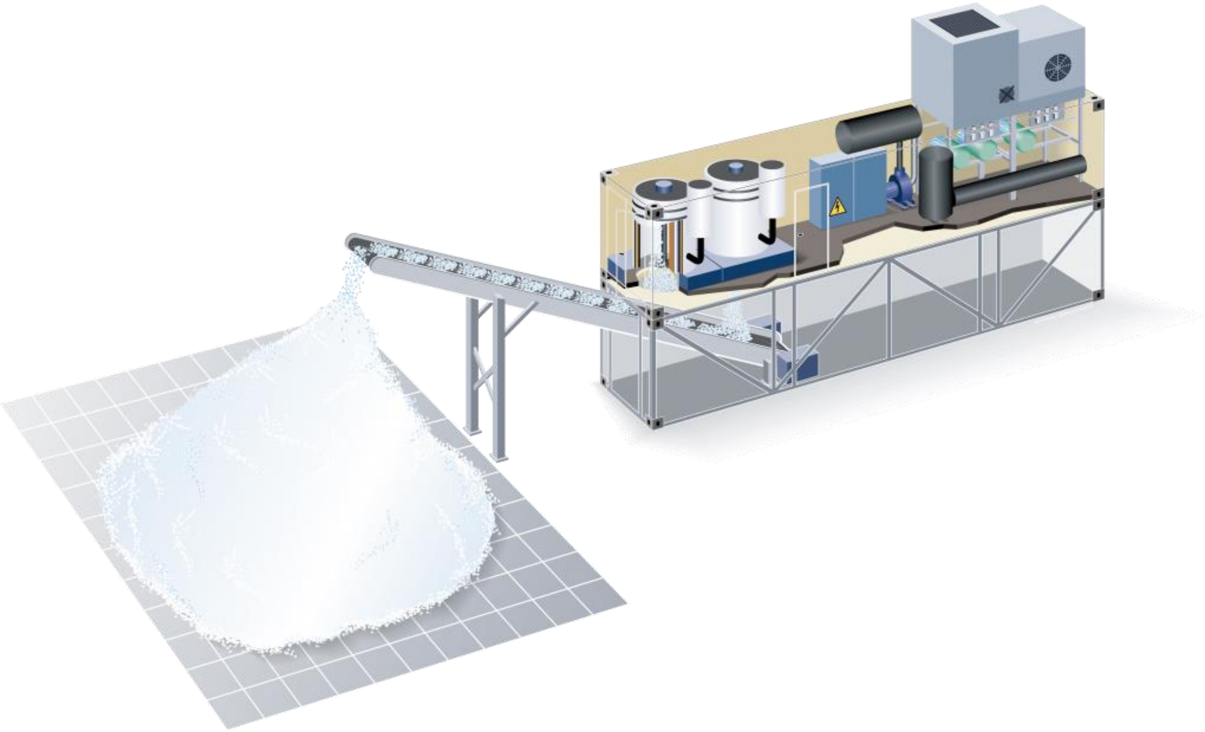


Figure 24: Schematic of the model SF200 (Technoalpin)

The previous process description corresponds to a system with rotating blade that scraps the ice from the inner surface of a stationary drum. Other configurations are also possible, as for example a drum-shaped cylinder that rotates and a stationary scraper on the outer surface.

3.5.2. Plate Ice systems

The technology of the plate ice system is similar to the flake ice machines. Water is also sprinkled over an ice freezing surface, but in this case, it is a vertical or inclined refrigerated plate. The layer formed results thicker than for the previous case. After the layer of ice is formed, water is sprayed on the other side to defrost the plate, producing a loss of adhesive force that results in the ice plate dropping into the ice crushing gadget. Another alternative is to create ice layer on both sides of the plate, and run defrost water in the inside of the device as shown in Figure 25

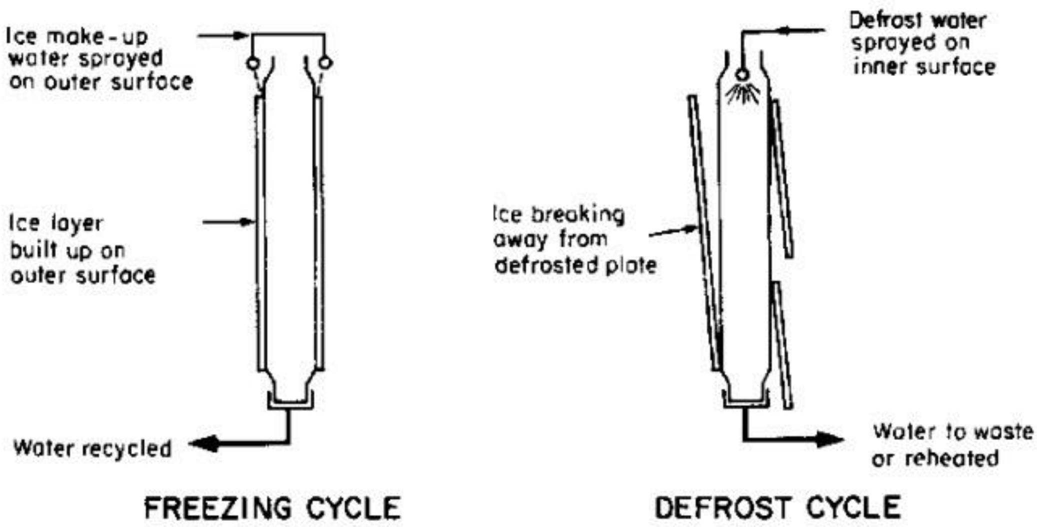


Figure 25: Schematic diagram of a plate ice machine

The thickness of ice particles is about 17 mm. The system operates in cycles, during the freezing cycle the cold water is sprayed on the outer surfaces and the ice layer is formed, after that a defrost cycle comes, with the warming up of the plates with defrost water
SnowMagic Inc. from USA was the first manufacturer to offer a TIS in 1993. SnowMagic applies a plate ice machine as the source of snow. After the ice is released from the plates, it is sent to an ice crusher to create smaller particles. SnowMagic use a patented technology to make even finer particles of ice after the ice crusher.

3.5.3. Ice Slurry systems

Ice slurry is a mixture of ice particles and a liquid, containing up to 40% ice [40]. The size of the ice particles can be between 0.1 and 1 mm in diameter [41]. The liquid can be pure water, or a brine of water and freezing point depressant. Due to the latent heat of fusion of the ice crystals, ice slurry has a high energy storage density and the temperature remains constant during the cooling process. This provides a higher heat transfer coefficient compared to water and other single-phase liquids. In addition, it has a fast cooling rate due to the large heat transfer surface area created by its numerous particles [41]. Ice slurry has many areas of application, such as comfort cooling, commercial refrigeration, industrial production processes, medicine and artificial snow production [42]. Ice slurry can be an excellent snow substitute, and it can provide a better skiing surface than flake ice.
A typical system consists of a vacuum freeze evaporator, compressor, condenser and a vacuum pump [43] as shown in Figure 26.

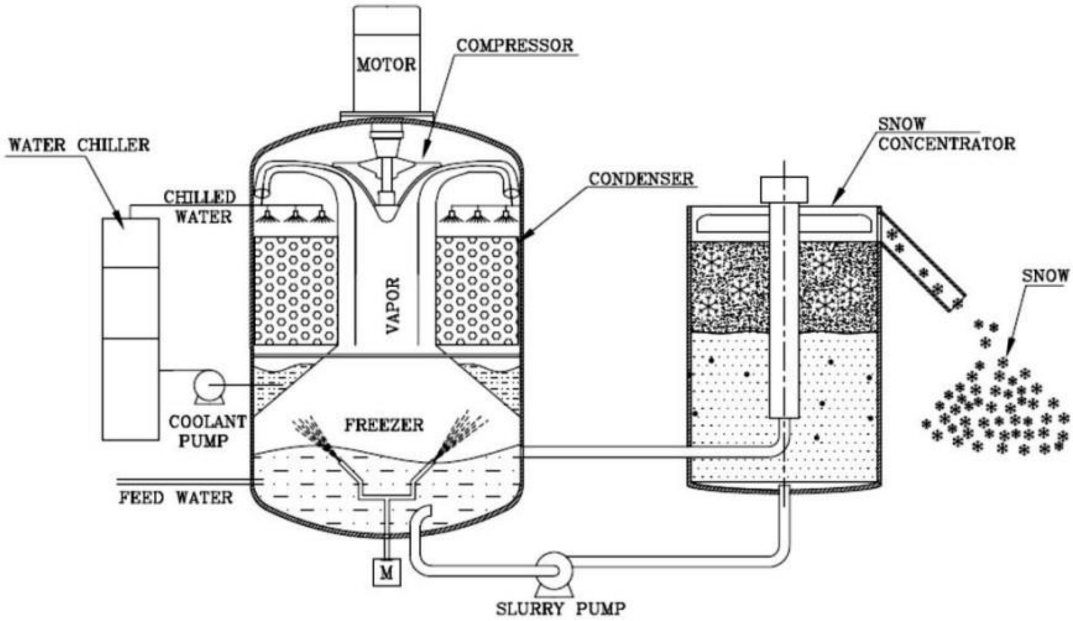


Figure 26: Schematic of a vacuum ice maker.

Air is introduced with the water entering the system, and the vacuum pump is used to deaerate the system in case of leakage into the system [44]. The presence of air in the system reduce the heat transfer of the condenser and the capacity of the compressor. The operating principal for the vacuum ice maker is to bring water to triple-point conditions, where the pressure of water is 0.006 atm and the temperature is 0,01^{o}C [44] as shown in Figure 27 [45].

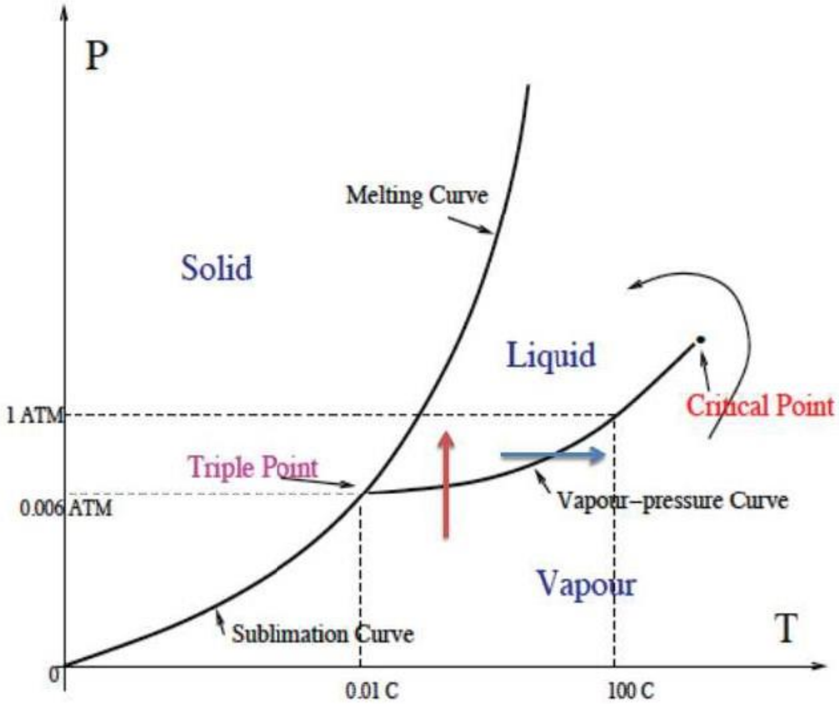


Figure 27: Phase diagram of the water [45]

At triple-point conditions, the water starts to boil and evaporate at the same time. Energy as heat is released and this causes a decreasing of the water. Eventually it will freeze, and create an ice slurry. The latent heat of fusion and vaporization is 333 kJ/kg and 2500 kJ/kg, respectively. This means that the mass of ice produced is 7,5 times the mass of water vapour [44]. A critical aspect is the maintaining of the vacuum. The vapour has to be evacuated, and this is done by the compressor. The compressed vapour is brought to the condenser, where heat may be recovered, before being injected back into the evaporator. Another method to maintain vacuum, is to deposit the water vapour on refrigerated plates inside the vacuum freezer. The vapour will condense and reject heat. Frequent defrosting of the plates is necessary in order to maintain the vapour condensation. Moreover, a circulation pump is installed in the evaporator in order to agitate the slurry. If there is no agitation, the freezer specific capacity and crystal quality will be poor [46]. The ice slurry is then continuously removed from the evaporator and collected in a tank, where ice and water can be separated. The working fluid in these machines are the water itself, and no separate refrigeration system are required.

3.6. Hydrological basins

The hydrological basins used for the accumulation and supply of water for the production of artificial snow in the ski resorts are divided into natural and artificial. The first are of natural origin and in this specific context are of glacial origin, formed thanks to the melting of glaciers, or Fluvial origin produced by running water [47] while the second are artificially created for water supply reasons. The main difference is that in natural lakes there are organic elements due to the presence of plants and soil. In addition, there are infiltration phenomena in the walls that do not occur in artificial lakes. In the figure it is possible to see the main phenomena that characterize the energy and mass exchanges of a hydrological basin.

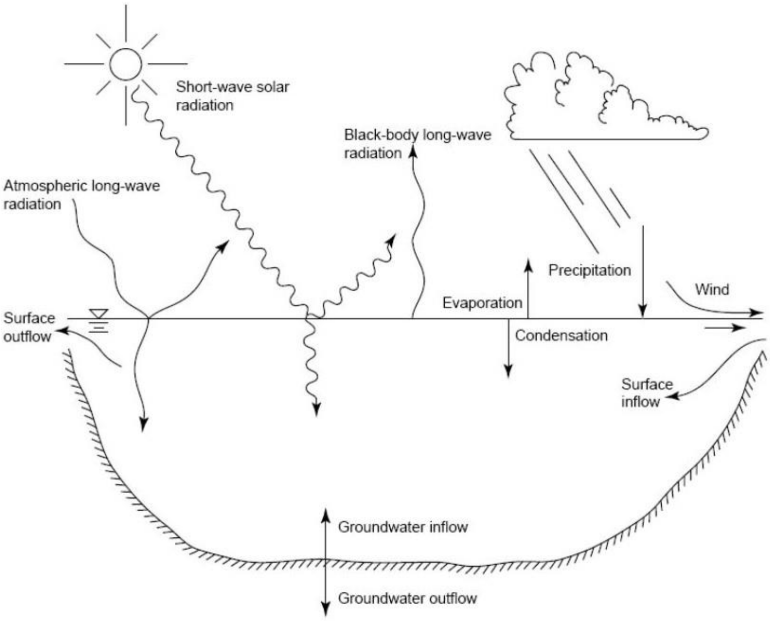


Figure 28: Energy and mass balance

The main actors are the sun and the wind that act on the surface temperature and on the turbulence of the water motion on the surface. The energy balance is linked to kinetic (E_k) , thermal (E_t) and potential (E_p) energy exchanges (internal stratification) as expressed :

$$\frac{dE_{tot}}{dt} = \frac{dE_p}{dt} + \frac{dE_k}{dt} + \frac{dE_t}{dt}$$

In particular the net heat flux depends on different factor such as the short-wave solar radiation, the long wave diffused radiation that depends mainly on clouds and the atmosphere composition, the reflected radiation by the water surface, the latent and sensible heat flux, and the inlet/outlet temperature of the water flow. Among the different parameters of water quality that are affected by temperature, the difference in density (ρ) causes a different thermal stratification depending on the season and reshuffling phenomena localized in summer and global in autumn and spring, as shown in Figure 29.

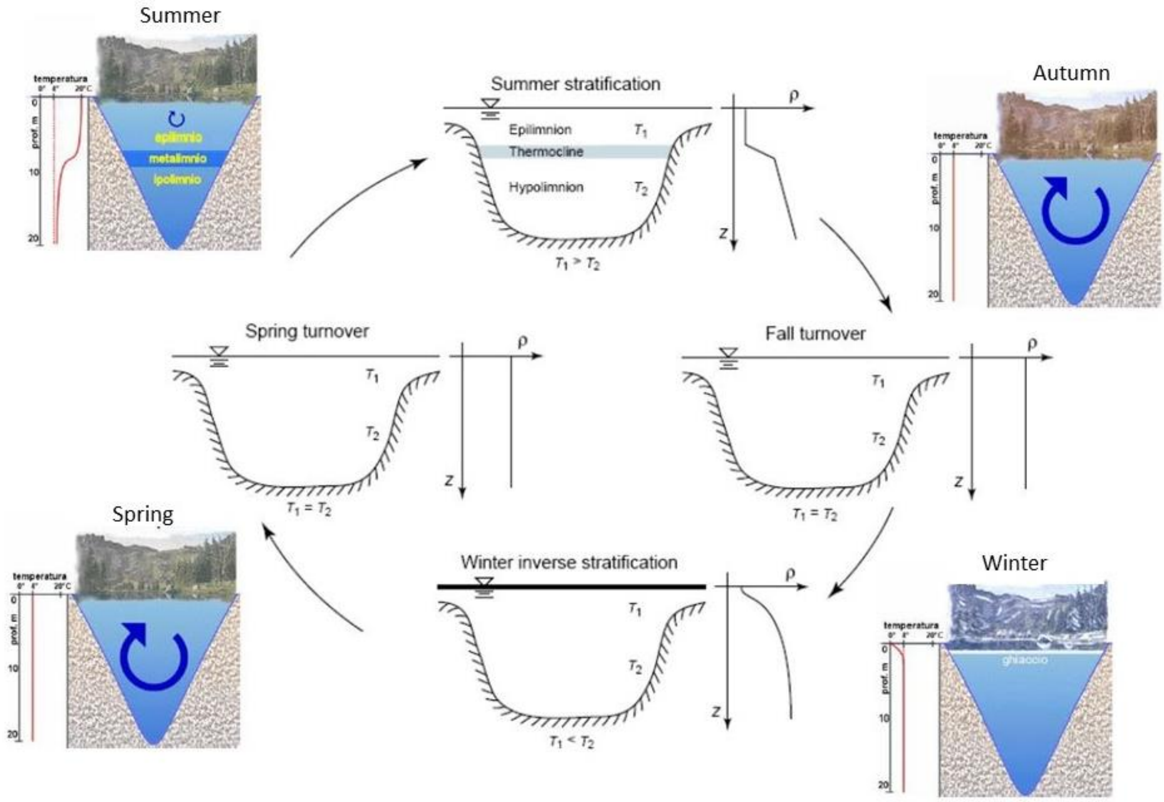


Figure 29: Seasonal cycle of thermal stratification

In particular, in summer, it is possible to identify three zones: the epilimnion which is mainly affected by solar radiation, night cooling and wind action; the metalimnion that is the central part that act as a barrier for vertical fluxes and the hypolimnion that is the deep region that remains isolated. Furthermore, the thermocline that is inside the belongs to metalimnion, represents the strongest density gradient as shown in Figure 30.

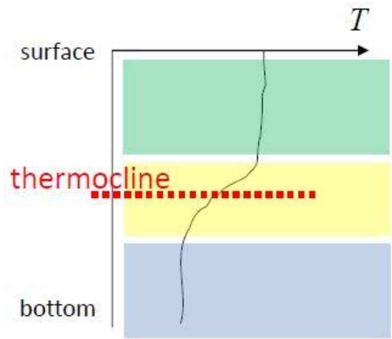


Figure 30: Summer density stratification

It should also be considered that two types of recirculation take place, the barotropic and the baroclinic circulations. The barotropic ones neglect the effect of density variation and they are characterised by depth-averaged flow and external waves such as wind, while the baroclinic ones consider the density variation and are characterised by internal waves.

According to Mosimann [48], the water input from artificial snow usually reaches 0.7 to 5 times that from natural snow. Usual amounts of water applied as artificial snow are 100–600 mm. These values were confirmed by a Swiss study, where the average water input from the melting snowpack was almost double the natural level (about 750 mm vs. 400 mm) [48]. This may change the local hydrology and increase the erosion intensity. As the water used for snowmaking is usually pumped from rivers, lakes or ground water sources, it is enriched in minerals from the catchments, including ions that are essential for plant growth, such as Ca^{2+}, Mg^{2+} , Na^{+}, K^{+}, Cl^{-} , $SO4^{2-}$, NH_4^{+} or NO_3. Baloh et al.[49], aimed to investigate the presence, source and ice nucleating properties of these particles in the water cycle of an alpine ski resort in Obergurgl, Tyrol, Austria. They sampled artificial snow, river water, water pumped from a storage pond and compared it to samples collected from fresh natural snow and aged piste snow from the area of the Alpine Ski Resort in Obergurgl, Austria. The aquatic chemistry among different water samples is significantly different for most parameters as shown in Figure 31 [49].

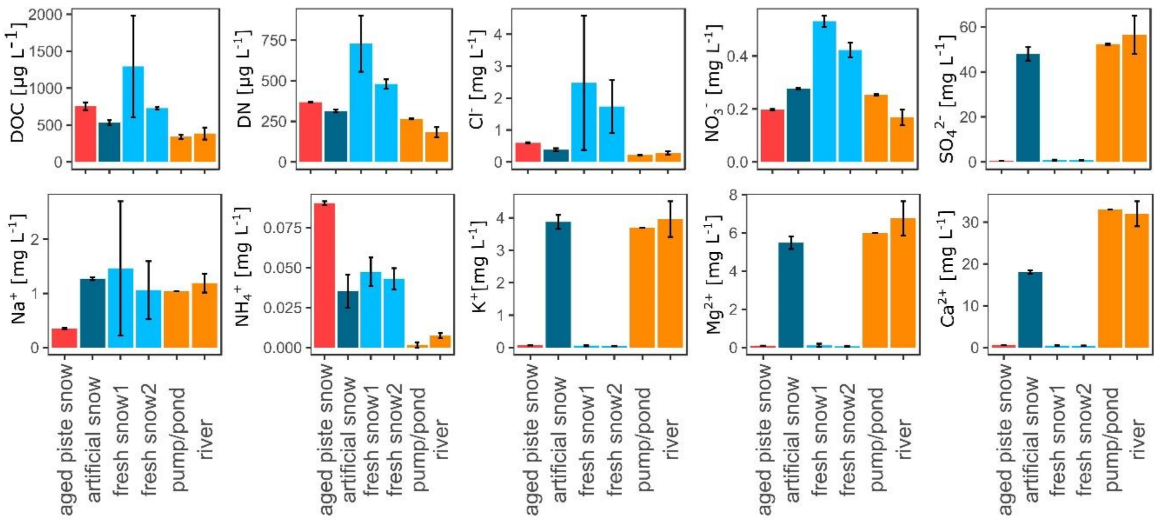


Figure 31: Chemical elements concentrations for different water samples [49]

The natural fresh snow samples were collected in two different locations and for the determination of dissolved organic carbon (DOC) and dissolved nitrogen (DN) samples were acidulated with 200 µL 2N HCl to reach a pH of 1.5–2. The fresh snow samples and the aged snow showed the highest values for DOC, DN, and Cl^{-}, whereas the samples from the river water cycle (river, pumping station, artificial snow) showed lower values. NO^{3-} was also highest in the fresh snow samples, but not in the aged piste snow. SO_4^{2-}, K^{+} , Mg^{2+} , and Ca^{2+} were all low in the fresh and aged snow samples. Na^{+} values were significantly lower for the aged piste snow samples in comparison to all other samples. NH_4^{+} was significantly higher in the aged snow samples, in medium range for artificial and fresh snow and lower for the river and pumping station samples. The vegetation composition changes in response to inputs of water and ions. A study near Savognin, Switzerland, showed that the artificial snow led to changes in mesotrophic habitats, like grasslands with little fertilisation [50]. Plants tolerant of dry, low-nutrient conditions (e.g. Koeleria pyramidata, Silene nutans, Thymus pulegioides) were replaced by more common mesic and nutrient-demanding species (e.g.

Chaerophyllum hirsutum, Myosotis silvatica, Pimpinella major). Changes were less pronounced on fertilised meadows [1]. The vegetation composition changes in response to inputs of water and ions. A study near Savognin, Switzerland, showed that the artificial snow led to changes in mesotrophic habitats, like grasslands with little fertilisation [51]. Plants tolerant of dry, low-nutrient conditions (e.g. Koeleria pyramidata, Silene nutans, Thymus pulegioides) were replaced by more common mesic and nutrient-demanding species (e.g. Chaerophyllum hirsutum, Myosotis silvatica, Pimpinella major). Changes were less pronounced on fertilised meadows. In soils down to a depth of 15 cm, significant higher pH-values on snowed piste compared to control plots were recorded. These values were attributed to the high pH of the river water that was used for snow production [51]. In 13 ski resorts in Switzerland similar changes were suggested by differences in the ecological indicator values. In particular the moisture and nitrogen values were higher on snowed pistes than at control plots besides pistes. A Canadian study analysed the effects of watering with melt water from natural or artificial snow on the germination success of birch and spruce trees but failed to show any significant [52].

3.7. Energy Storage Systems (EES)

The role of renewable energy production in the ski resort is increasing in last years, so it is useful to have an optimal management of energy production, consumption and storage. Different renewable energy systems (RES) have been studied because they are carbon-free and have a longer lifetime than systems that use conventional resources of fossil fuel that cause several problems such as the greenhouse gas (GHG) emissions. But because of the intermittent nature of the renewable energy resources, it is necessary to use energy storage systems (ESS) in order to cover a given continuous energy demand such as the ski lift or snow making system electrical demand. According to the technology used, energy can be stored in a certain state, and then can be converted to electrical energy when needed. There are different types of energy storage systems divided according to the type of stored energy (electrical, chemical and mechanical) as it's possible to see in Table 7 [53]:

Table 7: Energy Storage System types

<table>
<tr><td rowspan="2">Electrical</td><td>Superconducting magnetic (SMES)</td><td rowspan="2"></td></tr>
<tr><td>Super capacitors (SC)</td></tr>
<tr><td rowspan="10">Chemical</td><td rowspan="4">Batteries</td><td>Lead-Acid</td></tr>
<tr><td>Li-ion</td></tr>
<tr><td>NI-Cd</td></tr>
<tr><td>NaS</td></tr>
<tr><td rowspan="2">Hydrogen</td><td>SOFC</td></tr>
<tr><td>PEM</td></tr>
<tr><td rowspan="4">Flow batteries</td><td>ZnBr</td></tr>
<tr><td>VBr</td></tr>
<tr><td>NaBr</td></tr>
<tr><td>Sodium polysulfide</td></tr>
</table>

Mechanical	Fly wheel (FES)	
	Compressed air (CAES)	
	Pumped hydro (PHS)	

The ESS acts as buffer to store surplus energy and supply it back to the system when needed. In order to maintain the voltage of the main BUS of the grid, as constant as possible. Moreover, they have the role to regulate instantaneous power variations, maintaining power quality. Each EES have different key characteristics such as: energy density; power density; cycle life; response time and cost as summarized in Table 8 [54].

Table 8: Main key characteristics of different EES

EES	Energy density	Power Density	Cycle life	Response time	Cost
Chemical Battery	High	Low	Short	Medium	Low
Flow battery	Medium	Low	Short	Slow	Medium
Super Capacitor	Low	High	Long	Fast	Medium
Fuel Cell	High	Low			
Flywheel	Low	High	Long	Fast	High

A preliminary analysis of the energy demand is necessary to choose the best type of storage to use. For example, the electrical demand of a ski lift that is generally powered by a DC motor is quite linear and constant during the operating cycle, so a storage with a medium low response time could be suitable.
The different EES have a different energy and power density as it is possible to see in Figure 32:

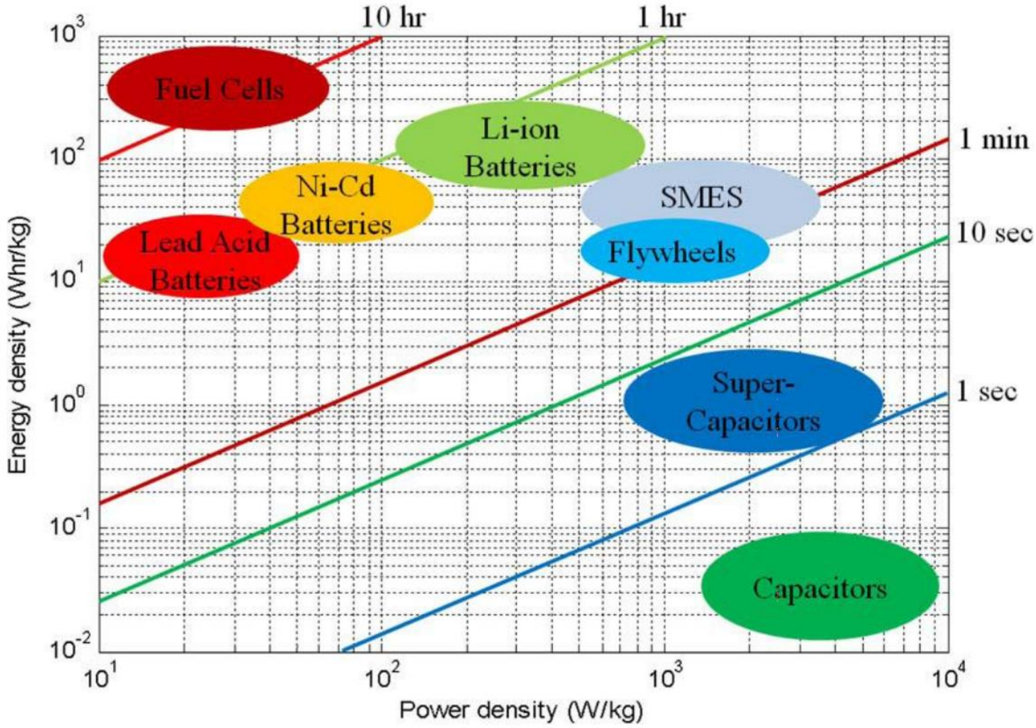


Figure 32: Energy density and power density of different EES [55]

Locally distributed energy storage systems (ESS) may provide the capacity to temporarily decouple production and demand. In this sense, the most implemented ESS in local energy districts are small–medium-scale electrochemical batteries. However, hydrogen systems are viable for storing larger energy quantities thanks to its intrinsic high mass-energy density. To match generation, demand and storage, energy management systems (EMSs) become crucial. If there are different EES in the grid, the EMS systems of an electrical grid is generally based on a specific EES priority. Furthermore, a series of AC-DC and DC-DC converters are also required for proper integration between renewable energy sources (RES), energy storage systems (EES) and the power grid. An example of an hybrid renewable microgrid architecture is shown in Figure 33. It is an application for the University of Huelva (Spain). It integrates a mixed type, AC/DC electrical topology presenting a high-voltage DC bus (400 V DC) and a standard 1ph-230 V/3ph-400V AC bus, like the one usually used in ski resorts [56].

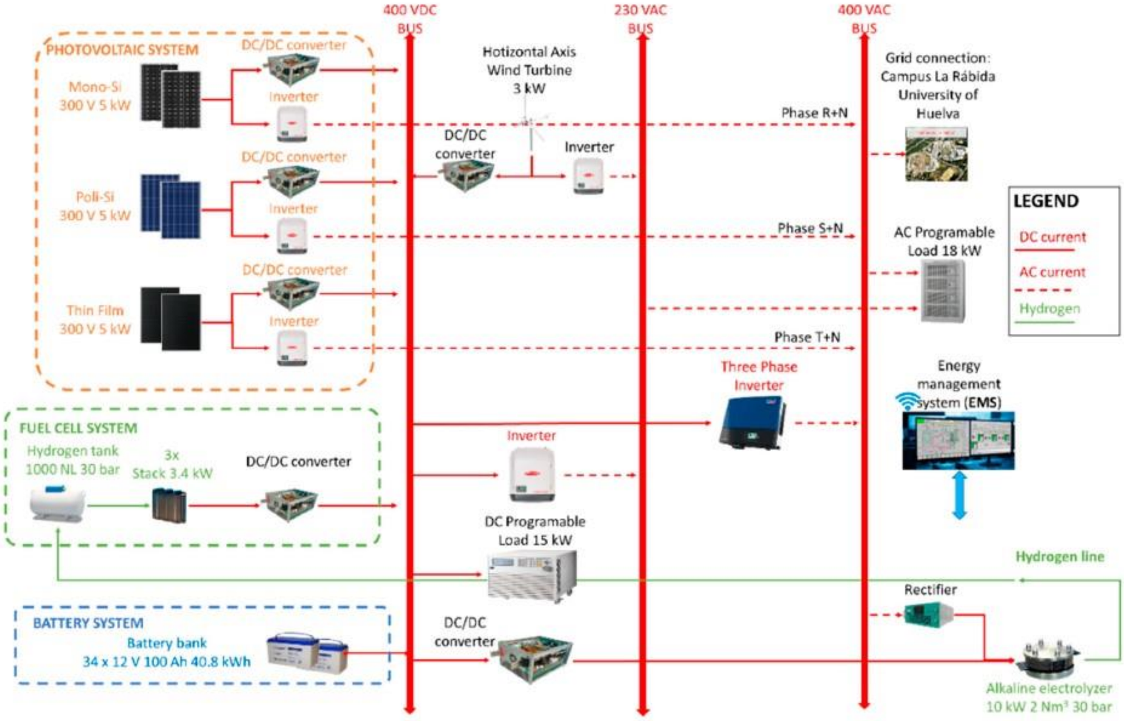


Figure 33: Integration of RES, EES and grid for the University of Huelva

The results of this study [57], show that the hydrogen-priority strategy allows the microgrid to be led towards island operation because it saves a higher amount of energy, while the battery-priority strategy reduces the energy efficiency in the storage round trip. This demonstrates that that conventional EMS for microgrids' operation based on battery-priority strategy should turn into hydrogen-priority to keep the reliability and independence of the microgrid in the long-term operation.

3.7.1. Hydrogen as energy vector

Fuel cells are electrochemical systems capable of transforming the chemical energy of a fuel (usually hydrogen) into electrical energy. These technologies have a significantly higher efficiency than traditional thermal engines. The operation is very similar to that of flow batteries, only unlike these fuel cells use oxygen or more commonly air as an oxidizing agent. A fuel cell consists of two porous electrodes separated by an electrolyte. The different fuel cell technologies differ mainly in the type of electrolyte used and the operating temperature but they are based on the same reactions. At the anode there is the oxidation of hydrogen (H_2) which flows steadily while at the cathode there is the reduction of oxygen (O_2) present in the air [58]. The electrolyte has the function of allowing the H^+ ions that are formed and preventing the passage of electrons e^- that instead pass through an external circuit. Moreover, the transformation of chemical energy into electrical energy is exothermic, so it is necessary to extract heat in order to keep the operating temperature of the cell as constant as possible.
By classifying the fuel cells according to the type of electrolyte, you have:

1 Alkaline fuel cells (AFC);
2 Solid oxide fuel cells (SOFC);
3 Phosphoric acid fuel cell (PAFC);
4 Melted carbonate fuel cell (MCFC);
5 Proton exchange membrane fuel cell (PEM)

Among all these types, PEMs are fuel cells that work with a lower temperature range (20-180 °C) [59][60]. Some of the advantages of using hydrogen as an energy carrier are the possibility of long-term storage and the easy "scale up" of the system, since the use of an hydrogen storage can be carried out where necessary without any particular restrictions on the location of the system. The main components of a hydrogen-based energy storage system are the following:

- Input converter

A conversion system capable of converting incoming electrical energy into hydrogen at the output. It can be based on different technologies such as Proton Exchange Membrane (PEM), Anion Exchange Membrane (AEM), Solid Oxide Electrolyser (SOE);

- Hydrogen Storage

A hydrogen storage system. Particular interest has been directed towards the storage of hydrogen in gaseous form in containers under pressure up to 70MPa or in liquid form at temperatures of 20-22 K (-253 °C) or in solid form with e.g. reversible metal hydride;

- Output converter

The output converter is a system to convert hydrogen into electrical energy output. It consists of a fuel cell based on different technologies listed before.
It is also possible to use reversible fuel cells that integrate the functionalities of an electrolyzer and a fuel cell, in order to realize a more compact and economic system even if generally two separate devices are proposed on the market.

3.8. Optimising transport facilities

Road transport today is responsible for a significant and growing share of global anthropogenic emissions of CO2. Moreover, it is almost entirely dependent on oil-derived fuels and therefore highly vulnerable to possible oil price shocks and supply disruptions.
At the European level, transport accounts for about 30% of GHG production, with constant growth in recent years: 23% compared to 1990 levels [61]. Using oil-derived fuels in internal combustion engines generates tailpipe emissions of pollutants such as PM_{10}, NO_x and VOC_s which are harmful to human health. Improving road transport requires all these issues to be addressed. Managing demand and promoting co-modality can provide a partial solution, however introducing alternative transport fuels and vehicles will also be necessary in order to achieve the objectives of decarbonisation, energy security and urban air quality
In France, according to the trade association Domaines Skiables , the 57% of a ski resort's greenhouse gas emissions are related to the skiers' mode of transportation from their home to the resorts. Green transportation and electric mobility are thus being taken seriously. In addition, these solutions could help ski resorts obtain *Flocon Vert* certification. Similar to the "Blue Flag" label for coastal areas*, Flocon Vert* certifies that mountain destinations comply with rigorous sustainable development standards [61]. The skibus of the ski resort

of Megève, France, has been replaced by a fleet running on natural gas which should emit 96% of particles, 70% of nitrogen oxide and 30% of CO_2 less. In Val-Thorens, an autonomous electric shuttle is in operation and ten other stations, including La Plagne and Les Deux Alpes, have expressed their interest [62]. In Haute-Savoie, Les Gets ski resort has set up the first self-service mountain bike service in 2015 and the enthusiasm is there every year [63].

3.8.1. Electric Vehicles (EVs) characteristics

It is possible to distinguish three macro categories of electric vehicles (EVs):

- Plug-in hybrid electric vehicles (PHEVs) ;
- Battery electric vehicles (BEVs);
- the Fuel cell electric vehicles (FCEV).

PHEVs have both an internal combustion engine (ICE) and electric motor. These vehicles are powered by an alternative or conventional fuel , such as gasoline, and a battery which is charged up with electricity by plugging into an electrical outlet or charging station. There are two PHEV configurations: the series PHEVs in which only the electric motor turns the wheels while the gasoline engine generates electricity and the parallel PHEVs in which both the engine and the electric motor are mechanically connected to the wheels. In this last case the electric-only operation occurs only at low speed.
BEVs typically do not have a fuel tank or exhaust pipe and rely only on electricity for propulsion. While easy on the environment (and the wallet), owners may suffer from range anxiety as they must ensure their BEV contains enough energy for travel. Charging involves connecting to a standard 120-volt outlet, 240-volt household/public Level 2 or a Level 3 power source.
FCEVs are a type of EV that uses hydrogen, via a fuel cell, to power an electric motor run on compressed liquid hydrogen. When hydrogen is combined with air inside the fuel cell stack, the reaction powers an installed electric motor to drive the wheels. Similar to a BEV they are quiet, produce no emissions. While deployment of FCEVs is low compared with BEVs and PHEVs, several countries have announced ambitious targets towards 2030.
The use of alternative technologies, such as fuel cells, aims to overcome the problems related to charging anxiety, since the FCEVs have a greater autonomy and a shorter recharge time. FCEVs are more appropriate for long-term units, since their autonomy is much longer than PHEVs or BEVs but require special charging infrastructure.
Considering the particular context of a ski resort, it is necessary to have the reliability of the vehicle operation at low temperatures. The main key requirements of a generic electric vehicle in a ski resort are: cost effective, frequent starts and operation at low T (-40°C); high power to weight ratio, high low-end torque, high energy demand, high flexibility, excellent efficiency and additional services APU. It is possible to see in Figure 34 the differences between the BEV and FCEV.

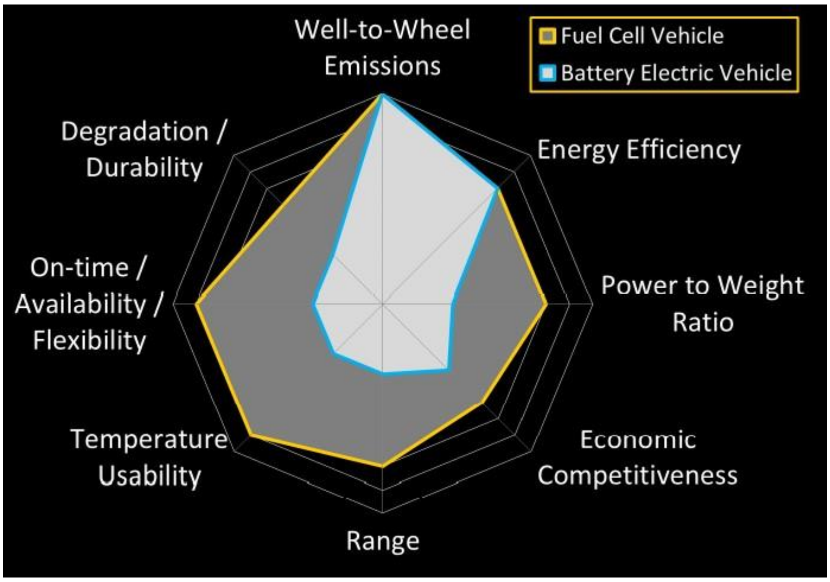


Figure 34: FCEV vs BEV key requirements [64]

Range refers to the distance an electric vehicle can travel before the battery needs to be recharged [65]. The vehicles interested in these technologies are not only cars but can also be applied to buses, trains, ships and even special vehicles such as those used in ski resorts: snow mobiles for internal mobility and snow groomers for the process of flattening and levelling of the slopes. Some examples of FCEVs applications for special vehicles used in ski resorts are presented below. Rotax[66], for example, has presented a concept vehicle for its first zero-emission snowmobile in Europe. The new Lynx HySnow, shown in Figure 35, is based on the Lynx 69 Ranger Alpine, a snowmobile that has proven its worth in Austrian skiing areas for many years.

Figure 35: Lynx HySnow [66]

The vehicle has been completely refitted and given a high-quality electric powertrain powered by a hydrogen fuel cell. In addition to its zero emission characteristics, it has additional benefits such as Its innovative powertrain system means the vehicle runs almost silently, regardless of temperature fluctuations, and is able to operate over a greater range and achieve faster acceleration than conventional electric drives. Moreover, Rotax has constructed an integrated hydrogen ecosystem and filling station in the ski resort of Hinterstoder (Austria). Hydrogen is an innovative energy source and works in conjunction with a fuel cell to provide electrical energy. The Lynx HySnow is filled under high pressure, with the hydrogen being stored in its gaseous form. This station is able to produce *green* hydrogen because it generates electricity for the electrolysis needed to produce hydrogen, from photovoltaic or RES sources [67].

Electric drives with hydrogen fuel cells have their future especially where heavy loads have to be transported over long distances. As well as short refuelling times are required and sustained high performance is required at low temperatures. In the event of a crisis, the emergency power supply can be ensured with hydrogen fuel cell systems.

Moreover, an Austrian consortium has been developing a multifunctional hydrogen snow groomer concept at the Green Energy Center Europe in Innsbruck since June 2019. This project is supported by the Fuel Cells & Hydrogen 2 Joint Undertaking (FCH2 JU) of the EU Commission. The aim of the project is to develop the world's first prototype of a multifunctional hydrogen snow groomer as shown in Figure 36.

Figure 36: HySnowgroomer prototype [68]

A Fuel Cell Electric (FCE) Powertrain is integrated into a snow groomer that can be used as an emergency power supply unit in the event of a crisis. The holistic, multifunctional system also includes a mobile hydrogen re-fuelling concept (mobile HRS), which can be used to ensure that the snow groomer is adequately supplied with hydrogen. Also, in this case, the system is supplied with green hydrogen, which can be produced from water anywhere where it is needed. For this purpose, water is broken down into the gaseous components hydrogen and oxygen in an electrolysis system with the supply of clean electricity from hydropower and photovoltaics [68].

Another example is the hybrid snow groomer *PistenBully 100E* shown in Figure 37.

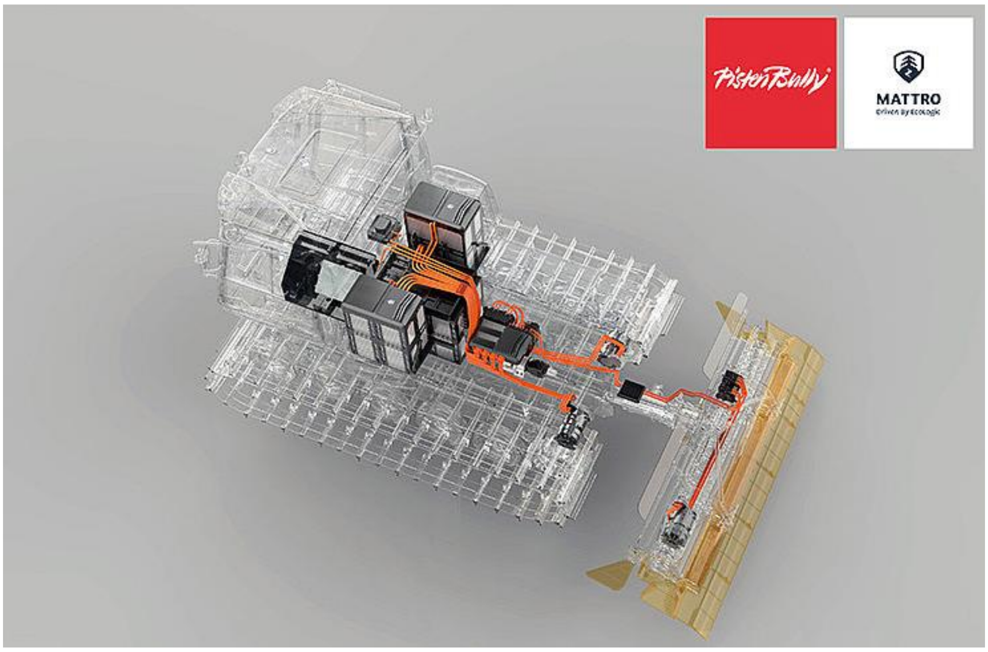


Figure 37: Plug-in hybrid electric snowgroomer

It has been developed by Pistenbully together with Mattro Production GmbH, a company from Schwaz, Austria, specializing in electric mobility. The PistenBully 100 E energy capacity of the battery is 126 kWh with a rated voltage of 400 V. The charging time is of particular interest. At 5 hours, the SoC (State of Charge) is at 75%. After 6.5 hours, the battery is completely charged. In purely mathematical terms, this provides an average driving time of 2.5 to 3 hours. Its forerunner, the 600 E+ also has an all-electric drive train, but uses a diesel engine to drive a pair of generators, which in turn power the electric motors that control track-propulsion and the snow tiller. It has 20% lower fuel consumption for significant savings in operating costs and CO_2 emissions.

3.8.2. Charging stations

Conventional EVs electric vehicles equipped with a battery (BEVs) have a completely different charging mode compared to FCEVs. The BEVs, are basically charged through electric energy through dedicated charging units while for FCEVs the compressed hydrogen tanks on the vehicles are refuelled.

3.8.2.1. Electric charging stations

The wide deployment of the electric vehicle is strictly linked to the development of the associated infrastructure for recharging the EV batteries [69]. Different recharge possibilities exist, described by standard IEC 61851-1 in 4 different modes considering factors such as output power, control and protection equipment or connection type. A brief summary of each charging mode is presented in Table 9 [70].

Table 9 Charging mode for BEVs and PHEVs

<table>
<tr><td></td><td colspan="2">Mode 1</td><td colspan="2">Mode 2</td><td colspan="2">Mode 3</td><td>Mode 4</td></tr>
<tr><td>Grid connection</td><td colspan="2">Plug type A, B , C</td><td colspan="2">Plug type A, B , C</td><td colspan="2">Plug type A, B , C</td><td>Plug type C</td></tr>
<tr><td>Communication</td><td colspan="2">Not necessary</td><td colspan="2">Pilot control wire compulsory</td><td colspan="2">Communication between vehicle and post compulsory</td><td>Communication between vehicle and post compulsory</td></tr>
<tr><td>Phase</td><td>I</td><td>III</td><td>I</td><td>III</td><td>I</td><td>III</td><td>DC</td></tr>
<tr><td>Max power (kW)</td><td colspan="2">11</td><td colspan="2">22</td><td colspan="2">44</td><td>240</td></tr>
<tr><td>Max current (A)</td><td colspan="2">16</td><td colspan="2">32</td><td colspan="2">63</td><td>400</td></tr>
</table>

The charging Mode 1 has been traditionally used for charging processes. It uses alternating current (AC) mains socket (current 16 A) but implies very long battery recharging times (6 to 8 hours). It is suitable if the vehicles are stationed for a long time, but it might be an issue for long distance trips or when the vehicle is parked for little time. In order to solve this challenge, quick (or fast) chargers allow the EV owner to charge the batteries in a very short time (80% of battery capacity in 15-20 minutes) when needed, in a similar way than the current gas stations for combustion vehicles, thus solving one of the main barriers for a massive deployment of EVs: the range anxiety.

Given the considerable development of electric vehicles, ski resorts must therefore also adapt to this trend, offering tourists the opportunity to recharge their electric cars. As during the development of petrol car's economy, now it is important to keep up with the times and meet this increase in demand. This increase must be considered when a conversion of these areas into environmentally friendly and low environmental impact is planned [71]. Particular attention must be paid on this aspect, especially for the remote areas and where it isn't possible to have a lot of electric power in surplus compared to that already used by conventional structures. For this reason, the increase in demand should be assessed if one thinks of an increase in production from RES (renewable energy sources).

If in on one hand, the problem of the supply of electricity can result complicated, on the other hand, the increase of the number of these electric vehicles allows to exploit the batteries installed inside them as accumulators and use them to carry out a modulation of the energy request. Another problem with the electricity grid is the relationship between energy demand and production. The trend in demand is linear and is often in contrast to production from renewable sources, which has a typically variable trend. Unlike the traditional load curves, which show a drop in demand during the central hours of the day, due to the types of activities carried out, the load curve for the ski resort behaves differently [72]. It presents a stable consumption during the central hours of the day, caused by a stable consumption by the ski lifts , then it presents a peak in the evening caused by the snow making systems demand and the increase in the use of recreational facilities and finally, in the night there is a very low consumption of electricity. The use of vehicles as vehicle-to-grid storage as shown in Figure 38, allows to outline a drastic lowering of the evening peak which is then compensated during the hours of lowest use such as the night [73]. This can allow to define almost straight loading curves and the management of the required power does not vary during the day.

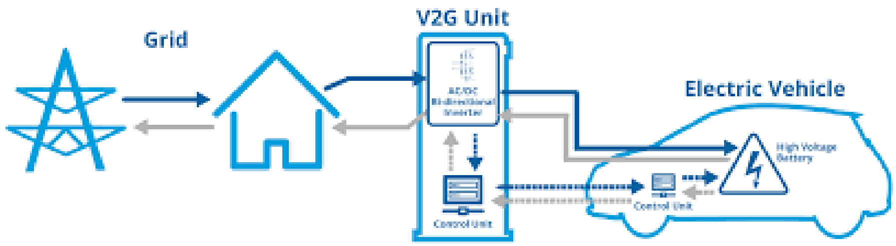


Figure 38: Functioning of vehicle-to-grid

In the sky resort area, the use of this kind of technology could be suitable. The great amount of electrical power, which is necessary for the use of energy-efficient ski lifts which only work for a few hours during the day, could be used to power the charging stations too. Moreover, with an appropriate management it is possible to use the battery for current modulation ensuring skiers a full recharge of the electric vehicle during the day.

3.8.2.2. Hydrogen refuelling stations

Hydrogen can be stored in gaseous, liquid or solid form. Application research related to mobility is currently mainly focused on the gaseous form. At constant temperature, the easiest way to decrease the volume is to increase the pressure through special compressors. These devices have an efficiency between 80 and 91%, reaching a pressure of about 700 MPa. At this pressure the hydrogen has a density of 42 kg/m^3. In addition, the storage performance of hydrogen is much better than that of electric batteries. For example, 100 kWh of energy is equivalent to 3 kg of hydrogen which at 700 MPa occupies a volume of 130 l compared to conventional lithium batteries which would occupy 670 l [74]. In order to avoid a fragmentation of competences, an ISO 19880 Standard has been created. This provides a whole package to cover all technical and safety aspects concerning the refueling of FCEVs.

3.9. References

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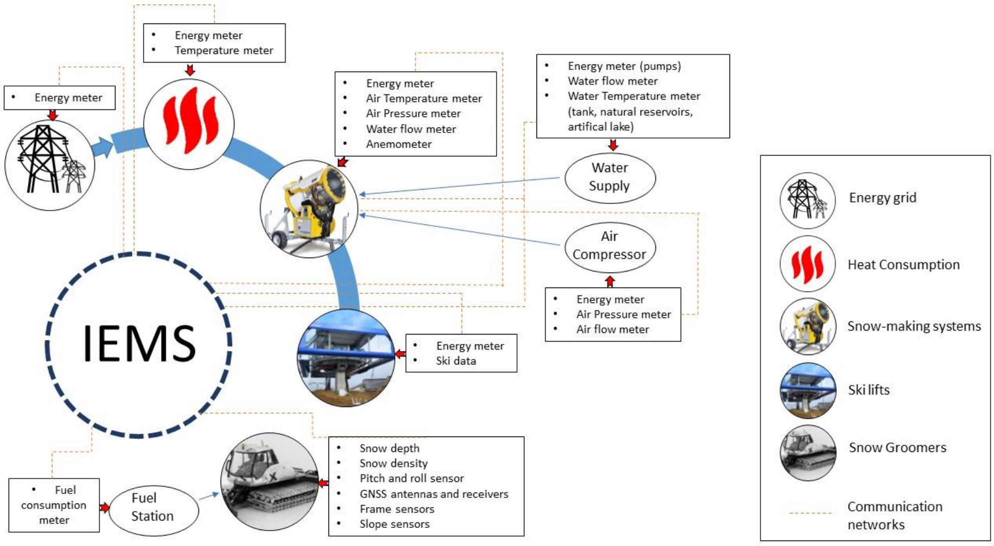
4. Implementation Model: Energy Management System

Document: Public/Confidential
Responsible partner: FBK (Michele Bolognese, mbolognese@fbk.eu) **Involved partners: FBK, TS**



4.1. Executive Summary

In this implementation model , an integrated energy monitoring system (IEMS) suitable for a generic ski resort is described. A ski resort is characterized by considerable energy consumption and a multitude of electrical and thermal energy flows. Through an adequate IEMS it is possible to avoid energy waste by ensuring maximum operating efficiency. As result, costs are reduced due to lower energy and fuel consumption and emissions in terms of CO2 are reduced. An IEMS is necessary to upgrade a more efficient and more sustainable ski resort.

At first, the main components of a ski resort are identified. These mainly involve ski lifts, artificial snow production systems, snow groomers activities and indoor space heating of a generic ski resort. Their operating conditions and know-how are described, including a brief physical thermodynamic treatment of the different phenomena. Subsequently, the sensors and communication systems required for an adequate IEMS are described. Moreover, an Application/technology matrix and monitoring systems is presented. This includes the units of the different types and technologies described in the report with the respective suitable sensors. By filling in this matrix it would be possible to define a status of the IEMS installed in the different living labs considered for the "Smart Altitude" project. Finally, the example of the IEMS implemented in the living lab in Madonna di Campiglio is described.

4.2. Introduction

Following more than 100 years of development skiing developed into a popular tourist activity that satisfied social and cultural needs and combined sport, recreation, and athletic endeavours. Ski tourism has become a major industry in many countries endowed with rich snow resources, and the scale of the skiing industry has increased rapidly. With its strong reliance on specific climatic conditions, the ski industry is regarded as the tourism market most directly and immediately affected by climate change. Alpine regions have been identified as particularly vulnerable to climate change impacts [1] [2]. It' estimated that the number of snow-reliable ski resorts in the Alps could be reduced from 85 % to between 44-63 % [3][4]. More recent studies, however, reported that vulnerability to climate change of the ski industry can be reduced by snow-making technology [5].

Figure 39: Italian Alps

Several technological strategies have been adopted to try to avoid global warming problems using snowmaking systems such as ski guns. Ski resorts use a significant amount of energy, and purchasing this energy is a considerable expense for the companies in the sector. It is estimated that the energy-saving potential at the largest ski resorts could be hundreds of megawatt-hours, corresponding to tens of thousands of euros each year.
The energy demand of a ski resort includes the energy consumption of snowmaking and maintenance of the slopes, ski lifts and lighting, as well as the maintenance and service buildings in slope operations. In fact, as far as the environmental implications of snowmaking are concerned, it is possible to identify two main aspects: water consumption and energy consumption. The *Commission Internationale pour la Protection des Alpes*

(CIPRA) needs between 600000 and 1.5 million litres of water and between 5000 and 27,000 kWh of electricity [6]. The costs of snowmaking are important, especially for the small and medium-size installations, and can be divided into three different factors: investment, operational, and maintenance costs. In Europe, you can look forward to 37,748 km of slopes: the ski resorts are served by 15,800 ski lifts. In the Alps there are 1132 ski resort with slopes of 26.693 km. The ski resorts are served by 8088 ski lift. An energy management system is therefore necessary in order to monitor and optimize energy consumption.

4.3. Energy Management System

Energy management embodies engineering, design, applications, utilization, and to some extent the operation and maintenance of electric power systems to provide the optimal use of electrical energy [7]. The most important step in the energy management process is the identification and the analysis of energy conservation opportunities In this way it's possible to make a technical and management function in order to monitor, record, analyse, critically examine, alter and control energy flows through systems so that energy is utilized with maximum efficiency [8]. Another important step in an EMS upgrade or replacement project is to examine and define the requirements for energy management and controls. Energy management systems (EMS) are one of the emerging technologies that enable an organization to collect real-time information on the energy use through monitoring, assessing, and visualizing energy consumption.

The ISO 50001 standard was published in June 2011 and defines an EMS as "a set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes and procedures to achieve those objectives [9]. Furthermore, ISO 50001 provides a road map and path for continually improving energy performance. The purpose of this international standard is to allow organizations to determine the systems and processes required to improve energy performance, including efficiency, use and consumption of energy. The implementation of this international standard is designed to reduce the number of emissions of greenhouse gases and other related environmental aspects and energy costs through systematic energy management. Any EMS to work properly needs an EMIS (Energy Management information System). An IEMS (Integrated Energy Management system) based on specialized software application solution that enables regular energy data gathering and analysis, used as a tool for continuous energy management. The main advantage of an EMIS application is the possibility of data collection, processing, maintenance, analysis and display on a continuous basis. Moreover, with an EMIS it is possible to monitor the time series of the data (hourly, monthly or yearly) and it is possible to evaluate the points of the system where there is a lower efficiency. A modern EMIS is integrated into an organization's systems for online process monitoring and control. An EMIS provides sensitive information to manage energy use in all aspects and is therefore an important element of an EMS. The nature of the EMIS will depend on different aspects of the case study such as: inputs, process, products, cost incurred, instrumentation, control systems, historical data, reporting system etc.

For Sky Resort an adequate EMS must include a recording of technical-environmental parameters (temperature, solar radiation, air pressure and humidity, wind speed and direction, polluting etc.) with the identification of a series of KPIs (Key Performance

Indicators) and optimization of operating performance a detailed analysis and monitoring of energy consumption of different devices such as:

- Fan guns and lances for snowmaking system;
- Ski lifts;
- Snow groomers;
- Mountain huts, shelter and chalet;

In Figure 40 is possible to see the data transmission structure of different energy consumptions of the devices aforementioned and the recording of techno-environmental parameters.

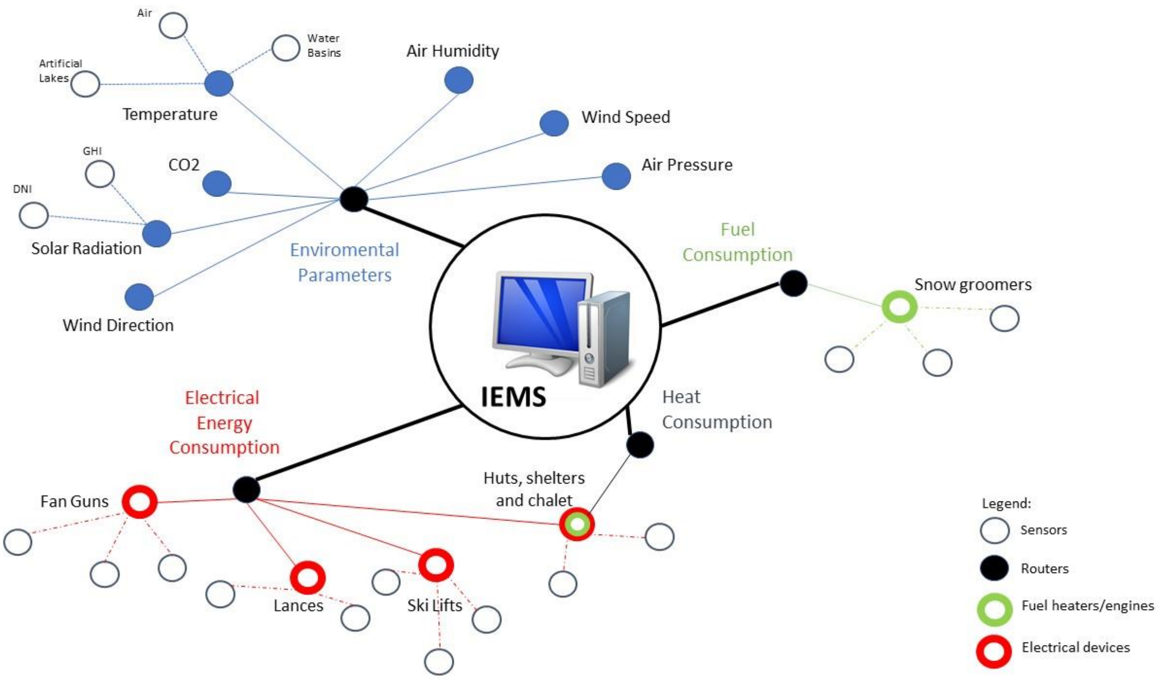


Figure 40: A generic structure for an IEMS of a ski resort

4.4. Snow Making System

Reliable snow conditions represent a crucial economic prerequisite for the skiing industry. Artificial snow production is the key adaption strategy to rising temperature due to global warming, increasing requirement of winter tourists and enhanced economic competition.

In 1903 Oscar Reynold (USA) built a first prototype to produce small balls of ice. Subsequently, in 1950, the first real machine for the production of artificial snow was created by Art Hunt, Dave Richey and Wayne Pierce. The patent was called "TEY". In 1958 Alden Hanson patented the first fan gun. The first artificial snow production system in Europe was is the 1960s. In 1967-68 the first European patent called "Lindle" was filed by the still existing company *Sufag.* In the 80's there was a technological development with the creation of fully automatic systems. The famous companies *Demac-Lenko* in Switzerland, *Areco* in Sweden, *Ampitech White* and *Techno Alpin* in Trentino Alto Adige, *Wintertechnik* in Austria and *Snowstar* in France were born. Over the years, the production technique has been improved and refined. Today, there are about 15 manufacturing companies in the world market [10]. The development of programmed/artificial snowmaking aims to produce snow with characteristics as close as possible to those of natural snow.

4.4.1. Natural Snow

In nature, snow crystals are formed by the presence of special climatic conditions. The crystal forms in atmosphere where there is a high concentration of water vapor (water molecules in suspension in the air). If the air temperature drops these molecules start to condense to form small drops of water; this process takes place usually around particles called *condensation nucleuses* (salts, pollens or suspended micro-dusts) with an average diameter of about 1 µm. When the air temperature drops under the temperature of 0 ° C is very is probable the formation of tiny ice crystals. The water vapor inside the cloud, remains in the state of overcooling (process of cooling of a liquid below the level of the its solidification temperature). When the air temperature decreases, the number of freezing nucleus increases and thus the number of ice crystals increases. It should be underlined that the freezing nucleus are not necessary condensation nucleus (responsible for the of the formation of raindrops). Most of the *freezing nucleuses* are suspended particles of clay, typically kaolinite [11]. Because the vapor pressure of the water is higher than that of the ice, at the same temperature, there is a migration of the water molecules, from the overcooled drops to the ice crystals, thus the crystal increases by the sublimation. Another cause of crystal growth is the collision, during the fall to the ground, with drops of water. This involves an immediate solidification of the water on the surface of the crystal. This process is called a hoar frost. When a crystal is frosted it usually falls more quickly because it is heavier, despite the resistance of falling air. [12]
Therefore, in the growth phase, for the two reasons mentioned above, there is an increase in the mass of the individual ice crystals so that they are more subjected to the force of gravity and begin their fall. During the fall the crystal is affected by stresses due to different variables that contribute to give the final shape of the snowflake. The main variables are:

- Air temperature;
- Air humidity;
- The speed of the fall (depending on the temperature and the mass of the crystal);
- Ascending currents.

The increase in mass and so the size of the crystal is proportional to the air temperature. In the air is warm the crystals have larger size because the probability that there is a higher concentration of humidity and so a further increase of the crystal during the descent, rather than only that happens in high altitude in the atmosphere [13]. In Figure 41 are presented possible configurations of the snowflakes in dependence of air temperature and supersaturation (grams of water per cubic meter [14]. Furthermore, when the snow crystal falls to the ground, a series of metamorphism processes modify its initial shape and physical characteristics. These transformations depend essentially on the temperature of the snow covering and on the content of water in the snow. The density of the snowpack can therefore vary from a minimum of 50 kg/m^2 to a maximum of 300 kg/m^2 [14][15].

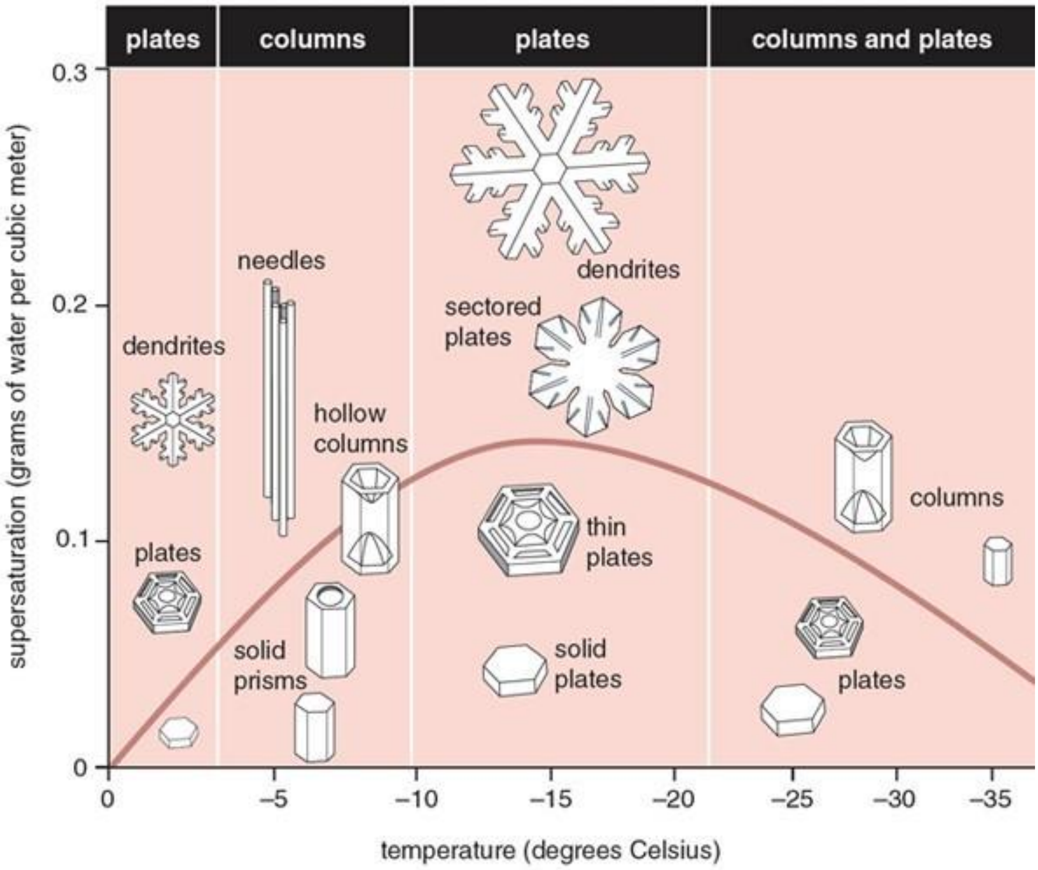


Figure 41: Possible configurations and shapes of the snowflakes *[14]* Figure 41

4.4.2. Artificial snow

Artificial snow is formed mainly from water in liquid form and is generally characterized by rounded crystals. It has a typical density between 360 and 450 kg/m^2, in most cases, with values therefore higher than the average density of freshly fallen snow. The production of artificial snow depends on factors such as temperature and humidity (which affect the yield) and on the speed and direction of the wind, which has a transport capacity proportional to the cube of the speed. Artificial snow, unlike natural snow, is not subject to any particular process of metamorphosis, except for the formation of bonds between the crystals, due to the freezing of the liquid water present in the interstices. Artificial snowmaking systems must ensure that the water is sprayed into droplets of an appropriate size and expelled in such a way that the droplets are completely frozen when they touch the ground.

On each snow-maker there are nucleators and nozzles, the first are bi-phasic atomizers that mix air and water in order to create an ice particle (nucleation germ) while the second provide droplets (Figure 42).

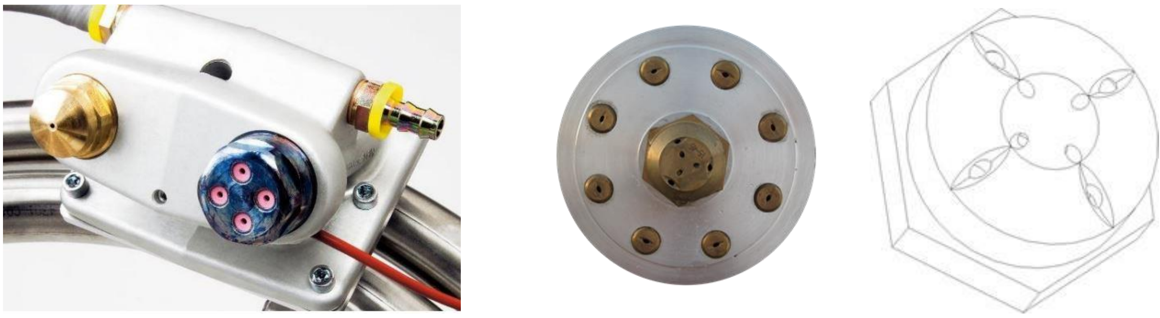


Figure 42 Nozzles and nucleators typologies

When these droplets reach a state of undercooling, they are hit by the ice particles produced by the nucleators. When this impact occurs, there is a first stage in which only a small fraction of the total mass of the drop freezes rapidly (dendrites form) and a second stage in which a freezing of the surface of the drop occurs. The thickness of this ice surface increases with the progressive freezing of the drop inwards. In the first stage a small part of the released solidification enthalpy is transmitted to the ambient air, while the most significant proportion is absorbed by the liquid part of the drop. The nozzle atomises the liquid mass to form a spray consisting of several spherical droplets that are cooled before impact with the ice particles (subcooling). This requires an appropriate time interval to ensure this necessary operating condition[17].

The main factors involved in this phase are:

- Output speed of the water flows;
- Radius of the particle.

When the speed is high, the time interval decreases, while when a drop has a larger radius, it is less affected by the resistance of the limb, and therefore in time it moves more, cooling less. A smaller size drop therefore requires less time to freeze completely.

Therefore, in order to achieve optimal cooling conditions, it is necessary to produce small droplets with low output speeds. It is observed that if you move away the point of contact between ice particle and water droplet, the last one then does not have time to freeze completely. A technique used is to optimize the nucleation (one of the mechanisms of crystallization) by properly orienting the nozzles and nucleators, so that the point of contact is neither too close (water not cooled sufficiently), nor too far (insufficient time to completely) freeze. Seeding means that nucleation sites are generated. Nucleation sites can be water molecules that coalesce alone, ions of for example Ca_2^+ , Mg_2^+ or impurities like clay particles or organic matter [18]. If the temperature is not low enough (<5°C) seeded materials are added to the water. Seeding can also be done by a stream of compressed moist air directed against the water jet. It will cause the moisture content in the expanded air to freeze into tiny ice particles which act as seeds. In this case the water has to be super cooled at the point of seeding. Super cooling condition occurs when the temperature of a liquid or a gas is lowered below its freezing point without becoming solid. In this condition the seeds melt as they come in contact with the water droplets. When a water droplets super cools its temperature drops below 0°C before solidification takes place, the vapor pressure lowers and the heat transfer rate decreases. The droplet may then only partially freeze before it hits the ground and will then freeze to ice on the ground by conductive heat transfer. Furthermore, the size of the water droplets is of crucial. Too small droplets may be transferred away by the wind and too big droplets may not freeze before they hit the ground. The optimal droplet size is between 200 and 700 μm [19]. Such droplets will freeze in less than 15 s. The main processes that govern the production of snow are therefore related to the vector air and water and are expressed in Table 10:

Table 10 Main processes of snowmaking

Water	Supply	Qualitative (cleanness) and quantitative (m^3) requirements
	Cooling	Use of cooling towers (temperature of about 2°C)
		Bullage
	Pumping	Pumping of cooled water along the snow-making lines (high and low pressure)
Air	Pressing	External air intake and compression by means of large compressors located in an engine room
	Cooling	The compressed air heats up, so it needs to be cooled down with special heat sinks
	Injection	air distribution in special pipes that supply the snow-makers

In order to obtain the cold water that is necessary to produce artificial snow there are mainly two options used: cooling tower and the “bullage” systems. Both solutions require electricity to cool the water. The mechanism of the cooling tower is shown in Figure 43.

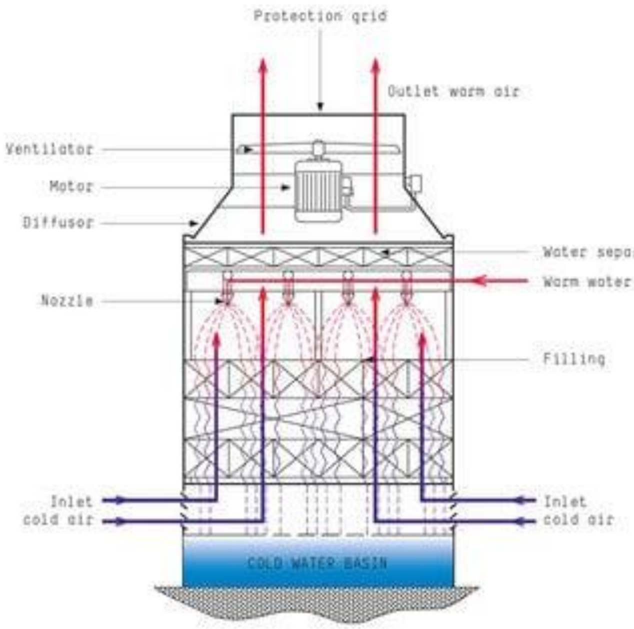


Figure 43:Cooling tower mechanism

In addition, the bullage system injects compressed air from the bottom of the hydrological basin, allowing the oxygenation of the water and breaking up possible superficial ice layer keeping the water free. This allows to avoid eutrophication phenomena. It is also advisable to regulate the output compressed air temperature of the bullage. This is injected at a warm temperature to cause thermal inversion of the water stratification and consequently an internal stirring while injecting cold air at the beginning of the winter season to lower the water temperatures. The sensors that are often used for this system concern on the one hand, the wind direction which is one of the agents that influences the stratification of the basin and, on the other hand, different temperature sensors for pressurized air and. It is appropriate to maintain an operating water temperature above 0°C in winter to avoid localized freezing phenomena and consequent damage to the piping and pumping system.
The role of pressure is fundamental in the creation of drops. At high pressure (40 bar), smaller droplets are created which can freeze at lower altitudes (altitudes) than droplets created at low pressure (12 bar)[20]. It is possible to identify mainly two different types of snowmaking machines:

- High Pressure models;
- Low Pressure models.

4.4.2.1. High Pressure snowmaking systems

High pressure snow-makers consist of a variable length rod (3-10 m) on which a special cylindrical head is placed, composed of a variable series of nozzles and nucleators in which air and water are mixed (Figure 44). Furthermore, the modern lances are equipped with an engine that can regulate the operation of the nozzles (opening and closing) according to the climatic conditions and situations. Relevant pressures are reached in the mixing chamber, while the trajectories of flight vary from 10 to 40 m depending on the length of the rod [21].

Figure 44 Snowmaking lances (a) and nozzle typology (b) (Technoalpin TL6 *[21]*)

They have an adjustable height(H) considering the flexibility to rotate as shown in Figure 45.

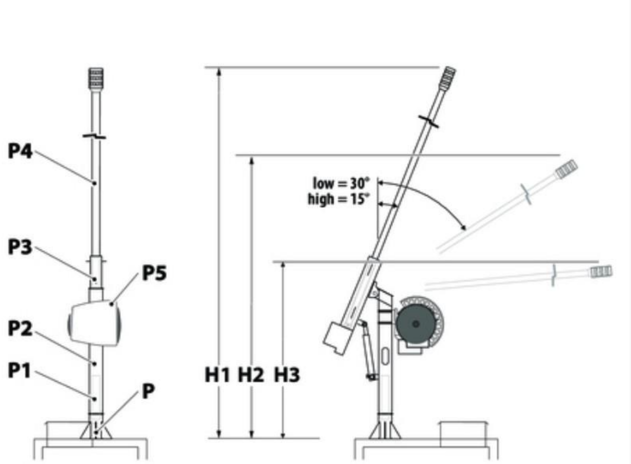


Figure 45 Snow lances rotation

This type is versatile and easy to use because it uses external components such as compressors and fans. External compressors use pipes parallel to those used for water and have a high consumption of electricity for the production of compressed air. The average power required is about 200-400 kW for 25-45 rods. After mixing water and highly compressed air, there is a phase of adiabatic expansion of the air at atmospheric pressure that results in a sensible cooling that allows the production of snow at a temperature of about 0 ° C.

4.4.2.2. Low Pressure snowmaking systems

Low-pressure snowmaking systems, called Fan Guns, typically consist of a cylindrical body of varying lengths (1-1.5 m). They are characterized by the presence of an internal fan and on the opposite end by a series of nozzles and nucleators usually arranged on external coaxial crowns. They differ in single and multi-ring fan systems. The first have got only an array of spray nozzles of varying sizes around the discharge end of a ducted fan with a nucleator. The nucleator is a small air water gun mounted at the bottom of the discharge end of the ducted fan. The second type utilizes several rings of nozzles. Many nozzles with fines water spray can produce higher quality snow.

Figure 46: Figure 5 Fan Guns with quadrijet nozzles (Technoalpin [22])

It acts as a snow particle propeller, guaranteeing trajectories of about 50 m, sufficient time to completely freeze. The Technoalpin Fan Guns use 24 quadrijet nozzles (with 4 jets) and 8 nucleators. These nozzles have a high resistance because they contain ceramic inserts. The four-jet technology is used to optimize and equalize the spray action and therefore to guarantee top snow quality. Modern snow fan guns are equipped with special valves that prevent the return of water droplets or ice particles and can control the activation and the deactivation of the nozzles. Parameters to take into consideration are the energy consumption and the heat produced by the turbine and the compressor. This heat must be removed to avoid negative influences on snow quality. A turbine with internal motor running at about 1.460 rpm makes the machine insensitive to vibrations and significantly reduces the sound emissions, another environmental parameter that should be considered. About this, some types also have the ability to modulate the engine speed (rpm) in order to reduce the intensity of noise (dB). The diameter of turbine is about 90 cm. The energy consumption is about 18.5 kW for the fan output and 4 kW for the compressor. The big advantage of the low pressure is the considerable versatility; in fact, the unit is autonomous as regards production of compressed air and therefore only requires an electrical connection and hydraulic system for water supply. In addition, there is also the possibility of mounting them on snow groomers or to particular structure, a lift, in order to modify the radius and the trajectory as shown in Figure 47.

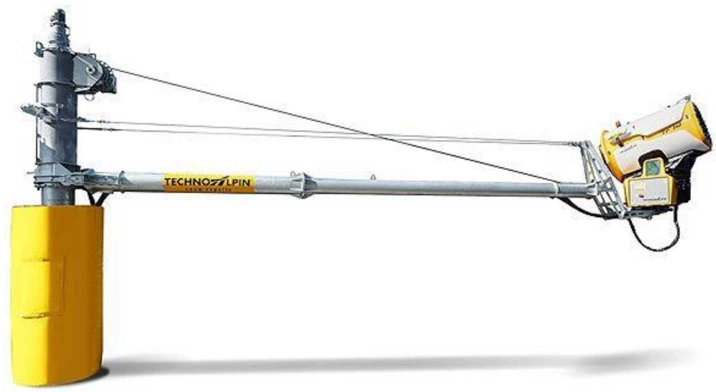


Figure 47: Adjustable mechanical platform for a snow gun (Technoalpin *[22]*)

When installed on a lift, the snow gun is applied to a steel column with a height of 3.5 m or 4.5 m with an adjustable mechanical platform. The platform has a positioning device to facilitate the installation. The snow gun can be operated comfortably from the ground using a Bluetooth remote control or with a manual control with a keyboard or touch display (optional). The typical areas of application are wide and shallow snowy slopes on which wind conditions make it necessary to install inside the slope. In order to obtain the optimum performance up-to-date weather information are necessary so that the snow gun parameters can be adjusted. Advanced snow gun in fact has got a little meteo-station with sensors for air temperature and relative humidity, wind direction and speed and snow depth. In general, 1m3 of artificial snow (including amortization, energy, and personnel costs) has a cost between EUR 3 and 5 and in Switzerland, for instance, for each km of ski run, an investment of about EUR 650,000 is considered normal [23]. Steiger and Mayer [24] report how in the winter season of 2006–2007, the Tyrolean ski industry invested EUR 55 million in snowmaking. [25].

4.4.3. Energy Volume Ratio (EVR)

The EVR is a measure of how much energy is needed to produce a cubic meter of snow with a certain system. It has been proved through several studies in many different locations and snowmaking systems, that the snow production potential is conditioned by the wet-bulb temperature (T_w). From measurements in various different snowmakers, a model to estimate the snow production as a function of T_w has been developed in the following empirical equations [26]:

$$PP_{fan} = -4.83\, T_w + 3.94$$
$$PP_{lances} = -3.94\, T_w - 4.24$$

In which, PP_{fan}, PP_{lances} are the potential of snow production for fan gun and for the lances respectively. The model is valid for a temperature of 2°C and a pressure of 25 bar and the equations are valid for a range of T_w (-13 ÷ -2 °C). The maximum value of PP (limited by the water flow) is 72 m^3/h for PP_{fan} and 51 m^3/h for PP_{lances}.

The average values of power needs for the two technologies generally is expressed in Table 11:

Table 11: Power needs for fan guns and lances

	Fan guns	Lances
$P_{compressor}\,(kW)$	3	4
$P_{heating}(kW)$	2	1
$P_{fan}(kW)$	18	

It's necessary to consider the power delivered by the pumps (P_{pump}) too in the total energy balance for the fan guns and the lances both. It's possible to express the power supply to the water pump as follow:

$$P_{pump} = \frac{\dot{V}\,\Delta P}{\eta}$$

The volumetric flow rate ($\dot{V}$) varies essentially with the production rate of the snow. Considering a ratio of 2.5 from water to snow volume. The efficiency takes into consideration all kind of losses, including the increase of temperature due to the pumping process, and it has a value of 65 % [27].

4.4.4. Snowmaking system plant

Referring to an artificial snowmaking system means considering a series of multiple interconnected sections. Each of these sections has a fundamental role for a correct functioning of the whole. The main parts can be defined as follows:

- water storage (tanks, artificial or natural lakes)
- water pumping station;
- water distribution network;
- electricity distribution network;
- control system;
- snowmaking machines (fixed or mobile);
- compressed air production stations and their distribution network (only for high pressure snowmaking machines);
- cooling systems;
- thermo-hygrometric sensors.

Each of these components can be located at different points in the snowmaking system. Medium and low voltage lines, water lines and compressed air lines must be properly planned and designed. In order to monitor and verify the correct functioning of all components, a single EMS system is useful which interconnects the EMS systems of the individual components and stations. In fact, even the guns are equipped with automatisms (thermo-hygrometric sensor). to enable the starting, shutting down and adjustment of the snow quality (based on temperature and humidity), without any physical intervention. This adjustment can also be made by acting manually by the operator or by the than from a remote terminal. In order to quickly snow the wide surface of the slopes, it is necessary to have a large number of machines for the production of snow. In fact, there are several of fan guns and lances with different characteristics depending on the positioning. Usually the lances are placed where the wind speed is lower, so that all the snow produced remains on the track. there are also turrets that are placed in the steepest sections of the track, where it is not possible to place mobile machines. Snowmakers on mobile arms instead are located in places where the track is very wide and to have snow cover better, they shoot in the middle of the runway instead of on the side. Water reservoirs can be located near the elevation of snow making systems so that the vertical distance that water needs to be transported to the system is minimized. Although water must initially be pumped from the water source to the reservoir, this pumping process can occur during the utility's non-peak hours when the energy charges (non-coincidental peak electric demand cost) are lower. Snow production can then occur at the discretion of the snowmaker with minimal utility peak hour charges (coincidental peak electric demand cost). Reservoirs located above the elevation of snow making systems can gravity-feed water and eliminate the energy consumption associated with pumping water from the reservoirs to the system. As far as the quality and optimisation of the water to be sent along the lines is concerned, in the water reservoirs, a remixing system called "bullage" is set up at the bottom of the reservoir itself, consisting of polyethylene pipe coils equipped with orifices useful and necessary for the blowing of compressed air [28]. This system allows to lower the temperature of the water (up to a temperature of about 1°C), avoiding superficial ice formations, allowing a continuous oxygenation of the tank and avoiding eutrophication of the water itself. Furthermore, the bullage system allows to manage resources with better flexibility and economy, in particular with regard to the cooling towers that with this solution will no longer be used. This remixing system allows the cooling of the water with lower energy consumption compared to the use of the cooling towers (which involve expensive energy expenditure to lower the water temperature). In addition, this system does not allow the formation of surface ice in the basin and allows, consequently, the protection of the waterproofing system and maximum use in terms of capacity and capacity of the reservoir [28].

4.5. Ski Lift

Ski lifts are devices serving for transportation of skiers up a hill. The lengths and structures for the ski lift are variable. Each lift has maximum capacity of persons carried per a unit of time, overcomes various elevations at various lengths and at various velocities.
Lift velocity is determined by engine power (torque), transmission type and track surface. A typical ski lift mechanism consists of:

- propulsion station;
- track supports;
- rope;
- towing equipment;

Figure 48: propulsion station (a) ,wire-rope clips (b), towing unit (c) and track supports (d) *[29][30]*

The basic technical parameter to consider for a ski lift are expressed in Table 12.

Table 12: technical parameter of a ski lift

Slope track length	m
Track elevation	m
Gradient	%
Transport velocity	m/s
Ride duration	s
Transport capacity	Persons/hour
Number of hinges	units
Hinges capacity	Person/hinges
Electromotor power	kW
Tension weight	kg
Tension force	kN
Total length of transport rope	m

Furthermore, it should also be considered that the operation of a ski lift system is the sum of a series of physical and mechanical mechanisms. A generic kinematic diagram can be summarized as follows in Figure 49.

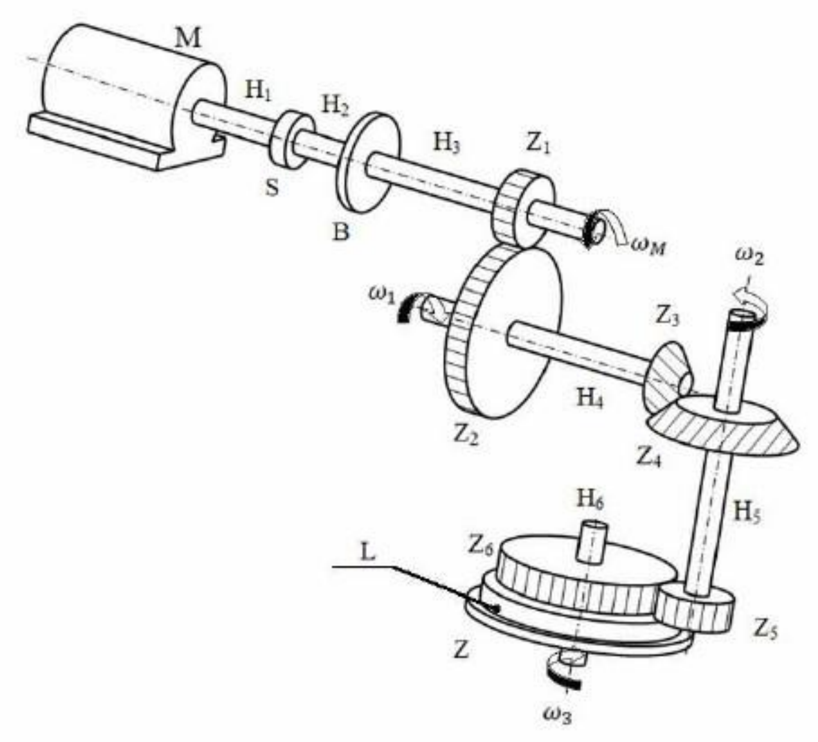


Figure 49: Kinematic diagram of a ski lift drive

In which $\mathbf{M}$ is the engine, $\mathbf{H_i}$ are the shafts, $\mathbf{S}$ is the transmission, $\mathbf{B}$ is the brake,$\mathbf{Z_i}$ are the cogwheels, $\mathbf{L}$ is the rope reel, $\mathbf{Z}$ is the flywheel and $\mathbf{w_i}$ are the angular velocities.
Each component is characterized by a specific mass and dimension (m), a moment of inertia (kg/m^2) and thus a specific kinetic energy (J).
The total kinetic energy of the system is the sum of each component ones. Moreover, the total kinetic energy is the sum of the members performing rotary motion (depending on angular velocity) and sliding motion (depending on linear velocity). A drive is defined as the complex of systems capable of producing the motion of a mechanical load while keeping the mechanical quantities of interest controlled. Each drive includes a power organ called actuator, which can be hydraulic, pneumatic or electric. The electric motor is the component that transforms the electrical energy supplied by a static converter into mechanical energy necessary for the motion of the mechanical parts. In ski resort the types of electrical motors that are used for ski lift or for air compressors are expressed in Table 13.

Table 13: Electrical motors typologies used in Ski resort

<table>
<tr><td colspan="4">Electrical motors</td></tr>
<tr><td colspan="4">DC engines</td></tr>
<tr><td rowspan="2">AC engines</td><td rowspan="2">synchronous</td><td rowspan="2">with permanent magnet</td><td>REL</td></tr>
<tr><td>IPM</td></tr>
</table>

<table>
<tr><td rowspan="3"></td><td rowspan="2"></td><td rowspan="2">without permanent magnet</td><td>PM</td></tr>
<tr><td>PMSM</td></tr>
<tr><td colspan="3">asynchronous</td></tr>
</table>

During the years there have been several technological improvements, and have been created several types of ski lift, each with different characteristics and sizes.
The most important lift types, ski lift types and types of lifts in ski resorts are the follow:

- **8-person chairlifts;**

This extremely comfortable and modern lift system with 8 seats enables a very high transport capacity of up to 4,000 passengers/hours.
The first 8-person chairlift in the world has been in operation in Vradal (Norway) in 1997/1998.

- **6-person chairlifts;**

This extremely comfortable and modern lift system with 6 seats enables a very high transport capacity of up to 3,200 passengers/hour. The first 6-person chairlifts have been in operation in Mont Original (Canada)

- **Gondola lifts;**

Due to the closed cabin, passengers are also protected from wind and weather. The cabins, with a capacity of up to 20 passengers, are connected to the haul rope by detachable grips. Depending on the cabin size, transport capacities of up to 3,600 passengers/hour can be achieved.

- **Combined lift**

This system combines the advantages of a detachable gondola lift with those of a detachable chairlift. Gondolas and chairs are used simultaneously. Due to the high level of flexibility, this system is very suitable for areas with both winter and summer tourism. Depending on the season, weather or client preference, the “mixture ratio” can be adjusted flexibly.
In the summer, the combined lift offers wheelchair users comfortable transportation by gondola. In the winter, the gondolas are much appreciated by families with children, while the “speedy” winter sports fans prefer the chairs because they need not take off their skis, snowboards, etc.

- **3-S ropeway lift;**

3-S ropeway lifts combine the benefits of a gondola lift with those of a reversible aerial tramway. This lift has two fixed, fully locked track ropes on which the carrier travels and a circulating haul rope which is clamped to the 8-wheel carriages. This detachable continuous movement system offers top performance and reliability. It has cabins for up to 38 passengers and maintains top ride comfort even in extreme weather conditions. These are detachable circulating ropeway lifts with a capacity of 30 passengers per cabin and a transport capacity of up to 6,000 passengers/hour

- **Funitels;**

This system is extremely wind stable, it can withstand wind speeds of over 100 km/h. The cabin offers a very high level of comfort and can contain 24 passengers. Transport capacities ranging from 3,200 – 4,000 passengers/hour are achieved at speeds of up to 7.5 m/s. The first Funitel went into operation in the 1990/1991 season in Val Thorens in Trois Vallees (France).

- **Funifors;**

The Funifor ropeway lift is a patented system from Doppelmayr. The haul rope is connected to the cabin with 4 horizontal cable sheaves. The first Funifor went into operation in the year 2000 at Stelvio Pass/Passo dello Stelvio/Stilfser Joch in Italy

- **Reversible aerial tramways/ aerial ropeway lifts**

They are transported by a haul rope along one or two track ropes. These are anchored at the mountain station and led along the route via rope saddles on the supports and are either anchored in the base station or tension is provided with weights. The cabins travelling along the track ropes are connected to each other via the upper and lower haul rope. In one of the stations, the rope is propelled by a drive system; in the other station, it is weighed down by a counterweight in order to achieve the necessary tension. The transport capacity of the aerial ropeway lift ranges from 4 to 200 passengers (depending on the cabin size), the speed is up to 12 m/s and capacity along the lift length ranges between 500 and 2,000 passengers per hour.

- **Cog railways**

Cog railways are trains with racked railways that are used to overcome inclines of up to 48%. These trains are normally used as feeder lifts across long routes in ski resorts. The individual trains can be moved independently of one another.

- **Single chairlifts**

The list of single chairlifts is constantly becoming shorter because they are usually replaced by lifts with higher performance levels. The transport capacity of a single chairlift is usually very low and is therefore no longer economically feasible. There are (almost) no more single chairlifts being built at this time.

- **Basket lifts/Cage lifts**

A basket lift/cage lift is a reversible ropeway with a reversible haul rope upon which fixed-grip baskets (sometimes with a roof) are fastened. The basket usually offers space for two passengers and (usually) does not slow down during boarding or exiting. For this reason, it is not very suitable for children or the elderly. Basket lifts are being replaced by lifts with higher performance levels and there are (almost) no more being built.

The main ski lift technologies are summarized in, in function of the operational speed, number of passengers and units in operation in the Alps.

Table 14: Summary of the main ski lift technologies

Lift technology:	Speed (m/s)	Carrying capacity	N. of passengers	Unit in operation (Alps)

8-person chairlifts		5-6	3000-4000	8-10	79
6-person chairlifts		5	2000-3000	6	742
Gondola lifts		5-6	2000-2620	8-10	678
Combined lift		6	3000-4000	8-10	45
3-S ropeway lift;		6-8	1500-3000	28-30	21
Funitels		7 m/s	3000-4000	24	14

Funifors		12 m/s	600-1300	60	12
Reversible aerial tramways/ aerial ropeway lifts		12 m/s	500-2000	4-200	248
Cog railways		10 m/s	1200-2000	-	13
Single chairlifts		3 m/s	500-700	1	11
Basket lifts/Cage lifts		1.5-3 m/s	300-900	2/4	11

4.6. Snow groomers

“Trail grooming” is defines as the activity of producing a smooth surface of snow with a uniform high density through the use of mechanical equipment. In 1980s there was an evolution in snowmobile trail grooming tractors and drags with a significant improvement of the effectiveness of snowmobile grooming equipment [31]. The grooming tractor is a heavyduty, two or four-tracked vehicle whose primary purpose is to provide the power to pull an implement (drag), power a tiller, or carry a compactor bar across the top of the snow. It may also be used to carry a front blade. Some areas also use farm tractors equipped with a track conversion to pull grooming drags. The overall objective of snowmobile trail grooming is to provide smooth trails that are suitable for all levels of rider experience. It is important to establish a trail base at the beginning of the season, to re-establish a trail after that heavy snowfall or strong blasts winds have obliterated and to restore it into a smooth surface after an intense use. Furthermore, it is crucial to build a solid base of snow “pavement” for grooming equipment to operate upon. The groomed trail base will be packed solid from the ground up while the snow off to the side of the trail will generally be soft and may be several feet deep.

Figure 50: Trail grooming

It is usually useful to establish and understand the minimum level “grooming frequency” or “grooming standard” that is established for trails in an area. This factor is always driven by the available budget and results in priorities needing to be set. Some areas categorize their trails as:

- Level 1: “Minimum” (no commitments for grooming);
- Level 2: “Preferred” (at least one every 5 days);
- Level 3: “Comprehensive” (at least one every 3 days);

In order to produce and maintain a durable trail, it is useful for grooming managers and grooming equipment operators to have a basic understanding of the properties of snow. Once snow has been deposited on the ground, it begins to change, or metamorphose. Three basic types of changes or snow metamorphism (Equi-temperature, Temperature gradient and Melt-freeze) are important for the groomer operator to understand [32]. These changes depend mostly on the snow temperatures, allowing water vapor to flow within the snowpack, or the migration of free water in the snowpack. Water vapor moves from areas of higher temperature or higher-pressure areas to lower temperature or lower pressure areas. Free water may be present in the snowpack and solar radiation can cause a change in the snow surface. It is important to note that the temperature of the snow, even at or near the snow surface, is not typically the same as the ambient air temperature[33]. Moreover, snow quality present regional and seasonal differences such as particle size, wetness, density, temperature etc. These parameters influence the ideal method for trail preparation. In general, the trail grooming has to reduce the snow particle size in order to maximize the number of bonding, producing an equal temperature layer to maximize the equi-temperature metamorphism[15] [34]. For grooming, the most important indicator properties of the snow are particle size, temperature, wetness, and the final snow hardness, or strength. Snow density instead, is not necessarily a good indicator property of snow. Melt-freeze snow can be of very high density but have very low strength [16]. Large particles or clumps that have developed perhaps due to melt-freeze changes (Melt-freeze metamorphism), may require a more aggressive grooming technique, such as tilling the snow. In many regions, the snowfall consists of relatively low density, small particulate snow and the snowpack remains dry. In such areas, a multi-blade drag can provide sufficient remixing of the snow surface [34]. It's better that grooming occur post-sunset, because the snow surface does absorb some solar radiation during the day which will increase the snow surface temperature. Furthermore, an equi-temperature metamorphism condition, and therefore better conditions for trail set up, is more easily achieved after sunset. In general snow hardness is the best indicator property for snow strength. There are many available methods for testing hardness, such as cone penetrometers, ram penetrometers, drop tests, etc. At any given time, there may be several types of snow :hard packed snow, soft snow, wet snow, dry snow, ice, freshly fallen snow, wind-blown snow that is typically small granules and some of the hardest snow, or snow that has been pounded and worked so hard by groomers that there is little consistency left in it. It is critical that all types of snow be “processed” to achieve proper trail compression and set up. The snow processing is accomplished by the establishment of a rolling or churning action in front of the blades as they move forward at a correct and constant speed. In many drag designs, the multiple blades are angled so the snow moves from side to side further mixing and homogenizing it.

While the snow is being mixed, it is also de-aerated (air space between snow particles is removed to make it denser). On the other hand, when using a single blade drag, it is critical that this rolling action is achieved since there is only one blade/one shot at properly processing the snow. While a tiller does an excellent job of processing snow, it can be limited by the depth of its tines.

In general, four basic operations are required to produce a well-groomed trail.

1. Removal of moguls;

The primary purpose of grooming is to remove moguls [35] and compact the trail base. This is not simply a matter of knocking off part of one mound and pushing the displaced snow into the adjacent dip. A “cut-and-fill” grooming operation produces an uneven snow density that can result in a poor riding experience. Even though the trail may initially look smooth, the trail will most likely quickly revert back to moguls as the soft snow is pounded out of the filled dips by passing snowmobiles.

2. Processing the snow;

After moguls have been cut and removed, the drag ‘processes’ the snow when the cut off snow is rolled and ‘churned’ through the series of blades in front of the spreader / compaction pan. If the snow is not freely rolling and churning within the drag – it is not processing properly, so adjusting the drag upward may be required to get snow flowing freely through the blades. This processing helps de -aerate the snow, break away points on snowflakes, and ultimately makes the snow denser.

3. Compression of the processed snow

The compression step helps to further de -aerate the snow, provide a denser, more uniform smooth trail surface while also increasing the trail base depth. If cutting and processing were done improperly or too fast, it’s often results in a compressed snow surface (after step 3) that is not smooth or a uniform density.

4. Trail Set Up.

After the cutting, the processing and the compression steps the trail must be allowed to set up and refreeze after. The set-up time is proportionally to the durable of the trail. Trail set up time will vary with weather, snow and moisture conditions – so can range from 2 hours to 6 hours to even 10 hours before the freshly groomed trail is frozen enough to withstand heavy traffic. Since set up time is critical to trail durability, night grooming is generally the best due to lower traffic volumes and lower temperatures.
Grooming is expensive, so an adequate EMS must be adaptive to changing needs and conditions to ensure funds and grooming time are best spent efficiently and effectively. Grooming management must remain flexible to best respond to local variables through potentially adjusting grooming times, frequencies and methods.
A system of this type can use a GPS tracking of the routes of the individual machines, and can analyze and estimate the best time in which to do the 4 phases of grooming. In particular, the set-up time can be optimized according to a statistical analysis of the environmental data of the snow quality, recorded by the individual machines, during the respective routes.

4.7. Sensors and smart metering

In order to achieve adequate EMS a number of technical-environmental parameters need to be monitored. The main components that characterize a ski resort such as snowmaking systems, ski lifts, snow groomers and heaters for garage, huts and chalets mainly consume electricity and fuel for engines as shown in Figure 51.

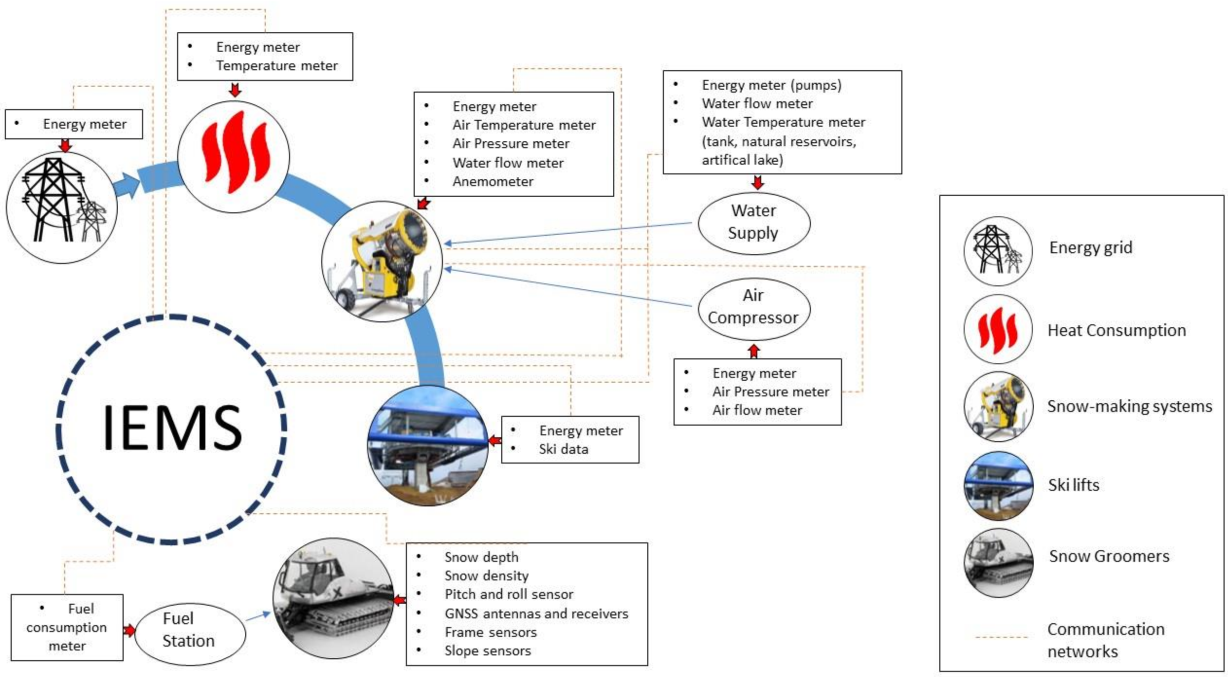


Figure 51: Sensors and communication networks for IEMS (Integrated Energy Management System)

Incorporating all this timely data and monitoring it in a single platform has a number of advantages in terms of management performance. A complete IEMS (Integrated Energy Management System) consequently leads to a significant reduction in energy consumption

and an improvement in the overall efficiency of the various processes. The control and management of the components of a ski resort as a whole can also be carried out remotely via a remote-control system from home, office, or any other location anywhere in the world, ensuring the optimization and flexibility of the operation of the ski resort as a whole.
Furthermore, the modulation of the operating parameters of each well (On/Off selection, snow quality, priority, maximum flow rate, etc.) can be done by going to the configuration menu of each well. For example, the Liberty software [36] allows to select graphically a well or a complete slope by modifying the parameters online. This solution allows the operator a great gain of time (plant parameterization speed and production).

4.7.1. Energy meters

In the snowmaking processes electricity is needed to transform the water in snow. In particular it is used to run fans, air compressors, water pumps, heating nozzles, etc. The input electrical power can easily be measured with an electric meter. Energy meters are used to determine the electrical energy to each snowmaking unit. They are usually designed for three phase (with current up to 80A) and is equipped with a display for manual reading of electrical power as well as energy.
With a router it is useful to share this real-time data in order to save it in a server and monitor it subsequently. Each energy meter is placed in an enclosure to protect the equipment from surrounding environment.
In the snowmaking system the water flow $\dot{V}$ is caused by a pressure difference.
A central pump located at water pumping station raises the water pressure from the ambient pressure to approximately 20 bar. The pump power (W) is a function of the difference in pressure and flow as shown in the following equation:

$$\dot{\mathrm{E}}_{pump} = \frac{\dot{V}\Delta P}{\eta_t}$$

In which the $\dot{\mathrm{E}}_{pump}$ is the pump power, $\dot{V}$ the water volume flow (m^3/s), ΔP is the pressure increase and η_t is the overall efficiency of about 65 %.
Another important device that consume electrical energy is the the air compressor is a machine which increases the pressure given to a gas using the mechanical energy to convert the potential energy into pressure energy. There are two types of compressor:

- Dynamic: The compression is generated by the speed you can impress on the fluid. The mainly used are the centrifugal.
- Volumetric: the compression is generated by a mechanical movement. The mainly used are the piston ones.

In the ski resort is necessary a high pressure 20-25 bar and high flow ≈ 400l/min therefore the best choice is a centrifugal compressor. The main characteristic of this typology is the capacity to increase the pressure in relation to the rotation frequency, usually higher than 10000 rpm. The flow rate remains constant and independent by the velocity. This machine is multistage, made by multiple impellers, where the pressure is increased step by step up to the correct pressure. This system has a high reliability though the manutention is expensive.

$$Q_{compr} = \left(\frac{p}{4}\right) \times V_f \times (d_2^2 - d_1^2)$$

There are several electrical devices for measuring alternating currents and impulse currents such as current transformers (CT), Hall probe sensors, and Rogowski coils. The latter shown in Figure 52, have the advantage of having more flexible and deformable probes, allowing the coiling around a conductor without disturbing it because they are not intrusive

Figure 52: Rogowski coils

In addition, they have a lower inductance as they are not wound on an iron core and this allows measurements to be made of sudden changes in current [37]. The Rogowski coil's theory is based on Ampere's law, which allows to know the magnetic field due to a current, and on Faraday's law that allow to know the electric field in the space due to derivative of current that fluxes in the conductor. The current fluxing in a conductor generates a magnetic field around the wire that depends on distance from the wire. This magnetic field is then converted in an in an equivalent voltage. This value is successively amplified by an interface supplied by a 12 Vdc, before reaching the sensor as shown in Figure 53.

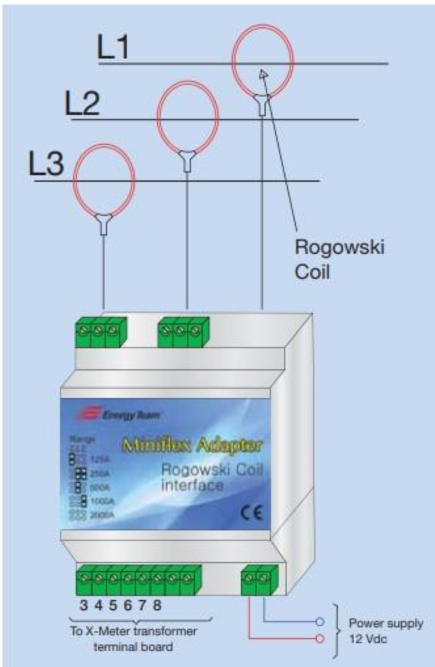


Figure 53: Rogowski Coil Interface

Modern energy meters have the possibility to measure voltage, line current, three-phase equivalent current and consequently provide a real-time output of active power, reactive power and apparent power values. The active power is defined as real electrical resistance power consumption in circuit while the reactive power is defined as the imaginary inductive and capacitive power consumption in circuit. Finally, the apparent power is defined as the required power and ca be calculated as:

$$S = (Q^2 + P^2)^{0.5}$$

Where S is the apparent power supply to the circuit (volt ampere, VA), Q is the reactive power consumption in load (volt ampere reactive, VAR) and P is the active power consumption in load (watts, W). They can be calculated in function of the measured voltage and current and in function of the phase angle φ between the electrical potential (voltage) and the current.

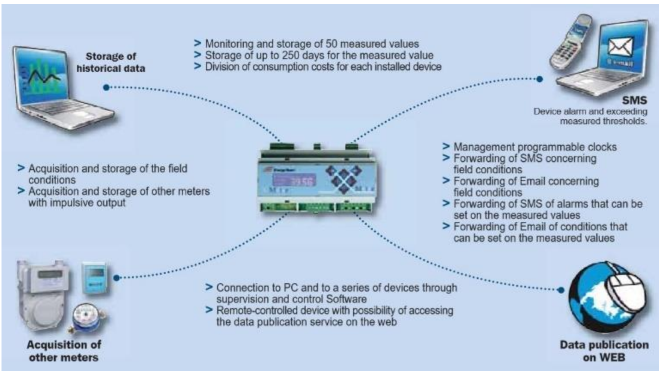
Table 15: Apparent, reactive and active power calculation for mono-three phase

	Single phase	Three-phase
S (apparent power)	VI	$\sqrt{3}VI$
Q (reactive power)	$VIcos(\varphi)$	$\sqrt{3}VIcos(\varphi)$
P (active power)	$VIsen(\varphi)$	$\sqrt{3}VIsen(\varphi)$

Reactive power (Q) is the imaginary or complex power in a capacitive or inductive load. It represents an energy exchange between the power source and the reactive loads where no net power is gained or lost. Reactive power is stored in and discharged by inductive motors, transformers, solenoids and capacitors. Furthermore, it should be minimized because it increases the overall current flowing in an electric circuit without providing any work to the load. Increased reactive currents only provides unrecoverable power loss due to power line resistance. Increased reactive and apparent power will decrease the power factor – PF [38]. The power factor is the ratio between the active power (P) that a facility uses and the apparent power (S) that the utility provides. It varies in function of electrical device used and it is defined as follow:

$$\mathrm{PF} = cos(\varphi)$$

Furthermore, the PF in electrical engines depends on the power demanded, the speed (rpm) and the percentage of load. For example the PF of an induction motors or asynchronous motors (AC) varies with load, typically from around 0.85 or 0.90 at full load to as low as about 0.20 at no-load [39] due to stator and rotor leakage and magnetizing reactance [40] while large DC lift motors in particular tend to have low power factors. For a large DC drive the PF typically ranges between 0.50 and 0.78. This is partially due to the gearbox ratio, which prevents the DC motor from operating at its rated nameplate speed. On the other hand, an electric device with resistive heating element for the heating of the rooms such as the snow groomer garage or the huts and chalet rooms, have a PF of about 1. Power factor can be improved by connecting capacitors either on an individual motor basis or on a common bus covering several motors. For economic and other considerations, power systems are rarely power factor corrected to unity power factor Power capacitor application with harmonic currents requires power system analysis to avoid harmonic resonance between capacitors and transformer and circuit reactance [41]. The harmonic distortions are defined as voltage and current frequencies in power systems that are either above or below the normal 50 Hz power provided by utilities in the Europe. Harmonics filters can be installed to eliminate the negative effects of harmonic distortion. In addition to cleaning voltage distortions, harmonics filtering has the added advantage of increasing the power factor. Electric induction motors require a reactive or magnetizing current that does no useful work. One of the modern smart electrical meters is the X-Meter DIN [42], a bi-directional meter that present different available options. The structure of the instrument and its communication possibilities are shown in Figure 54.



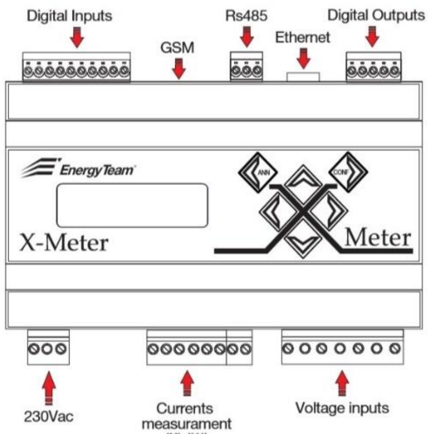


Figure 54 Communication interface (left) and available options(right) of X-Meter DIN [42]

There are different available options, such as:

- XM1 Memory Extension and Communication: this option allows a considerable increase in storage capacity (up to 250 recordable days with an integration time of 15 minutes for line voltage and phase voltage, three-phase line current, three-phase active power, three-phase reactive power, three-phase power factor);
- XM2 Bridge mod. A 232/485- mod. B USB/485: the 485 signals, coming from the X-Meter is converted in 232 serials towards the communication port of the Personal Computer or to USB;
- XM3 Digital Inputs Module: there are 8 self-powered digital inputs at 12Vdc that can be used for the acquisition of environmental conditions and pulses coming from external meters such as those for gas, water, air, etc.;
- XM4 GSM/GPRS Module Meter: a GSM/GPRS modem is installed inside the X-Meter device allowing for the sending of emails and SMS associated with conditions and alarms coming from the “field”, connected with the XM3 function (Module 8 digital inputs). Furthermore, it is possible to share these data online;
- XM5 Ethernet Module: Ethernet communication option for data collection;
- XM6 Harmonics Recording Module: module for harmonic measurements;
- XM7 Annual programmable clocks Module: this option allows the automatic control function to switch specific utilities on and off (controllable loads e.g., lights, motors,

fans, etc.). Each X-Meter can be programmed with up to 12 daily profiles + profiles 2 special periods + 20 special days;

The cost of this sensor is comparable to any other simple multifunction device but it has better initial features (graphic display, pulsed outputs for power taken, short storage of consumption levels.

On the other hand, the device implemented in the Integrated Energy Management System of Les Orres (Smart Altitude Deliverable D.T1.2.1) is the Raptor Manager. It is 868 MHz radiofrequency mesh network. It is possible to connect it to different sub metering modules that can collect several data using different sensors. The Raptor system equipment is shown in Figure 55:

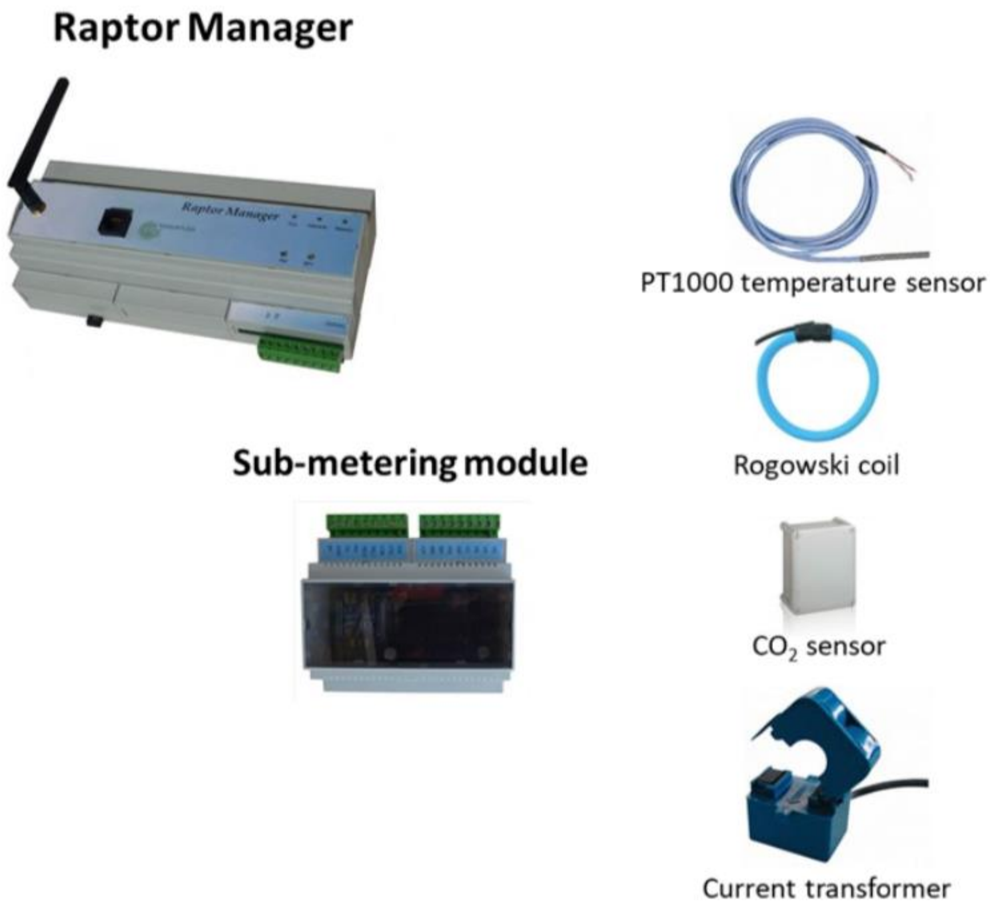


Figure 55: Raptor Manger System Equipment

Sub-metering modules collect the data measured by one or several sensors such as the Rogowski coils, current transformers but also some environmental parameters such as the temperature and CO_2 concentration in the air. Then they transfer this data by IP or 868 MHz radiofrequency to central device called raptor manager. Each raptor manager includes an SQL database and an embarked web server. After that the data is collected from the sub-metering modules via the radio network, then it is processed and transferred via IP protocol to a dedicated supervision platform and/or a third-party data supervision platform.

4.7.2. Water flow

Because of high pressure used in the snowmaking process, an ultrasonic flow meter is usually used to measure the water flow to each snowmaking unit. An ultra-light flow meter measures the flow regardless of pressure. The sensors are mounted externally, outside the tube in which the water flows. The water speed is calculated with two ultrasonic transducers and the volume flow ($\dot{V}$) multiplying the water speed by the internal area of the tube. The average velocity is measured along the path of an emitted beam of ultrasound by recording the frequency shift from the Doppler[43] effect or by the time averaging of difference of velocity between the pulses of ultrasound propagating into and against the direction of the flow [44]. The first transducer works as transmitter and the second as a receiver as shown in Fig.1.

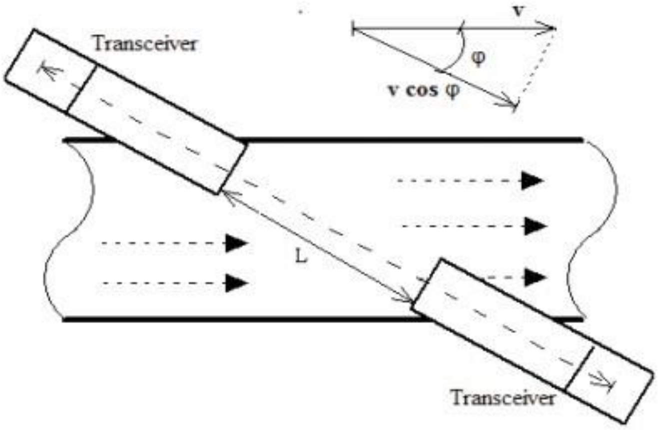


Figure 56:Transit time ultrasonic flowmeter

Both the transducers are mounted outside of the pipe, so that one is at a distance (L) upstream upon another. When downstream transducer transmits a pulse, upstream transducer detects this pulse and gives 'transit time' for the upstream flow. Similarly, it happens for the upstream transducer. The pulse transmit time in downstream direction can be expressed as:

$$t_d = \frac{L}{c + v cos(\varphi)}$$

While the pulse transmit time in upstream direction can be expressed:

$$t_u = \frac{L}{c \; - \; v cos(\varphi)}$$

In which L is the distance between the two transducers, v is the velocity of fluid flow and c is the velocity of the sound through the fluid. In terms of the difference of these pulses transmit times (ΔT) is then calculated the volume flow rate ($\dot{V}$)as follows [44]:

$$\dot{V} = AK_{FM}K_{\alpha}\frac{\Delta T}{2\,t}$$

In which K_{FM} is a fluid mechanical correction factor, K_{α} is the acoustical calibration factor and A is the cross-sectional area of the inner pipe A.
These sensors have a series of benefits including low maintenance because it is not necessary to move internal parts. A calibration method consists in the shifting of one of the transducer through an internal stepper motor axis [45].
FLEXIM shown in Figure 57, matches each ultrasonic transducer pair according to their individual characteristics. Due to unique transducer built-in temperature probes, the FLUXUS F721 automatically detects and compensates temperature differentials between pipe and transducer, ruling out measurement drift (ANSI/ASME MFC-5.1.-2011 regulations). Also, every transducer and transmitter is factory calibrated guaranteeing specified accuracies and ensuring highest traceability and flexibility.[46]

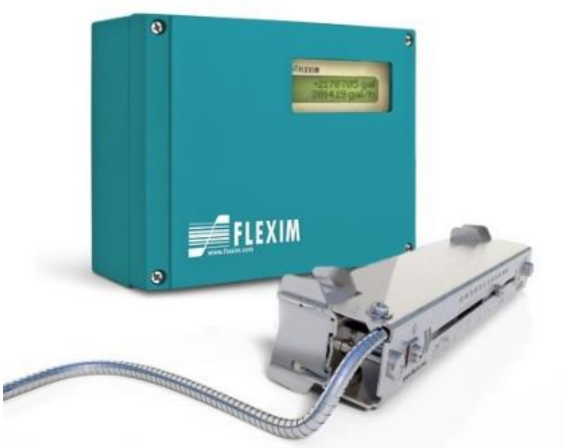


Figure 57 Flexim FLUXUS F721 water flow meter

Moreover, The FLUXUS F721 comes with all common communication protocols: HART, Modbus, Foundation Fieldbus, Profibus PA, BACnet and M-Bus allowing bidirectional field communication and online diagnostic.

4.7.3. Temperature

One of the parameters that mainly influences the snowmaking process is the temperature. It is necessary to consider both the temperature of the water needed for the production and the ambient air that determines the quality of the snow produced. The water temperature is measured by using normal thermocouples. These sensors consist in two wires of different materials that are separated from each other with an insulating material except from the ends of the threads. In one end these wires are assembled together and in the opposite end they are separated. A temperature difference ΔT between the two ends then is proportional to a potential difference ΔV between the wires in the end where they are not assembled. The data logger of the sensor the converts the voltage data in temperature data. Thermocouples of type T have an accuracy within 0.2 °C and are used in a temperature range between -200 °C and 350°C. For the snowmaking process, in addition to the value of the water temperature measurement, it is also necessary to know the air temperature value.

The ideal weather conditions for production of artificial snow are humidity lower than 80%, a temperature between -5°C and -15°C and a light breeze Temperature meters The Dry Bulb (T_{db}), Wet Bulb (T_{wb}), and Dew Point (T_{dp}), temperatures are important to determine the state of humid air. The Dry Bulb temperature is the air property that is most commonly used, and refers to the ambient air temperature. It is called dry because the sensor used to measure it, it is not affected by the moisture of the air. Wet Bulb temperature is the adiabatic saturation temperature and can be measured by using a sensor with the bulb wrapped in wet muslin. The adiabatic evaporation of water from the thermometer bulb and the cooling effect is indicated by a "wet bulb temperature" lower than the "dry bulb temperature" in the air. The rate of evaporation and the difference of temperatures between the dry and the wet bulbs depends on the humidity of the air. When the air contains more water vapor the evaporation rate decreases. Finally, the dew point is the temperature when water vapor starts to condensate out of the air, in this point air becomes completely saturated. In Figure 39 is possible to see the snowmaking viability (in green) as function of the wet-bulb temperature.

Wet-bulb Temperature (°C) as a function of air temperature and relative humidity

← Air temperature (°C) / Relative humidity (%) →	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
-15	-17.2	-17.1	-17	-16.9	-16.7	-16.6	-16.5	-16.4	-16.3	-16.2	-16	-15.9	-15.8	-15.7	-15.6	-15.5	-15.3	-15.2	-15.1	-15
-14	-16.4	-16.3	-16.1	-16	-15.9	-15.8	-15.6	-15.5	-15.4	-15.2	-15.1	-15	-14.9	-14.7	-14.6	-14.5	-14.4	-14.3	-14.1	-14
-13	-15.6	-15.4	-15.3	-15.2	-15	-14.9	-14.7	-14.6	-14.5	-14.3	-14.2	-14.1	-13.9	-13.8	-13.7	-13.5	-13.4	-13.3	-13.1	-13
-12	-14.8	-14.6	-14.5	-14.3	-14.2	-14	-13.9	-13.7	-13.6	-13.4	-13.3	-13.1	-13	-12.9	-12.7	-12.6	-12.4	-12.3	-12.1	-12
-11	-14	-13.8	-13.7	-13.5	-13.3	-13.2	-13	-12.9	-12.7	-12.5	-12.4	-12.2	-12.1	-11.9	-11.8	-11.6	-11.5	-11.3	-11.1	-11
-10	-13.2	-13	-12.8	-12.7	-12.5	-12.3	-12.2	-12	-11.8	-11.7	-11.5	-11.3	-11.2	-11	-10.8	-10.7	-10.5	-10.3	-10.2	-10
-9	-12.4	-12.2	-12	-11.9	-11.7	-11.5	-11.3	-11.1	-10.9	-10.8	-10.6	-10.4	-10.2	-10	-9.9	-9.7	-9.5	-9.3	-9.2	-9
-8	-11.7	-11.5	-11.3	-11.1	-10.9	-10.7	-10.5	-10.3	-10.1	-9.9	-9.7	-9.5	-9.3	-9.1	-8.9	-8.7	-8.6	-8.4	-8.2	-8
-7	-10.9	-10.7	-10.5	-10.3	-10	-9.8	-9.6	-9.4	-9.2	-9	-8.8	-8.6	-8.4	-8.2	-8	-7.8	-7.6	-7.4	-7.2	-7
-6	-10.2	-9.9	-9.7	-9.5	-9.3	-9	-8.8	-8.6	-8.4	-8.1	-7.9	-7.7	-7.5	-7.3	-7	-6.8	-6.6	-6.4	-6.2	-6
-5	-9.4	-9.2	-8.9	-8.7	-8.5	-8.2	-8	-7.7	-7.5	-7.3	-7	-6.8	-6.6	-6.3	-6.1	-5.9	-5.7	-5.4	-5.2	-5
-4	-8.7	-8.5	-8.2	-7.9	-7.7	-7.4	-7.2	-6.9	-6.7	-6.4	-6.2	-5.9	-5.7	-5.4	-5.2	-4.9	-4.7	-4.5	-4.2	-4
-3	-8	-7.7	-7.4	-7.2	-6.9	-6.6	-6.4	-6.1	-5.8	-5.5	-5.3	-5	-4.8	-4.5	-4.2	-4	-3.7	-3.5	-3.2	-3
-2	-7.3	-7	-6.7	-6.4	-6.1	-5.8	-5.5	-5.3	-5	-4.7	-4.4	-4.1	-3.9	-3.6	-3.3	-3.1	-2.8	-2.5	-2.3	-2
-1	-6.6	-6.3	-6	-5.7	-5.4	-5	-4.7	-4.4	-4.1	-3.8	-3.5	-3.3	-3	-2.7	-2.4	-2.1	-1.8	-1.5	-1.3	-1
0	-6	-5.6	-5.3	-4.9	-4.6	-4.3	-3.9	-3.6	-3.3	-3	-2.7	-2.4	-2.1	-1.8	-1.5	-1.2	-0.9	-0.6	-0.3	0
1	-5.3	-4.9	-4.6	-4.2	-3.9	-3.5	-3.2	-2.8	-2.5	-2.2	-1.9	-1.5	-1.2	-0.9	-0.6	-0.3	0.1	0.4	0.7	1
2	-4.6	-4.3	-3.9	-3.5	-3.1	-2.8	-2.4	-2.1	-1.7	-1.4	-1	-0.7	-0.4	0	0.3	0.7	1	1.3	1.7	2
3	-4	-3.6	-3.2	-2.8	-2.4	-2.1	-1.7	-1.3	-0.9	-0.6	-0.2	0.2	0.5	0.9	1.3	1.6	2	2.3	2.7	3
4	-3.4	-3	-2.5	-2.1	-1.7	-1.3	-0.9	-0.5	-0.2	0.3	0.7	1.1	1.4	1.8	2.2	2.6	2.9	3.3	3.6	4

Figure 58: Correlation between ambient temperature, wet bulb temperature , humidity and relative snowmaking viability (green is suitable condition, red is not suitable condition) [47]

It is possible to notice that the limit for snow production is a wet-bulb temperature of about -2 °C. The right corner in red in the bottom shows the ambient condition of temperature that are not suitable for snowmaking. Furthermore, the quality of the snow depends on the wet bulb temperature. The snow is considered of good quality when wet bulb temperature reaches about -7 °C [47].

However, it is necessary to remark that the freezing of the water particles creating snow crystals or snowflakes is not guaranteed. The nucleation of homogeneous crystals can take place at temperatures as low as -40 ° C, meaning that the water can be supercooled down to that point before actually freezing, but only if it is completely pure water. Otherwise, small particles dissolved or suspended in the water can act as nucleation starters, leading to an earlier formation of the snow crystals. Water from sources like lakes or dams contain many substances such as minerals, plant matter, microorganisms or other organic chemicals, that can only act as nucleators at temperatures up to -8 ºC or -10 ºC. Hence, the formation of snowflakes is normally ensured by adding a protein of natural origin, called *Snomax*. This has the ability to enhance and activate the nucleation process at higher temperatures, being able to reach -3 ºC, and allowing snow production in a much wider range of temperatures, including temperatures very close to the operation limits. [48].

4.7.4. Atmosphere humidity

The atmosphere humidity is an important parameter to establish when is advantageous or divinations make snow production. Indeed, a lower or higher humidity can compromise the writhe formation of the snow. This parameter is monitored with a hygrometer, a device which measure the differential between the ambient and the landmark. To give back a better maturation, the digital instrument use 2 sensor which can test a major area.

4.7.5. Pressure transducer

The pressure transductor is an electromechanical instrument used principally to traduce the pression into an electric signal which can be interfaced with a PLC or a control system. To generate the signal a diaphragm, normally in Stirling steal, is proportionally deformed by the pression exert on it. In the potentiometric transductor connected to this piece there is a potentiometer which can convert the mechanical movement into an electric signal. This kind of instrument is simple to manufacture at a low cost. Thought the mechanical parts are subject to the thermal expansion or contraction. The temperature in the ski resort is prohibitive, it can reach -25/30°C, however are low enough to generate relevant error.

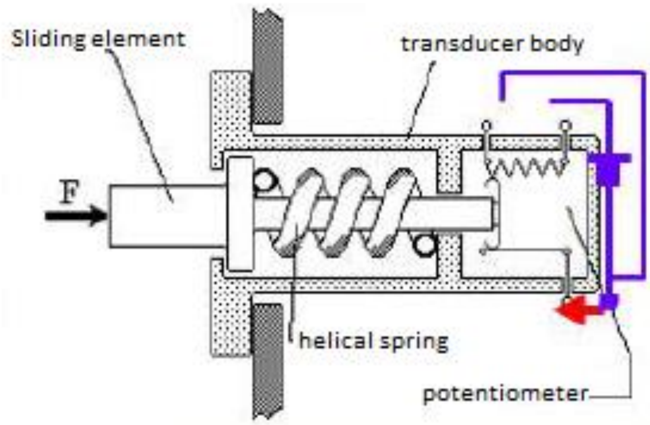


Figure 59: Pressure transductor

The construction technology isn't the only difference we can find in the pressure transductor. Another one is the reference system. The relative maturation compares the measured pressure to a reference pressure measured in the factory while the absolute one uses the absolute vacuum as a reference. Due to this reason, the second type gives back a value not influenced by weather conditions or altitude.

In the snow making system despite the high altitude, more than 2000 m asl, the difference between the real measurement and the data read on the instrument isn't considerable on the pressure at stake equal than 20 bar. This is the reason why, installing a relative transductor on the main water or air supply gives back a quite precise value. On the contrary, on the fan guns snow machines), we need a greater accuracy: it's important to monitor the pressure on the nozzle. In the first part we have spoken about the electrical signal given us from the transductor but this must be managed and it must be connected with the monitoring system.
There are two different ways to handle the signal: analog or digital. The analog communication uses a signal wire because there is a transformation of the pressure in electricity that happens through physical correlation. An example is the 4-20mA signal. In this case there is a correlation between the increase of pressure and the increase of the current. When the distance between the sensor and the control system is short, this system gives a chipper alternative to have an accurate measurement.
However, on the long distance there are some interferences that can compromise the quality of the signal so it's better to use a digital signal. This type of communication converts the pressure into binary system (0-1) without a correlation with another physical dimension. The bit thus generated can be transmitted for a long distance without a damage on the signal. Another vantage of this technology is the possibility to use a wireless relay to connect the sensor and the PLC (Programmable Logic Controller) without a wire.
In the ski resort it's necessary to install the transductor in two different places. In the pump station is preferable to use on the main pipe, both for water and air, an analogic one. Actually, it is possible interfacing this signal on the pump's PLC. On the contrary, the device installed on the fan guns is a better choice to use a wireless connection to eliminate the long distance between the sensor and the PLC and it allows to move the system all over you want.

4.7.6. Snow Density

The higher density of artificial snow compared to natural snow imply that a lower snow depth is required in order to assure good skiing conditions [49]. In order to make a good slope 20 cm of groomed artificial snow is required. An amount of 10 cm of artificial snow correspond to 40 cm of natural snow.
After the snow making process, the snow crystals or ice grains result forced close together by the mechanical compaction of grooming equipment, at which time energy is introduced into the snow by the mechanical action, resulting in a partial melt, and thus increasing the density of the snow. As a result, a transfer of water molecules, necks of ice form between adjacent grains, strengthening the snowpack. On re-warming during the day, the necks between the ice grains will be reduced thereby weakening or destroying the bond between grains. The Table 16 gives typical snow densities and indicates suitable densities for various levels of use. Kilograms/cubic metre (Kg/m3) is the usual measure of density.

Table 16: Guideline for trail surface density

Trail condition	Density (kg/m^3)	% water
New snow	150-200	15
Wind-packed snow	250-300	25-30
Packed with snowmobile alone	300-350	30-45
Recreational Trails	450	45
Racing Trails	500	50
Word Cup and higher events	540-560	54-56

The snow density and snow wetness are determined from measurements of an open RF resonator. Changes in the relative bandwidth of the open resonator is related to the wetness; changes in the resonant frequency is related to the snow bulk density (esp. when the snow is dry). The RF source is the wireless radio unit which is integrated into the microprocessor chip. The RF detector is an LTC5505-2 which converts the incident power into a DC voltage that can be digitized by the onboard analogue-to-digital converter (ADC) on the microprocessor. The grain size affects the transmission of light from a single emitter to up to four photodetectors, as the scattering of light is dominated by the number density of air-ice interfaces. The emitter is driven by a constant current source, and the photodetector circuit utilizes synchronous detection and a bias current is imposed to accommodate the ambient light level.

4.7.7. Snow depth and snow water equivalence

The snow depth (d) is a measure of the vertical length of snow determined with respect to a reference datum normally taken as the ground. The origin of the measurement is an approximation of the ground surface. This is because the ground can have a vertical scale of roughness that is significant with respect to snow depth.

Snow water equivalence (SWE), the product of snow density and depth, is the most important parameter for hydrological study because it represents the amount of water potentially available for runoff. Measurement of the amount of water stored in the snowpack and forecasting the rate of melt are thus essential for management of water supply and flood control system [50].

There are different method and sensor typologies to measure these parameters. The SR50A Sonic Distance Sensor [51] for example provides a non-contact method for determining snow depth. It determines depth by emitting an ultrasonic pulse and then measuring the elapsed time between the emission and return of the pulse. An air temperature measurement is required to correct for variations of the speed of sound in air.

Also, GPS receivers can be suitable for measuring snow depth. GPS multipath is affected both by the geometry of the reflector with respect to the antenna and the dielectric constant of the reflector. GPS antennas for high-precision applications are designed to suppress multipath, but do not entirely remove it. Multipath from horizontal, planar reflectors – such as the ground – is straightforward to model [52]. The multipath contribution to GPS SNR (signal to noise ratio) data for a horizontal reflector can be represented by:

$$SNR = Acos(f\,sin(E) + f)$$

where E is the satellite elevation angle [53][54] while the amplitude A depends on the reflector's dielectric constant and surface roughness, as well as the gain pattern of the antenna. The frequency f will depend on the transmitted GPS frequency (1.2-1.5 GHz), the height of the antenna, the snow density, and on the moisture of the underlying soil.
Three-point measurement under the blade as shown in Figure 60 reduce the risk of collision with the terrain and ensures precision when working with a tilted blade. Three measurement locations ensure more precise positioning of the blade according to the design model. The dual slope technology ensures blade roll compensation which significantly enhances the accuracy of the snow depth measurements when rolling the blade up or down. Blade roll compensation is an advantage when grooming slopes and when creating snow parks and competition courses [55].

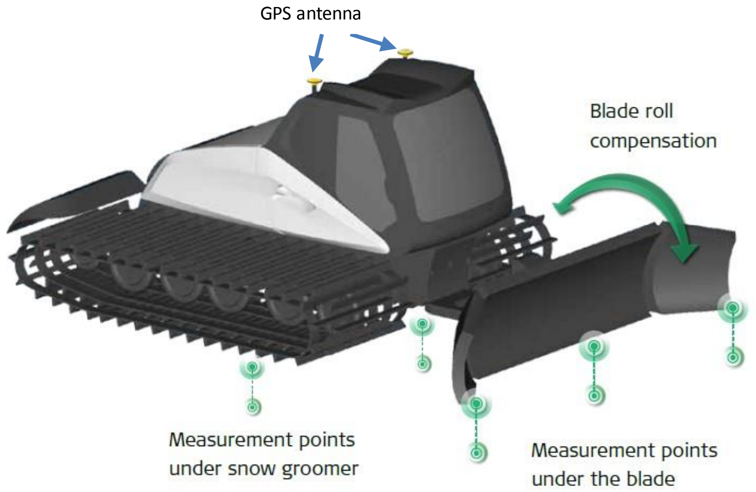


Figure 60:Snow depth sensor installed on the snow groomer [55]

The precise snow depth and the profile of the terrain are shown in real time on a monitor installed the snow groomer. The operator can thus immediately examine the data that has been prepared in real time while preparing the slope. The result is the optimisation of snow management from production to distribution and up to the time of preparation. The main software used is that offered by Leica geosystems. This uses a GNSS antenna, a Leica GPS Symbol 80-GNSS receiver and a 3D display located inside the vehicle that allows to check the operation in real time.

4.7.8. Fleet Management

It is possible to achieve an efficient management of the snow groomers fleet through a GPS tracking and data transmission system with CAN-bus communication. This system can work for any snow groomer brand and for the entire ski resort. The real time data transmitted, which are taken into account by Prinoth's Snow How software, are: vehicle status, working time, position, speed, cutter and lighting [56]. In Figure 61, it is possible to visualize the interface of the software.

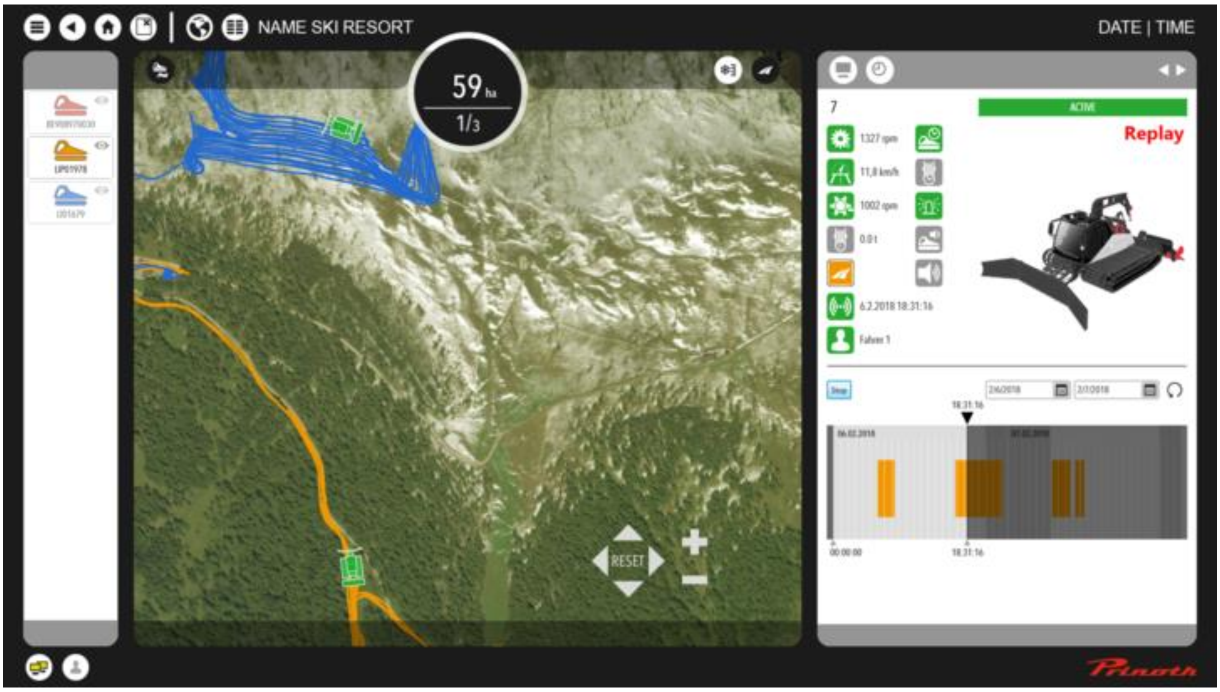


Figure 61: SNOW.HOW software interface [56]

This allows to obtain an efficient use of the vehicles in action, reducing management costs and fuel. The reduction of operating costs includes an optimization of the travel and operation plan, a reduction of operating times to the minimum and downtime (IDLE), resulting in a better yield of beaten surface per hour.

4.7.9. Ski data

The use of ski data sensors in the ski resorts' ski lifts makes it possible to monitor the real operation of the lifts by providing real time data to a central server through a communication system. Skidata access readers have different types, the most usual are those shown in Figure 62 [57].


Figure 62: SKIDATA access reader [57]

The Skidata readers have various turnstile options (one, two or three arms) and usually record the entry through a barcode reader. Moreover, they offer the best comfort and highest security against ticket fraud. They impress with speed, robustness and durability, as well as the ability to read a wide variety of access mediums. The marking of each skier allows you to know how many passengers there are for each ski trip. This can be a useful parameter to estimate how much energy expressed in kWh is consumed by the electric motors of the ski lifts to carry the individual passenger. Optimizing this process means filling the cabins in the best way possible, avoiding that they operate with few passengers. In addition, it is possible to use SKIDATA at the entrance of the ski resort car parks, in order to optimize the available space and the time needed to find a free parking space. Reducing queue times for parking implies reducing the emission of pollutants from fossil fuel vehicles.

4.7.10. Communication networks and systems

New smart meter capabilities require communication networks that are able to deliver accurate, reliable and large streams of real time data. The communication network connects the different smart meter devices to head-end systems that manage, transmit and receive data. A large variety of wired and wireless communications technologies can be used as shown in Table 17. Utilities typically combine multiple approaches and integrate with new systems involving multiple vendor products. Moreover, many utilities use common communications platforms using the same protocol to support multiple field devices.

Table 17: Advanced metering infrastructure communications technologies

Wired	Wireless
Fiber-optic cable	Radio Frequency (RF)-mesh network
Power-line communications (PLC)	RF-Point to multipoint
Telephone dial-up modem	RF-Cellular
Digital subscriber line (DSL)	

The choice of communication technologies and configuration requires utilities to examine multiple requirement, considering all smart technologies that may be used in the networks. Another important device is the datalogger used for the collection of data. The logger usually is equipped with pulse counters, and relays capable of breaking current of up to 2 A at a voltage of 300 V. Moreover, the output can control other low-voltage (0-10 V) or low-current (4-20 mA) applications.

4.8. Application/technology matrix and monitoring system

In order to check the state of advancement of the IEMS and evaluate possible improvement strategies of the 3 living labs of the Smart Altitude project it could be useful to fill the cells of the following *application/technology/monitoring system matrix* for each ski resort. For the most devices, in the third and fifth column should be inserted the number of technological devices indicated and the number of sensors related to them while for the snow groomers the total km and the operating hours have to be inserted. In the last column on the right, the communication system should be declared, if it exists and what type it is.

Application		units	Sensors (Y/N)		Communication (Y/N)
				units	
Snow Making Systems	High- pressure System		Energy Smart meter		
			Air temperature meter		
			Water flow meter		
			Anemometer		
			Compressed air pressure		
	Low- Pressure System		Nozzle control		
Weather			Air temperature		

Station			meter		
			Anemometer		
			Pluviometer		
			Solar radiation meter (GHI)		
			Wind direction		
			Wind speed		
Snow Groomers	Fuel		Fuel meter		Wireless
	Snow quality	Snow density	Ultra-sonic sensor		
			Microwave sensor		
		Snow depth	GPS system		
			Ultra-sonic meter		
		SWE			
	Operating conditions	Operating hours			
		Km	GPS/GNSS system		
	Slopes quality		Frame sensors		
			Pitch and roll sensor		
			GNSS antennas and receivers		
Ski lifts	Engine	AC	Energy Smart Meter		
		DC			

	Operating conditions	Number of passengers	Ski-data		
Heating systems	Technology	Electrical	Energy Smart Meter		
		Biomass	Biomass meter (kg/h)		
		Natural gas	Gas meter		
	Operating conditions	Operating hours			
		Indoor temperature	Temperature meter		
Water	Supply	Natural lake			
		Artificial lake	Temperature meter		
		Tanks	Temperature meter		
	Cooling	Cooling towers	Temperature meter		
		Bullage	Air pressure meter		
			Temperature meter		
	Pumping		Energy Smart Meter		
Air	Pressing	Air compressor	Energy Smart Meter		
	Cooling		Temperature meter		

Energy Grid	Power limit (kW)		Energy Smart Meter		

4.9. IEMS in Madonna di Campiglio

In the living lab of Madonna di Campiglio, the company Energenius of Trento [58], has developed a unique integrated energy monitoring system, collecting in a single platform all the data recorded by different sensors installed in the ski resort. These data, as seen before, include the energy flows and the most important physical and thermodynamic parameters of the main actors of a ski resort such as: ski lifts, snow groomers, snowmaking systems, water supplies conditions, weather forecast, and indoor spaces temperatures.
In order to facilitate the visualization of the data flow, it was appropriate to divide the ski resort area into several sub-areas, mainly divided according to ski lift stations, in order to visualize the time variations in a more detailed view.
This type of monitoring allows to analyze the historical and real-time data series and to identify the most effective improvement actions. As result, it it possible to maintain an high level of excellence in respect of the environment, through a careful control of consumption and emissions.

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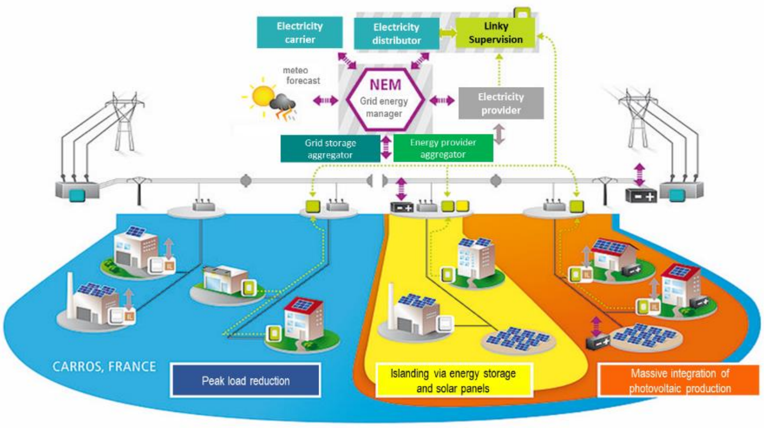
5. Implementation Model: Smart Grid

Document: Public/Confidential
Responsible partner: Les Orres (Yann Bidault, yann@ybsolution.com) **Involved partners: Les Orres, EDF**



5.1. Introduction

This document presents a territorial implementation plan specific to Smart Grid technologies. It aims at presenting Smart Grid models for maximizing GHG reduction, economic impact and stakeholder benefits.
The general characteristics of smart grids, presented in a first part, allow stakeholders to measure the economic and environmental impact of such technologies.
A second part, more specific to the technique of a smart grid, with Nice Grid & Les Orres examples, allows to evaluate the measures to be taken for the implementation of a smart grid.

5.2. Deploying smart grid: context, objectives, and challenges

5.2.1. From centralized electrical system

Most national power systems have been built around centralized means of generation. The electrical distribution is ensured by a national power grid, interconnected to the European power grid. Conventional means of electricity production (thermal, nuclear, hydraulic) are called up according to the energy demand, so that there is always a balance between energy supply and energy demand. This global architecture is possible thanks to the flexibility of the means of energy production and to a lesser extent, that of energy consumption.
Flexible means of production, i.e. means whose output can be changed up or down in a matter of seconds, include the following:

- Coal

- Gas
- Petrol
- Hydro power
- Biofuels
- Waste energy

Nuclear power plants are not considered as flexible means of production due to the inertia of ignition and shutdown.
It is mainly these flexible means of production that are involved in system services, i.e. the upward or downward modulation of production in order to ensure the overall balance between production and consumption. In 2000, these flexible means of production accounted for 68% of electricity production in Europe (Figure 1).
Since the 2000s for wind farms and the 2008 for solar farms, intermittent renewable energies have been increasingly appearing in the European energy mix (Figure 2). These means of production cannot be activated on demand to restore the balance between energy production and consumption. In 2017, the share of these intermittent energies (wind & photovoltaic) in electricity production was 14%. Therefore, the share of flexible means of production now covers 61% of electricity production in Europe (Figure 1).
We are therefore increasingly moving towards an energy mix that will no longer be able to adapt to meet a one-off energy demand on the electricity markets.

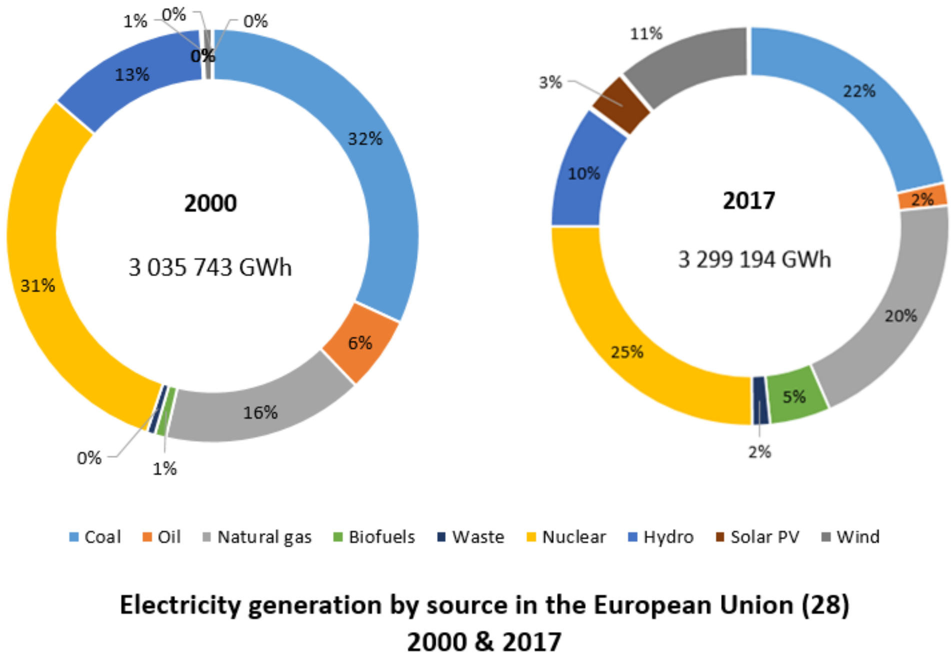


Figure 63 – Comparison of the electricity generation by source in the European Union 28 between 1990 & 2017. Source: IEA.

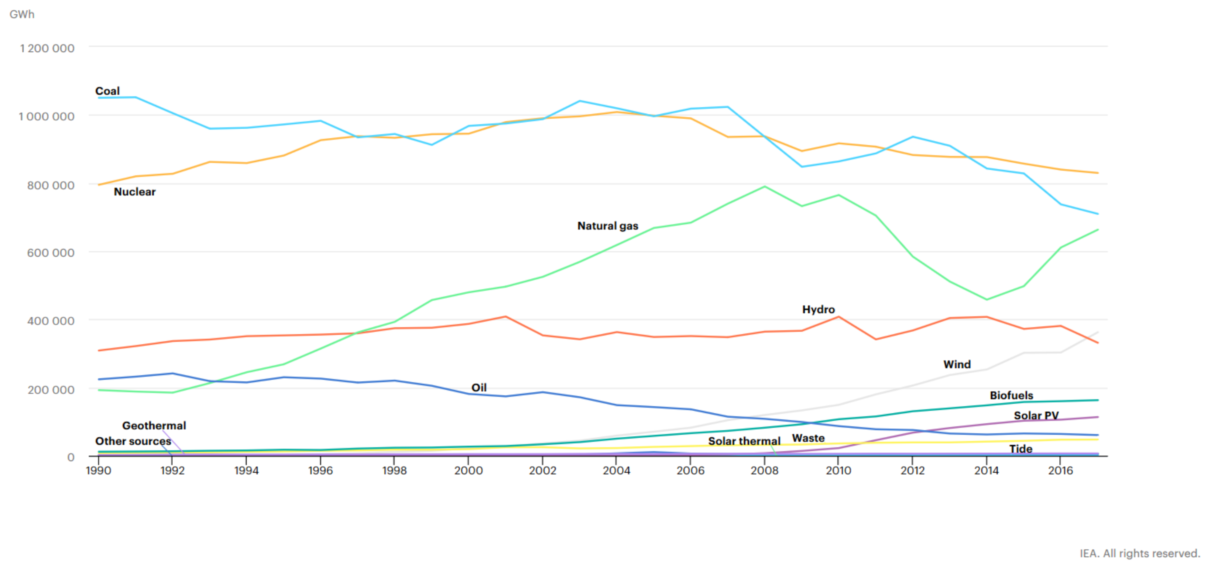


Figure 64 – Evolution of the electricity generation by source in the European Union 28 from 1990 to 2017. Source: IEA.

On a smaller scale, and in particular at the national level, large differences are observed between the energy mixes of each country (Figure 3).
For example, the share of flexible means of electricity production varies widely between France, Slovenia and Italy:

- France: 21 %
- Slovenia: 60 %
- Italy: 84 %

This same difference can be observed at the territorial level, city level or district level because of the appearance of self-consumption.

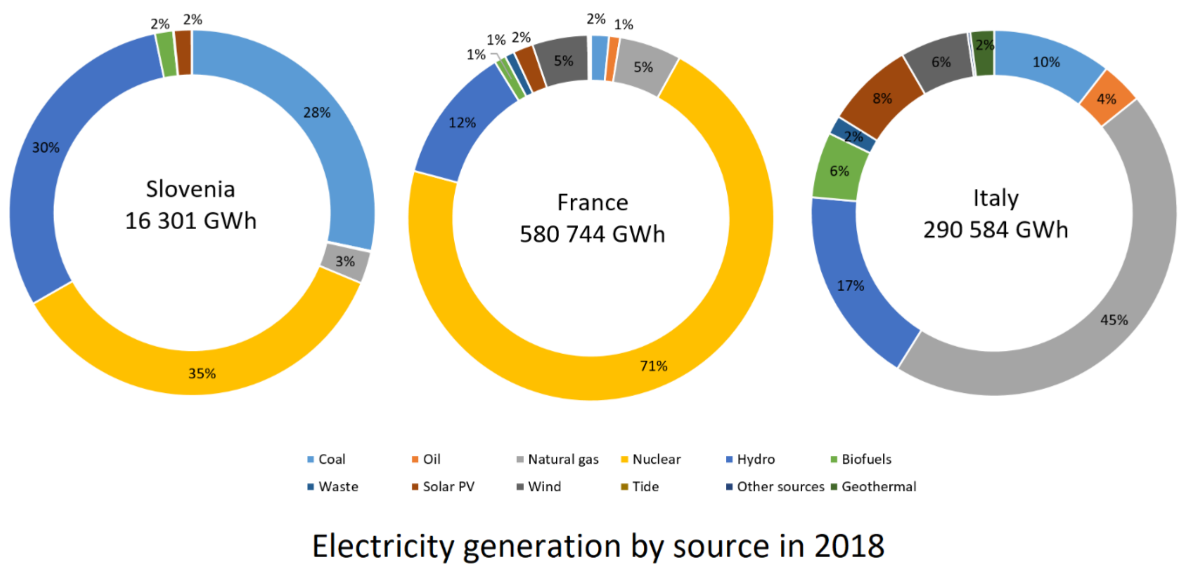


Figure 65 – Comparison of electricity generation by source in Slovenia, France and Italy in 2018. Source: IEA.

Compared to Slovenia or Italy, the French energy mix is therefore not suitable for guarantying the power balance as only 21% of the French electricity production can be modulated up or down to meet a one-off energy demand.
On the other hand, the Italian means of electricity production can still easily adjust their production to meet a one-off energy demand. In facts, 84% of the Italian electricity production is carried out by flexible, but carbon-intensive means of production.

5.2.2. Which requires flexible means of production

The power grid frequency is used to characterize the balance between electricity production and consumption. The normal frequency of the European network is 50 Hz.
When the frequency is higher than 50 Hz, the production is in excess compared to the consumption of electricity. When the frequency is less than 50 Hz, the means of energy production cannot supply all consumers. (Figure 4)

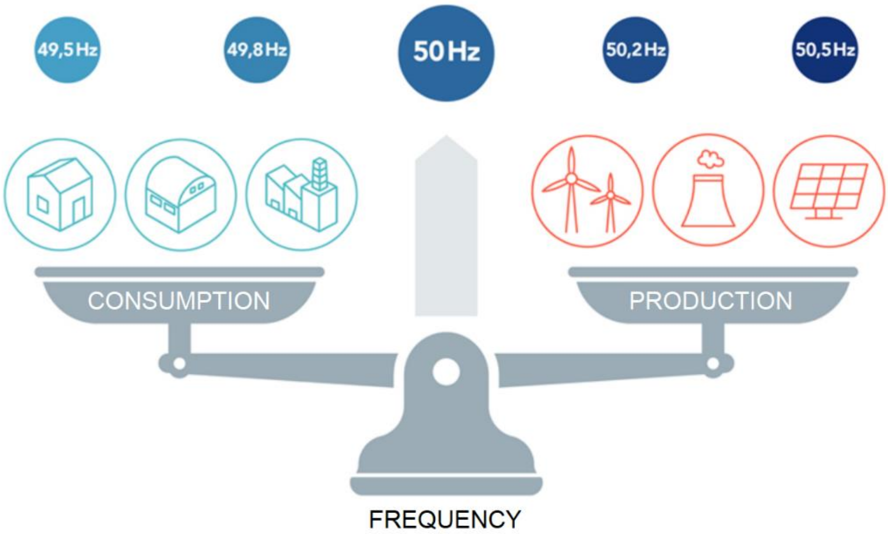


Figure 66 – Evolution of the grid frequency as a function of the balance between electricity productions and consumptions.

In order to restore the balance between production and consumption, electrical mechanisms are set up automatically: Power grid system services.
The primary reserve, composed by all European producers with flexible means of electrical production, is activated automatically (in less than 30 seconds) upwards or downwards when an imbalance is detected. This primary reserve amounts to 3,000 MW, including 600 MW for France. It makes it possible to restore the observed power deficit or surplus and thus stop the drift.
The following focuses on the example of France. In the event that activation of the primary reserve is not sufficient to restore the balance, the secondary reserve is then activated automatically over a time interval between 30 seconds and 15 minutes. This reserve between 500 and 1,000 MW is called up to restore the frequency to 50 Hz. It is only made up of electricity producers located in France, whose operating power is greater than 120 MW. Producers participating in the secondary reserve must permanently keep available power of at least 120 MW.

Finally, the tertiary reserve can be manually activated by the electricity transmission manager thanks to the adjustment mechanism. It is used to supplement the secondary reserve if it is exhausted or not sufficient to deal with the power grid imbalance. It can also intervene in place of the primary and secondary reserves or even anticipate a frequency imbalance. Different actors can participate in the adjustment mechanism such as producers, consumers or demand response operators. Unlike primary and secondary reserves, the tertiary reserve can therefore be ensured by eliminating electricity consumption.

5.2.3. Towards a decentralized Smart Grid system which requires flexibility in electrical use

It is on this very model of a tertiary reserve that Smart Grid technologies are emerging at a local level, on the scale of a territory, a city, a district, or even a building.
In order to guarantee the balance between electrical production and consumption, flexibility is no longer limited to the means of production but also to the uses of electricity.
Smart Grids use computer technologies to enable real-time communication on the electrical status of power grid at the local level. This real-time communication allows to activate or not the flexibilities of production, consumption or storage, upwards or downwards according to their respective availability. In a Smart Grid, all the local players therefore play a role in guaranteeing the balance between production and consumption. The main difference with tertiary reserve mechanisms lies in the absence of an electricity market. In a smart grid, all the players are involved according to predefined scenarios and priorities.

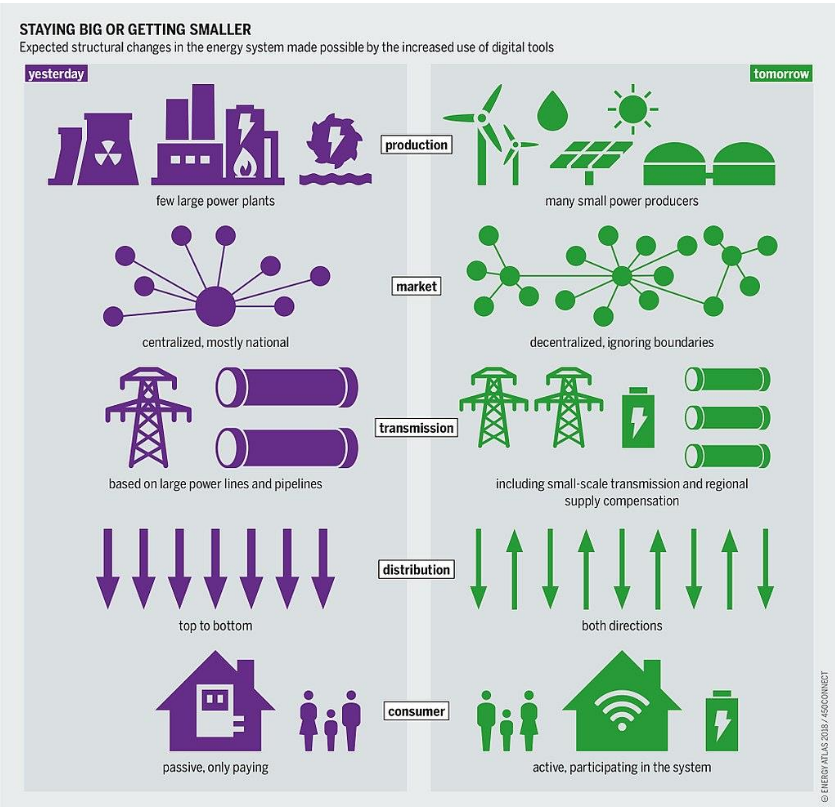


Figure 67 – Evolution of the energy systems made possible by the increased use of digital tools. Source: Energy Atlas.

5.2.4. Which technical solution to manage the electrical balance of a Smart Grid?

The implementation of a Smart Grid is mainly based on the setting up of a communication infrastructure between all the different electrical systems within a defined perimeter.
This communication infrastructure is based on smart meters for energy production and consumption. It encourages consumers to use energy when it is most abundant. Conversely, consumers are requested to limit their energy use when energy production is low.
The modulation of energy consumption, upwards or downwards, can be done manually or automatically. Manually, a request can be sent to the various consumers depending on the availability of energy. This solicitation, whether coupled with financial incentives or not, is therefore based on the virtuous behaviour of consumers.
When the Smart Grid is coupled to an Energy Management System (EMS), it is possible to modulate energy use upwards or downwards automatically. This Smart Grid model is then based on the coupling between sensors and communicating actuators allowing remote control of energy use. Predefined scenarios allow the selection of the uses to be deleted/activated according to their current state and the available energy. These scenarios are defined by artificial intelligence algorithms to guarantee the energy efficiency within the perimeter of the Smart Grid.
For example, in the context of a “smart mountain grid”, a typical predefined scenario could be to reduce the speed of a chairlift by 10% to compensate for the loss of solar production due to a cloudy weather. The selection of the chairlift in question will be made on the basis of the current consumption of all the ski lifts and on the basis of the real time traffic. The choice to modulate the speed of a chairlift rather than to play on the snowmaking system is made by the operator’s hand, by defining beforehand the priorities of clearing between the different uses. At any time, the ski resort operator can regain control over the predefined scenario and modify the actions manually.

5.2.5. Which electrical systems can participate in the power balance of a Smart Grid?

Every electrical system of the defined Smart Grid perimeter can participate in the power balance.
We thus find:

- Electrical supply systems:
  - European power grid
  - Local self-consumption production systems
    - Photovoltaic
    - Wind farms
    - Hydro power
    - Biomass
    - Etc.

- Electrical storage systems:
  - Batteries
  - Compressed Air Energy Storage - CAES
  - Hydro pumped energy transfer station
  - Heat storage (hot water for instance)
  - Etc.

- Electricity consuming systems:
  - Ski resort related systems:
    - Ski lifts
    - Snow making systems
    - Heating of operating buildings
    - Etc.
  - Other electricity consuming systems (not specific to ski resorts):
    - Heating of residential and tertiary buildings
    - Hot water production for residential and tertiary buildings
    - Lighting of residential and tertiary buildings
    - Public lighting
    - Charging stations for electric vehicles.
    - Heat pumps for swimming pool
    - Ice production for rinks
    - Etc.

There is no minimum power limit to participate in the power balance of a Smart Grid. However, the most energy-consuming systems on the Smart Grid perimeter will be selected as priorities, if their use is flexible.

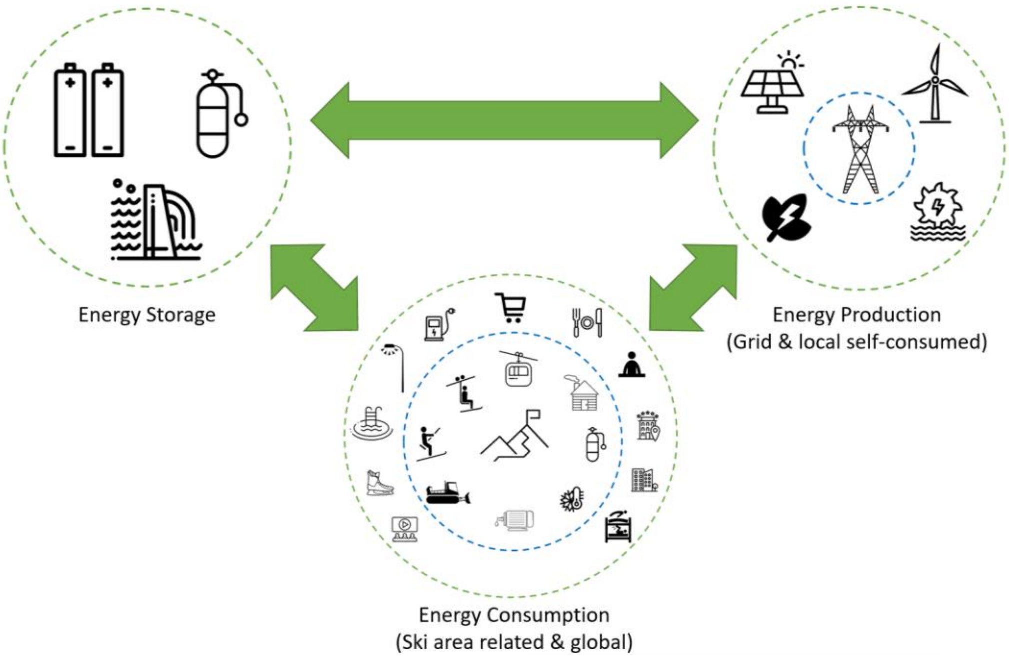


Figure 68 – Energy systems involved in a Smart Grid conception.

5.2.6. What are the benefits of a smart grid?

The main benefit of setting up a Smart Grid is the massive integration of intermittent renewable energies. By modulating energy consumption according to the available power, Smart Grid technologies make it possible to maintain a reliable, durable and secure electricity supply.

For renewable energy penetration rates of less than 10%, the current power grid system can respond to intermittent production. For rates higher than 10%, Smart Grid technologies are required to ensure that electricity is supplied according to demand.

With the implementation of Smart Grid technologies, the electrical system is also more resilient. Indeed, to face an energy production defect, it is possible not only to modulate upwards the other production systems, but also to erase a whole set of local energy uses.

Finally, Smart Grid systems are of real interest from an economic point of view. On the one hand, the transport of electricity is shortened since the self-consumption of locally produced energy is preferred. Energy transport losses and costs are therefore minimized. The necessary investments in electricity transport infrastructure can thus be postponed thanks to the emergence of Smart Grid technologies.

On the other hand, energy savings are observed by the implementation of a Smart Grid. Some consumption is effectively deferred in order to avoid consumption peaks. The simple display of consumption usage by usage also allows a real awareness which leads to energy sobriety.

In 2030, the overall annual savings linked to Smart Grid technologies should be around 400 million euros / year (Figure 7).

From an ecological and environmental point of view, the energy savings observed and the increase in the penetration rate of renewable energies thanks to Smart Grids makes it possible to drastically reduce the associated carbon footprint. In the United States, it is estimated that the integration of Smart Grids by 2030 could reduce national energy consumption by 12 to 18% and therefore the associated CO_2 emissions (442 million tonnes of CO_2). (source: US department of Energy - Pacific Northwest National Laboratory)

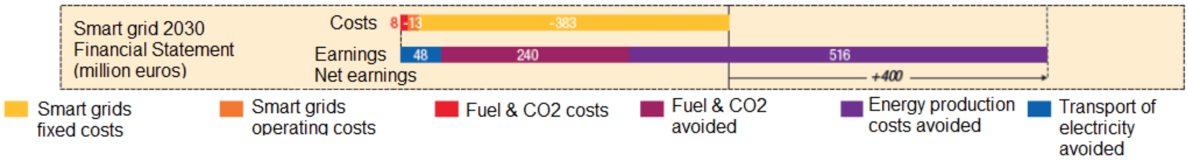


Figure 69 – Smart Grids costs/benefits analysis in France in 2030. Source: www.les-smartgrids.fr

5.3. Field deployment: the example of Les Orres

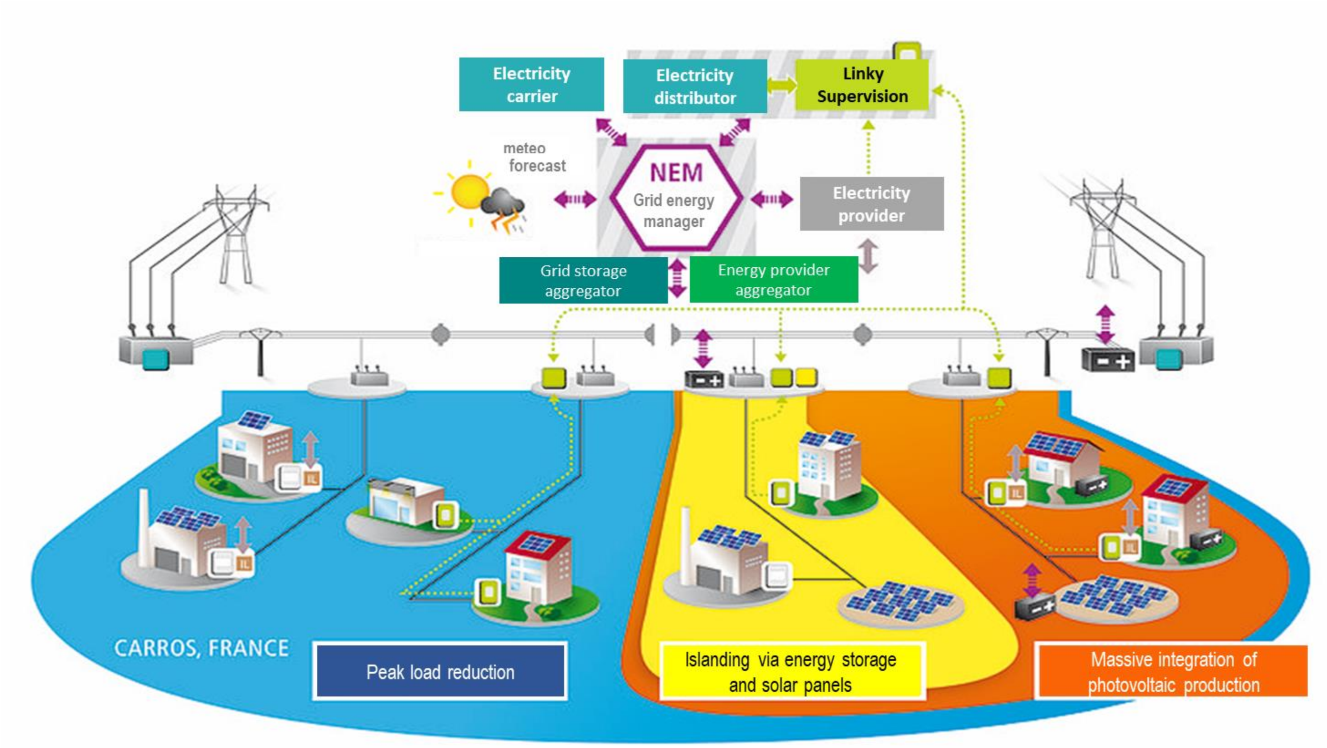
5.3.1. Provence Alpes Côte d'Azur: a region with Smart Grid expertise

5.3.1.1. Description of a smart grid deployment in the Mediterranean Alps

The Provence Alpes Côte d'Azur Region has been conducting several pilot experiments in Smart Grid deployment for several years. These include the Nice Grid project, presented below (sources: Nice Grid website and Wikipedia), led by several players, including Enedis (leader), EDF, Saft, GE Grid Solutions.

NICE GRID is an experimental project launched in the summer of 2011, for a period of 4 years, designed to test the integration of photovoltaic electricity into the electricity grid of residential areas through a Smart Grid. The objective was to experiment with ways of storing the photovoltaic electricity produced and managing local consumption through diffuse erasure and the creation of "solar off-peak hours". The project was extended for one year until the end of 2016.

This project, based in France, in Carros (near Nice), was piloted by Enedis and was part of the



European Grid4EU project, financed over 4 years to the value of 30 million euros, including 4 million by Ademe, the French national agency for energy, and 7 million by the European Commission. It aimed to involve 2,500 homes and businesses in the experiment, equipped with Linky smart meters. This pilot project included 200 sites for the deployment of photovoltaic panels for a total production capacity of 2.5 MWh. To manage this production of electricity from renewable energy sources, a system was installed to store electricity in the form of batteries, distributed at different points on the electricity grid and at volunteer users' homes, capable of storing 1 MW for 30 minutes. This photovoltaic production/electricity storage system is used in another aspect of the Nice Grid project: the islanding experiment. This process consists of running a district of Carros in complete autonomy, for a given period of time, without any electricity input from the external grid.

Figure 70 – The "Nice Grid" Smart Grid -- Source: Thomas Drizard, ENEDIS (captions translated in English).

The "NEM" (Network Energy Manager), or energy network manager, makes it possible to solicit various aggregators, which optimise responses to the constraints observed on the network, depending on the time of day. These responses correspond to local flexibility offers made to participants. They encourage them to shift their consumption when solar production is high, and/or to reduce their consumption during cold peaks. For example, in the summer, in the event of overproduction of photovoltaic energy, they can take up the residential flexibility offers of the aggregator, which proposes "solar bonuses" (solar off-peak hours between 12 noon and 4 p.m.), remote activation of the water heater for voluntary customers, and storage of electricity in batteries. Conversely, in winter, during consumption peaks, the NEM can take up offers of lower heating via the Linky meter or proposals for battery discharge, from the grid battery aggregator.

The NICE GRID project demonstrated the usefulness of the Linky smart metering system as a building block for implementing Smart Grid functions. The experiments made it possible to carry out programmed and unannounced islanding operations, with disconnection and synchronisation phases to the main network without interruption and with no impact on users, and efficient control of the energy storage system's load/discharge cycles.

The project is continuing with several developments under the Nice Smart Valley programme, in particular Enedis' FLEX MOUNTAIN project to secure the electricity supply to the Isola 2000 resort, with the creation of a flexibility remuneration service that can be used to set up a local energy pilot.

5.3.2. Mountain Smart Grid

5.3.2.1. Mountain Smart Grid specificities

Compared to Nice Grid, the implementation of a mountain Smart Grid presents a certain number of particularities that we expose below:

- Smaller territorial dimension
- Seasonality of frequentation and therefore of energy consumption
- A very specific winter evening/night consumption peak (snow production)

- Low summer consumption ((e.g. station operations: energy demand of around 250 kW against a winter power peak of more than 3 MW)
- A potential energy production mix comprising mainly hydroelectric production and secondarily solar and other renewable energies. In Les Orres, the production potential is mainly hydroelectric (23 GWh) and more marginally solar (423 MWh). Wind power does not seem relevant compared to other sites and resorts. Biomass is also used for heating communal buildings, and gas heating for part of the heating installations in tourist accommodation buildings
- An imbalance between consumption needs and production capacity: the needs are greatest in winter when production capacity is low (winter low flow, low photovoltaic production due to the short duration of sunshine and the greater prevalence of solar masks).

5.3.2.2. Why Les Orres

Les Orres resort was a pioneer in the implementation of an integrated energy management system in the Alps by becoming an experimental site within the framework of the European Apine Space ALPSTAR programme, over the period 2012-2014. On this occasion, Les Orres carried out a complete energy assessment of the station's operations and set up an energy management system with the contribution of two design offices: Ecomesures and Roquétude. This action has made it possible to reduce energy consumption by 20%, greenhouse gas emissions by 100 t CO_2 and the station's energy bill by 25%.
Since then, Les Orres has become the "Mountain resort of tomorrow" pilot of FLEXGRID, a programme for the deployment of smart grid solutions led by the Provence-Alpes-Côte d'Azur Region and operated by the Capenergies competitiveness cluster. The resort and the commune of Les Orres have continued their commitment to the deployment of responsible energy solutions, alongside their partners EDF and Enedis, and the commune of Les Orres has become the leader of the Alpine Space SMART ALTITUDE project to extend its EMS to model a real mountain smart grid.

5.3.2.3. Les Orres case study

Les Orres presents the typical mountain specificities as presented in 2.2.1. The table below presents the typology of seasonal energy consumption and production of the diverse equipment being potentially included in the Smart Grid model. The elements presented in the table are qualitative only. In order to successfully implement an efficient model of local energy pilot, it will be necessary to determine as precisely as possible the values of consumption at the appropriate time step for each consumption and production category of equipment.

Electricity Consumption units	Ownership	Type of operator	Winter Season	Summer Season	Off-Season
Ski Lifts	Semlore	Semi-public	H	L	
Snow Production	Semlore	Semi-public	H		
Utility buildings	Semlore	Semi-public	H	L	
Offices	Semlore	Semi-public	H	L	L
Tourism office	Semlore	Semi-public	H	L	
Theatre	Semlore	Semi-public	H	M	
Cultural & leisure center	Semlore	Semi-public	H		
Ice Rink	Semlore	Semi-public	H		
Swimming pool	Municipality	Public		H	
School	Municipality	Public	M		M
Town hall	Municipality	Public	M	M	M
Other public buildings	Municipality	Public	M	M	M
Fire & rescue center	Department	Public	M	M	L
Health Centre	Municipality	Public	H	M	L
Tourism residence	Joint	Private	H	M	
Condominium	Joint	Private	H	M	L
Hotel	Personal	Private	H	M	
Stores & shops	Personal	Private	H	M	
Individual housing	Personal	Private	H	L	L
Energy production					
Photovoltaic/parking	Municipality	Private	L	H	M
Photovoltaic/roof	Municipality	Private	L	H	M
Hydroélectricity	Municipality	Semi-public	M	L	H
Other (biomass)	Private	Private	H	L	M

Table 18 – Energy consumption and production by category of equipment over time periods. (L: Low ; M: Medium ; H: High)

Unlike Nice Grid, the aim is not to adopt a total islanding approach, but to achieve the best possible balance in the system in order to reduce consumption and greenhouse gas emissions, as shown by the introduction of the EMS, and to reduce the impact on the networks of the seasonality of demand. In this respect, the integration of tourist housing into the overall system offers much greater scope for erasing consumption peaks through the new diversity of uses provided, including through the storage of energy by hot water tanks.

It should be noted that Les Orres, a pilot station for the deployment of Linky smart meters through an agreement with Enedis, is now fully equipped with these devices, the importance of which Nice Grid has demonstrated for grid management. The energy sensors can be connected to the TIC (customer information contact) of the Linky smart meter to transmit the history of electricity consumption or production information and transmit the measurements in real time via IP gateways to the hypervision solution that constitutes the local energy pilot. The local energy pilot can control load shedding and other regulation or adjustment operations via various IP-bus field gateways that route orders directly to the equipment.

For the organisation of an energy management system, please refer to deliverable D.T1.2.1. Live monitoring system specifications. The diagram below shows the constituent parts of the

Orres smart grid with the central position of the local energy pilot, interacting with the station EMS, the public lighting supervisor, and the various monitoring and control equipment that will be installed in public and private facilities and tourist accommodation buildings.

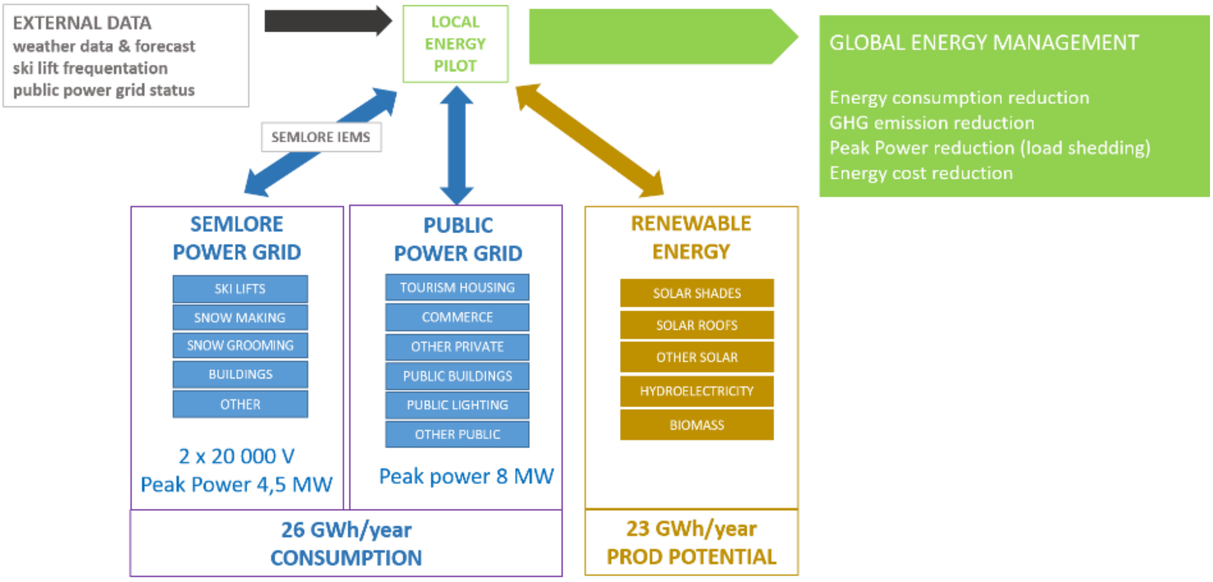


Figure 71 – Organizational principle of Les Orres' Smart Grid

5.3.2.4. Rollout – Deployment of mountain smart grids

The resort of Les Orres has a certain number of specificities which do not necessarily correspond to the conditions that all Alpine resorts are confronted with:

- In France, as previously mentioned in the first part of this report, electricity is more decarbonised and cheaper than in most countries of the Alpine space.
- Consequently, most of the heating of tourist accommodation is electric, which reinforces the interest of integrating this component into a smart grid approach by the high regulation and energy demand erasing capacities it represents.
- The renewable energy production mix can vary considerably depending on the geographical context and available resources.
- The typology of stakeholders can vary considerably from one country to another, and even within the same country. Les Orres has the advantage of having a semi-public operator with the municipality as major shareholder, which facilitates integration between the public (municipality) and the semi-public (resort operator) in a common Smart Grid approach. However, the integration of the private party is complex to implement, due to the multitude of players involved (multi-owner tourism housing).

The following diagram is a simplified process flow proposal of the functional design of a mountain microgrid, adaptable to each configuration.

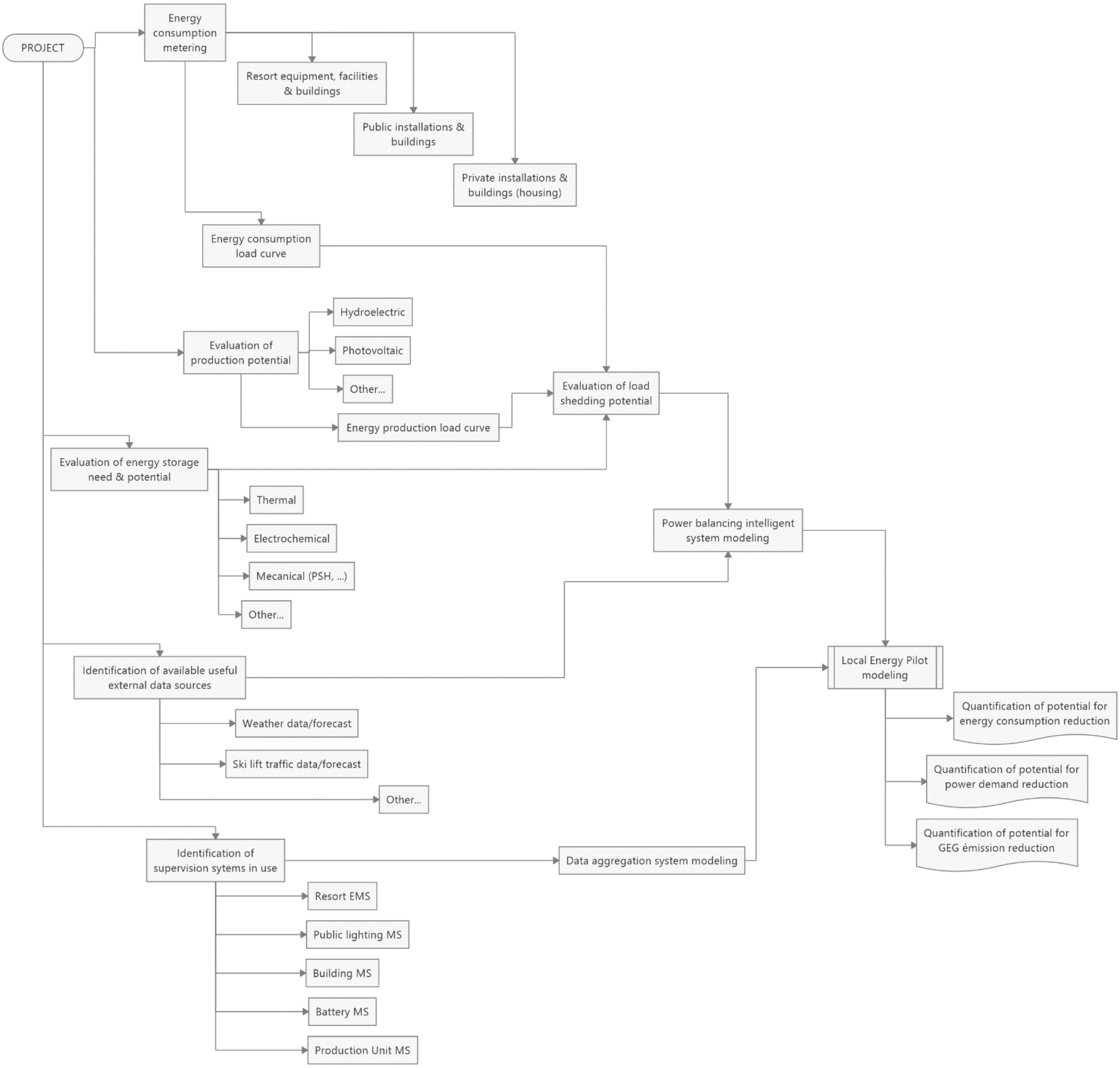


Figure 72 – Simplified process flow of a mountain smart grid design.

5.4. Conclusion

This report has attempted to highlight the characteristics of Smart Grids, their advantages and conditions of deployment. The approach was then clarified through an example of the deployment of a Smart Grid experiment in the Mediterranean Alps (Nice Grid), followed by a presentation of the constituent elements of the Smart Grid in Les Orres, and finally an approach to generalise the approach to all mountain territories.

However, certain conditions of deployment are not addressed here, in particular the administrative and regulatory aspects specific to each country. In France, the Commission de Régulation de l'Energie (CRE) recently adopted the principle of experimentation territories within a framework that derogates from the conditions set by the texts on collective self-consumption, in particular. The notion of local energy communities is emerging at the European level, which over time would eventually remove the obstacles to the deployment of local Smart Grids at the resort level. Recommendations for territorial policy makers to facilitate the deployment of mountain Smart Grids will be further developed in the framework of the Smart Altitude project.

6. Implementation Model: Value creation through low-carbon innovation

Document: Public/Confidential
Responsible partner: S2i (Yann Bidault, yann@ybsolution.com) **Involved partners: S2i, FBK, Les Orres, CREM, RTC Krvavec**

Strengths • What do you do well? • What unique resources/ assets can you draw on? • What will others perceive as your strengths?	**Weaknesses** • What could you improve? • Where do you have fewer resources / assets than others? • What will others perceive as weaknesses?
Opportunities • What opportunities are open to you? • What trends can you take advantage of? • How can you turn your strengths into opportunities?	**Threats** • What could harm you? • What are your competitors doing? • What threats do your weaknesses expose you to?

6.1. Executive Summary

As any business, ski resorts need to innovate continuously in order to survive. This need is now becoming particularly pressing due to the challenges posed by physical impacts of climate change on the one hand and regulatory and legal obligations related to climate change mitigation on the other. Successful innovation management will ensure that ski resorts do not just survive, but create value for their businesses and for their customers.
This short guide to creating value from low carbon innovation will introduced the most important aspects and tools to consider when a ski resorts wants to innovate. Tools such as PESTEL and SWOT will be introduced in order to facilitate a sound understanding of the status quo of a ski resort and identification of its innovation needs.
In order to carefully plan for an innovation all implications on the supply-side and customer-side need to be understood. The value chain analysis can help with this this will then help to

crystallise the value proposition. The five forces of Porter[2] help to fine-tune the innovation and its market entry. Green or sustainable procurement can play a powerful role in fostering innovation and the most important aspects will be introduced.

Throughout the examples from SMART ALTITUDE pilots illustrate what innovations in ski resorts are possible and appropriate while also providing an understanding of barriers encountered and various contextual factors which allow for successful implementation of innovations.

6.2. Introduction

The reason many companies are constantly pursuing innovation is the need for continuous growth by increasing their performance [3]. Two main types of activities can be found in organizations: exploration which can be defined as searching for new knowledge whereas exploitation can be defined as extracting the most payoff from existing knowledge[4]. Often a business or organization may only focus on just one of these. However, exploration in itself does not necessarily generate returns and can only be sustained relying on external funding sources sustain (e.g. grants). Relying on exploitation entirely on the other hand harbors the risk of a business being obsolete as it is outperformed by a competitor who explores and subsequently exploits more powerful and valuable knowledge asset. Businesses therefore need to embraces both of these actions.

Ski resorts typically have been relying rather similar business models and value propositions for a long time. They do not face the same competition as for example technology companies, who are constantly being challenged by new internet offerings or start-ups. In the absence of such competition, existing ski resorts traditionally did not need to spend much effort in innovation[5].

Mountain resorts and in particular ski resorts are facing particular pressures to innovate, as in the longer term the current way of operating these resorts is threatened by climate change.

Even though some cynics may mainly see it as marketing trend, global warming is a major threat for the future of humanity. It also heavily affects the climatic evolution of the mountain areas, with less snow and milder winters. Some low-altitude resorts are already threatened by closure.

At high level, there is a strong need for ski resorts to be innovative in order to persist, both as tourism destinations and functioning local communities. Two key aspects can be defined:

[2] Porter, M. E. (2008). The five competitive forces that shape strategy. In Harvard Business Review - HBR's Must-Reads on Strategy (pp. 25-40).

[3] E.g. Chesbrough, H. W. (2007). 'Business model innovation: It's not just about technology anymore', Strategy and Leadership, 35: 12-17; Johnson, M. W., Christensen, C. C., and Kagermann, H. (2008). 'Reinventing your business model', Harvard Business Review, 86: 50-59. And others

[4] March, J. G. (1991). 'Exploration and Exploitation in Organizational Learning', Graduate School of Business, Stanford University.

[5] Cabani, A.P. (2015) Master Thesis: Innovating Ski Resorts' Business Model through a human centered approach, Lausanne

- The need to counteracting the effects of climate change with less predictable and less plentiful snow conditions, but also increased probability of severe weather events
- The need to sustain the livelihoods for local mountain communities.

There are also a number of more tangible practical issues driving innovation to name but a few:

- Energy costs and water costs associated with snow making and accommodating tourists are high and may increase.
- Traffic flows resulting from ski tourism can be disruptive to both locals and the visitor experience.
- Competition with other resorts mean that attractivity and image have to be continuously maintained and improved, be it by updating aging infrastructure or responding to increased climate change awareness.

Snow is the main asset for ski resorts. Yet it can be expected that the amount of snow in the Alps will be 30 percent less towards the end of the century, even if the efforts of achieving a 2-degree warming limit were successful, on the current trajectory it may be 70% less. Resorts below 1200 m are especially threatened[6]. Two distinct approaches need to be considered:

1) Resorts need to do their best to reduce their GHG-emissions in order to safeguard their own interests, by lowering the energy consumption through better control and management and developing local capacities of green energy.
2) Resorts need to prepare for the likely changes in climatic conditions to future proof their local communities and economic interests. This in turn means to optimise artificial snow making where temperatures allow on the one hand and on the other hand, reducing their reliance on skiing by diversifying resort activity towards all-season attractivity.

This document will mainly focus on the first aspect and show a pathway for resorts to benefit from endeavours in this direction by creating value through low-carbon innovations. There are many required technical solutions and precedents and good practice examples of organisational change which are ready to be transferred to mountain resorts. However, while these solutions may no longer count as innovations, even the integration of solutions which are already mature and proven in other context will require organisational innovations to adapt them to the specific conditions in ski resorts. Hence, this document intends to provide a roadmap for mountain resorts to innovate, by guiding them through a process of status quo analysis, identification of innovation requirements and aspects to be considered when developing innovations. There is some evidence that procurement can be a cost-effective instrument to trigger innovation, especially as and when public bodies are

[6] Marty, C., Schlögl, S., Bavay, M. and Lehning, M. (2016) How much can we save? Impact of different emission scenarios on future snow cover in the Alps, The Cryosphere, 11, 517–529, 2017 https://doi.org/10.5194/tc-11-517-2017 https://www.the-cryosphere.net/11/517/2017/ accessed Feb 2020

involved. Hence this topic is covered, too.[7] Based on a qualitative questionnaire survey undertaken, prior to compiling this document, the examples from SMART ALTITUDE pilots provide illustration as to what innovations in ski resorts are possible and appropriate while also providing an understanding of barriers encountered and various contextual factors which allow for successful implementation of innovations.

6.3. PART 1 – CHALLENGES MEET INNOVATION

6.3.1. Challenges for Mountain Resorts – Drivers for Innovation

The overall situation set out in the introduction is reflected in a number of typical challenges now faced by mountain resorts, which go beyond the aforementioned threats to snow. These combined provide strong drivers for innovation in order to future proof resorts. The challenges faced by the SMART ALTITUDE pilots are typical for many ski resorts and can be summarised roughly as changing local climate with associated energy and water challenges, the resulting need to adapt or diversify, competition with other ski resorts, local and regional policies and targets, the need to address the global climate crisis. SMART ALTITUDE pilots consider competition with other ski resorts the most important driver. However, innovation is also often driven by the personal motivation of some individuals or by innovative companies proactively promoting their solutions.
All of these drivers put together reveal a need for sound long-term planning in order to safeguard the long-term wellbeing of local communities. This requires a change from short-term thinking and innovative approaches. Low carbon innovations play an important role in this context.

6.3.1.1. Typical Ecological Challenges in Ski Resorts

Though not stated as important drivers by the pilots there are a number of typical ecological threats and challenges faced by ski resorts:

- Ecological and environmental issues arising from tourism: loss of bio-habitats, loss of eco-systems services provided by these,
- increased risk of landslides through deforestation and increase of severe weather events
- impacts on water management due to snowmaking
- impacts resulting from transportation needs: traffic jams, traffic chaos, disorderly parking, air quality, noise

[7] Aschhoff B., W. Sofka (2009), "Innovation on demand – Can public procurement drive market success of innovations?", Research Policy 38 (2009), pp. 1235–1247, Elsevier

6.3.1.2. Competition amongst Resorts and Growing Demand for Green Resorts

The Smart ALTITUDE resorts are generally some of the most popular and well- known ski-areas in their respective regions. Their aim is to maintain and capitalise on this competitive advantage.
Madonna di Campiglio's strategy is to provide high-quality ski-slopes and *ski-lifts with perfect snow conditions during the whole season. This requires modern infrastructure and dynamic management supported by real-time data.*
Similarly, Verbier sees the need to keep investing in ski lifts and slopes (snow cannons, groomers, etc) in order to maintain its attractivity and its competition advantage. Nowadays, the importance of "greenness" has become very important in this regard.
Similarly, some resorts have to adapt to growing demand – Krvavec is very popular, as it is somewhat less expensive than many competitors. The destination has not enough accommodation to meet demand, so the plan is also to increase accommodation capacity. Furthermore, a new 6 chair lift with two new slopes on Jezerca together with 1000 car parking spaces are being planned.
All SMART-ALTITUDE pilots report a growing awareness of environmental and climate change related issues amongst tourists and the demand for green resorts. Climate change has become a trending topic, which drives the top management of ski resorts to become interested in innovation and sustainability both as an operational matter as well as a marketing tool to promote their resorts to "green" customers.

6.3.1.3. Climate Change Adaptation – Energy and Water Challenges

All Smart Altitude Pilots experience the lack of natural snow at times, due to changing weather condition and rising temperatures while wanting to extend the skiing season. Hence, they needed to look for alternative solutions such as artificial snowmaking to guarantee a longer ski-season, which however, brings its own challenges.
The snow-making process requires high energy and water. Especially the water consumption can impact on local water management and ecosystems along water bodies, if not carefully managed to ensure an optimal and sustainable use. It also faces competing uses from local agriculture.

6.3.1.4. Concern for the Local Community

Most mountain communities are extremely dependent on tourism activity, which brings financial resources and seasonal employment. This in turn can result in a number of challenges such as

- Competing interests for land-use between agriculture, eco-system services provided by forests and skiing/ tourism
- Foreign investors into tourism influencing or dominating local agendas

- Dominance of seasonal workers in tourism, who will not feel responsible for the local area
- Rising property prices driving out locals
- Lack of job opportunities beyond tourism driving out the younger generation

Nevertheless, it is of the outmost importance to protect the local permanent population from the economic risks of a decrease in resort activity, which may result from climate change. This threat is also an opportunity to reconsider the economic model of mountain areas, i.e. decoupling income streams from tourism by developing full-time jobs and year-round activities, e.g. through local green-energy initiatives, short cycle farming and new services for the local population. Resorts and their surrounding communities can be future proofed if the local population is supported in managing and taking charge of the sustainable development of their community and territory.

6.3.1.5. Local and Regional Policies and Targets

Ski resorts are affected by the agenda of the local authority area and region they sit in. Driven by initiatives such as Covenant of Mayors as bottom-up movement or by top-down targets of national governments and the EU, more and more authorities have set their own targets regarding GHG-reduction or other environmental impacts.
For example, the Municipality of Bagnes (CH) to which Verbier belongs, is a “Cité de l’énergie”. This means it has defined objectives in terms of renewable energy production, reductions of energy consumption and greenhouse gas emissions. The label confirms that the municipality has implemented an energy policy and climate policy which are both coherent and pragmatic. The label concerns six sectors which are: Spatial planning, Municipality Buildings and installations, supply and decontamination, mobility, internal organisation and communication and cooperation. In 2018, Bagnes reached the score of 66%. In a next step, the ski resort of Verbier will be brought in line with the scheme and actions regarding low-carbon policy will be taken.
New legislation in the Swiss Canton of Valais is going to be set in place regarding large customers, such as ski resort operator, to oblige them to organise and plan actions in order to reduce their C02.
Therefore, the lift operator Téléverbier acts in an anticipatory manner in order to respect the new legislation. Furthermore, federal institutions or schemes (e.g. ProKilowatt, a swiss funding programme) support efficiency measures which reduce energy consumption. These motivate ski resorts and help them to invest in innovative technology.

Since 2016, Téléverbier has a so-called Quality-Security-Environment (QSE) policy which is included in the company charter, stating that the company implements appropriate solutions to reduce the impact of their activities in the areas of electrical energy and fuel consumption and also that they commit to promote the cautious use of resources and the environmentally sound waste disposal. Smart ALTITUDE-Partner FBK will collaborate with Trentino Sviluppo and cable car operator Funivie Madonna di Campiglio in designing a medium-term strategy to reach the goal of “Zero-Emission 2026”. Starting with Smart Altitude, the strategy will target three main areas: energy efficiency, integration of renewable energy and CO_2-emission offset. For example, the offsetting of CO_2 emission will include a joint forest planting and conservation project with the nature park "Adamello-Brenta".

6.3.1.6. Personal Motivation of Influential Individuals

Less of a challenge but all the more powerful as driver, both in Les Orres and Krvavec low-carbon innovation is driven to a large degree by influential individuals and their vision and sense of responsibility for the area. In Krvavec it is the operator of the ski resort, in Les Orres it is the mayor. The latter is deeply concerned with the various problems threatening the future of mountain resorts and territories. Since 2015, the international OCOVA[8] annual forum, which was created by the mayor of Les Orres in 2004, is held in Les Orres and totally focused on the mountain resort of tomorrow in all their dimensions: energy, mobility, all-season attractivity, governance and model evolution.

6.3.1.7. Innovative Companies Promoting their Solutions

Similar to influential individuals at the client side, partners at the supply side can sometimes "push" innovations, rather than being "pulled" by demand. Supplier-Partners of resorts want to increase their business by proactively offering new solutions to their clients. For example, Madonna di Campiglio is collaborating with local start-ups (e.g. Energenius) to develop, implement and replicate the new technologies over the territory of Trentino.

6.3.2. What are Low-Carbon Innovations for Mountain Resorts?

It is not the part of the scope of this document to provide a comprehensive overview over low carbon innovations – much of these are covered in the other SMART ALTITUDE implementation models. This document concentrates on the processes needed in order to create value for mountain resorts from such innovation. Nevertheless, examples from the pilots and a brief overview will be provided over typical low-carbon innovations currently found in mountain resorts, in order to set the scene. The measures do not just address carbon emissions from energy but also the ability of ecosystems to absorb CO_2.

6.3.2.1. Energy Management

Good energy management is central to reducing carbon emissions and can be financially lucrative. For example, in Les Orres', integrated energy management system (IEMS) is a good example of the entire process of implementing an innovative solution. It was the first fully integrated solution set up in an Alpine resort to monitor, control and command all points of energy consumption of the resort operations (ski lifts, snow making, heating systems of buildings). Although the technology is mature as far as sensors, energy automation, radio networks and data aggregation platforms are concerned, there was no off-the-shelve solutions available which was adapted to mountain resorts operations.

[8] https://www.ocova.eu/

Therefore, an innovative user-centric and co-creative approach was required to correctly define functional specifications matching the identified needs, then implementing the smart integration of technological building blocks, developing a data integration and analysis platform with user interfaces adapted to the business contexts. The developed system is flexible and constantly evolving to better fit new or changing needs. For example, control-command systems in the energy transformers are now powered by a combination of solar panels and batteries, so that it becomes possible to disconnect those transformers during the summer season when the equipment they power are not in use. This saves the energy related to core and copper losses of connected transformers.

From an organisational viewpoint, the equipment introduction was accompanied by a staff training process, leading to an ISO-50001 quality approach. This shows that introducing such an innovation into the way energy consumption was being dealt with in the resort operations is related both to technical and organisational aspects.

In Verbiers too, an integrated energy management system was implemented, which monitors the energy consumption for building heating and motors in real time. The platform can also interact with various systems such as temperature setpoint and it can send multiple alarms. It can also show the renewable energy potential of the ski resort.

In Madonna di Campiglio an integrated energy management system (IEMS) for the resort has also been implemented. It is a digital platform that collects and integrates real-time data from the mountain environment and skiing infrastructure. It monitors plant operation and the consumption of energy and water, generates reports, sends notifications and makes forecasts. The main goal is to use it as an integrated decision support system for environmentally sound decision making. In the IEMS, data is divided in 7 categories: electric grid data, snow production data, lake monitoring, snow grooming, weather, ski lifts and data related to skiers. The IEMS integrates 10 platforms: 2 new and 8 old monitoring systems.

SMART ALTITUDE INNOVATIONS in LES ORRES

In future, the IEMS implementation will be extended into a microgrid approach. It will integrate some major new points of energy consumption in tourism housing. It will also integrate the local green energy production which increases the resort's energy autonomy. In fact, the Smart Altitude project in Les Orres has the main purpose of building a local energy pilot system model for further implementation in years to come. Because of the diversity of stakeholders (energy producers, public organizations, timeshared properties, properties in multiple ownership, private operators…), there is a need for regulatory evolution and innovative models allowing the creation of peer-to-peer energy community. The Smart Altitude project is an opportunity to identify, list and submit these needs to the relevant European and national decision-making institutions.

6.3.2.2. Low-Carbon Technologies

The range of low-carbon technologies, which can be used in ski resorts is vast – the below are examples from the pilot resorts, some are still at the feasibility stage:

- Implementation of a heat pump for heat valorisation of motors to heat offices in the building nearby with an average COP of 6.
- Replacement of old inefficient motors by new ones which are much more energy efficient
- Replacement of a cable car lift motor by a new direct-drive system saving up to 20% of energy consumption.
- Comprehensive energy strategy for a building consuming a lot of energy – cornerstones of the strategy are recovery of heat from a motor, PV solar panels for electric needs, wood fire burner for heat generation and eventually small-scale district heating for the buildings nearby.
- Studying the potential of PV for ski-lifts and the use of heat-pumps using ambient heat for heating the snow-groomer workshop. The study will analyse the availability of renewable sources on site, the sizing of the technical solutions based on resource availability and user demand, the monitoring, the costs, and CO_2 emission-savings. (Madonna di Campiglio)
- Replacement of the heating system in cable car stations (Krvavec)

Measures found in other ski resorts include:

- Energy recovery on the down-hill journey of rack-and-pinion railways (e.g. at Zugspitze, DE)
- PV-installations which will compensate the energy used by lifts over the year. (e.g. at Wildkogelbahnen, DE, Europe's highest PV-park at 2.100 m above sea level, which covers 75% of electricity used.
- Replacement of large oil boilers with wood pellet boilers
- Comprehensive building insulation programmes

6.3.2.3. Snowmaking and Water Management

As explained previously, it is artificial snowmaking which is responsible for the high energy and water consumption and resulting environmental impacts of ski resorts. Therefore, tackling improvement potentials in this area have to be prioritised above all else.

In Krvavec a second much larger reservoir lake for snowmaking capacity for 100.000 square meters will be built in 2021 . It will have summer uses and can be used for preventing forest fires. The new lake will reduce energy consumption from pumps which currently have to refill existing lake several time.

For snow making for Madonna di Campiglio Intelligent water monitoring was implemented on Lake Montagnoli. The activity consisted of installation of 2 floating devices with an array of temperature sensors. The sensors provided real-time data on the water temperature at different depths, water surface and weather conditions. The collected data supports the optimization of the artificial snow production process thus saving energy and water and recovering heat.

Other measures found in ski resorts include:

- Using precise forecasts for seasonal snowfall and temperatures in order to optimise snow-making conditions[9]
- Low-energy snow canons and lances, e.g. a snow lance not requiring a compressor (e.g. in Davos[10])
- Snow-farming: storing snow in cold spots and covering it with insulation material throughout summer which can be redistributed in the next season, reducing the need for snowmaking (e.g. in Kitzbuehel). [11]
- GPS-guided snow-management to optimise snow-thickness, which substantially reduces the need for snowmaking (Energy savings of 600 MWh/ year and water savings, e.g. in Kitzbuehel, AT)
- Using snow lances in combination with a storage lake at higher altitude feeding the lances solely with gravity, eliminating the need for pumping.
- Combining snow-making infrastructure with a hydropower station, which provides power all year round (Rauris in Pinzgau, AT)

6.3.2.4. Transport

Transporting tourists to their desired resort and to the ski lifts is one of the challenges for ski resorts.
In Verbier a brand-new train station has been inaugurated recently, making Verbier now easily accessible by public transport. Lift operator Téléverbier offers the option to travel by train from Geneva for free.
Madonna di Campiglio is planning for electric mobility. The resort will analyse the current and future user-demand for charging electric vehicles, the needed charging infrastructure, the impact on the electric grid and a potential energy management plan for electric mobility.
Other transport measures found in ski resorts include:

- Car-free access schemes by providing adequate public transport and discouraging individual car use through punitive fees for parking.
- train station servicing main ski lift with free ski-bus travel to other nearby, including some electric busses, ski-coaches from larger towns in the region (Kitzbuehel, AT)

6.3.2.5. Climate Change Adaptation

Adapting to the changing climate will require large scale innovative solutions, which are only beginning to emerge. Some examples are:

- Geofabric on glaciers in summer to reduce melting (e.g. in Passo del Tonale)
- Skiing-Pistes made from high-tech materials such as textile mats, which can even be used in summer temperatures (e.g. in Mariaalm, AT)[12]

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[9] http://prosnow.org/portfolio/le-projet-prosnow/ - accessed 28.02.2020
[10] https://www.deutschlandfunkkultur.de/kunstschnee-umweltfreundlichere-schneekanone.1067.de.html?dram:article_id=275509 - accessed 28.02.2020
[11] www.snowplaza.de/weblog/7822-snowfarming/

- Dealing with economic impacts resulting from climate change by diversification of tourism offers, which can go as far as closing lower lying ski-resorts and finding new uses for these areas e.g. by creating nature reserves or nature parcs.

6.3.2.6. Organisational innovations

Creating tourism associations in which several resorts pool together their resources, define a unified strategy for local transport and other climate friendly offers (e.g. www.alpine-pearls.com)

Also, in Ponte di Legno/ Passo del Tonale an association of all lift operators "consorzio" was created, which is funded by all lift operators . All ski passes are issued by the consorzio and earnings are split between them in a fair way, based on a number of criteria. This allows for coordinated activities to further develop the tourism offer and marketing instead of lift operators competing against each other. It also allows for greater professionalism, while lifts and hotels remain in the hands of small family businesses. For example, prestigious additional attractions such as "Ice Music Festival" could be realised this way.

6.3.2.7. Ecological measures

The creation and maintenance of ski pistes often represents fundamental interventions into landscape, forest cover, and bio-habitats. A number of practices can reduce the resulting impacts.

- "Waseln" – a practice which consists of removing and storing the topsoil layer during construction works in order to reapply it after the end of works [13].
- Renaturing / replanting of pistes which do not have vegetation.
- Include ecologists in planning and implementation of construction projects.

6.3.3. Creating Value – The Benefits of Innovation

The main intend of the implementation model at hand is to emphasize the value which can be created for ski resorts by embarking on a journey of innovation in order to address the challenges and drivers identified earlier and contributing to decarbonisation in particular, while safeguarding their attractiveness, economic viability and benefits for the local community.
Much can be learned from the Smart Altitude Pilots in that regard, with main benefits arising in terms of operational cost savings, marketing benefits and improved visitor experience.

[12] www.aktiv-online.de/news/innovativer-stoff-ski-piste-aus-hightech-material-koennte-zum-exportschlager-werden-2773
[13] https://www.skiresort.info/ski-resort/kitzbuehelkirchberg-kitzski/test-result/eco-friendliness/

6.3.3.1. Operational Costs

Typically, energy is the second biggest expenditure of resorts after staff cost. Hence cost savings are a strong incentive for implementing energy saving innovations.
In particular for Krvavec the most important criteria for business management decisions is costs. Especially the costs for electricity and gas drive their decision to implement an EMS within the SMART ALTITUDE project. In Verbier, electricity consumption represents 8 million kWh per year so every kWh saved is welcome, even though it is covered by a 100% hydropower contract.

Having implemented their IEMS already some time ago, Les Orres on the other hand are now seeing savings of up to 25% or more off their energy bill. This compensates the increase of expenditure linked to additional snow making costs and strengthens the business model of the resort, irrespective of all other benefits related. Similarly, developing local renewable energy sources (photovoltaic, hydroelectric, wind, biomass…) is both beneficial in financial and environmental terms.

6.3.3.2. Visitor Experience

Low carbon innovations can lead to improvements in the actual experience of visitors on top of saving CO_2. For example, in Verbier more efficient ski lifts reduce energy consumption while transporting more people faster. Thermal comfort in buildings has also improved by the implementation of better controls and building insulation. Such benefits are tangible for visitors, while many green policies implemented by a ski resort will not necessarily even be noted by tourists. Therefore, specific approaches must be developed to integrate low-carbon actions into the overall visitor experience. This requires an innovative approach, using advanced communication means such as augmented reality, digital animations, Ludo-educational animations and activities etc. Les Orres for example is already using interactive display panels and is currently exploring further options, including augmented reality.

6.3.3.3. Marketing and Image

Whereas cost, quality and diversity of the activities offered, and comfort of the installations will remain the decisive factors, all SMART ALTITUDE pilots noticed that winter sports tourists are recently becoming more aware of the impact of global warming. The “greenness” of resorts will more and more become a criterion in selecting a destination.
In so far it is important to disseminate energy policy and sustainable development process of resorts through marketing channels.
Ski resort often do not use the full potential of online tools including that of their websites to promote relations with their customers[14]. Hence an easy first step is to evaluate and improve the use of online tools with regard to communicating sustainability information.

[14] Cristobal, E.; Daries-Ramon, N et al (2018). Ski Tourism and Web Marketing Strategies: The Case of Ski Resorts in France and Spain. Sustainability. 10. 2920. 10.3390/su10082920.

"Innovation is key to stay on top and consolidate the leading position of Les Orres. All the above criteria are of great importance, all are actively pursued since at least 8 years ago, based on 3 pillars:
- The first one is the Interreg Alpine Space projects.
- ALPSTAR 2012-2014, for which Les Orres was pilot, laid the foundation of the IEMS project. - SMART ALTITUDE 2018-2021, for which Les Orres is living lab and project leader, pushes further the process."

6.3.4. Barriers to Innovation

There are many obstacles to the implementation of low-carbon activities, roughly falling into the categories Awareness, organisational barriers, and financial barriers, regulatory barriers and infrastructure barriers. The analysis of barriers in the pilots also gives some guidance towards resolving these.

6.3.4.1. Insufficient Awareness

Numerous resort operators have not yet quantified the impacts of global warming and have not fully comprehended the way it will affect their business models. However, awareness is gradually evolving due to many actions by mountain organizations as well as some pressure exerted by the population (i.e. criticisms of growing snow making energy consumption, water consumption etc.). Awareness is also growing amongst tourists, as mentioned in relation to marketing.

6.3.4.2. Organisational Barriers

When for example setting up an energy saving system such as an IEMS, there is a need for organizational changes. The system needs to be controlled and monitored, thus it is necessary to recruit or internally train up an energy manager. Equally, all operational and administrative staff have to be trained in order to follow energy saving protocols and watch over successful implementation. This concerns inter alia snow groomer drivers, ski lift operators, administrative and technical staff occupying building and premises).
It has to be recognised that innovative solutions can be complex – for example it is far easier to replace an old oil burner by a new one with the same power than to investigate an alternative, which would have to be planned well in advance. Time to implement an innovative technology is often very short, often the company has only a few months outside skiing season (during summer normally) to realise the work in order to be operational in the coming season, which requires diligent planning and organisation.

6.3.4.3. Financial Barriers

Sustainability and low-carbon innovations are important issues for the ski-resort, but even though energy costs can be high, they will have a low impact on the over-all financial results of the Ski-resort. Therefore, energy saving is a secondary priority.

Qualified personnel, time and budget is required in order to identify specific technological eco-solutions for specific problems to begin with – all of these have financial impacts. Once this barrier has been overcome, the often-high costs of low-carbon technology have to be faced and acts as a major barrier for investment. Where subsidies and other financial assistance exists, this will help.
More specifically, there is some lack of knowledge on the real cost of implementing an IEMS and other measures for energy consumption reduction. Most of the time, systems which have the potential to save up to 25% of the energy bill can be set up in a reasonable timeframe (1-2 year), with very good ROI (< 3 years). Therefore, there is a need to advocate energy saving measures and deliver sound financial as well as technical information on such systems. Also, specific regional or national aids could be set up to help the most economically fragile resorts acquire the necessary equipment and engage into a global energy saving plan.

6.3.4.4. Regulatory Barriers

At least in some countries such as France, the regulatory environment is not favourable for the implementation of communal self-consumption, peer-to-peer energy trading and local energy communities. This also applies to some other EU countries. The situation is currently evolving, and it is hoped that setting up innovative approaches of energy sharing will become possible in the near future.

6.3.4.5. Infrastructural and Societal Barriers

Sometimes, the local community of a resort is not very engaged, even though their livelihoods depend to considerable degree on success of the skiing area.
Implementation is hampered in some important fields of sustainable development, such as green mobility, both by individual and societal barriers, though transport if often a critical issue in ski resorts.
Globally, individuals remain very attracted to individual cars rather than public transportation systems. The transportation infrastructure is largely out of reach of individuals and dependent on regional or national decisions. Mountain resorts are mass tourism destinations. Therefore, organizing a low-carbon transportation infrastructure and promoting low-carbon solutions such as public transportation and electric vehicle, connecting big agglomerations and mountain valleys and resorts must be thought through at all levels.
For Slovenia the problem is also that the regional and national government does not participate in investment programs in the same way that most other Alpine countries do.

6.4. PART 2 – INNOVATION MANAGEMENT FOR SKI RESORTS

6.4.1. Innovation Audit – Assessing the Needs of Resorts to Innovate

For mountain resorts to succeed in the long term as a business it needs

- A sound product or offering, which fulfils a genuine need or customer desire and can reliably provided
- Unique selling proposition
- An Identifiable brand
- A sound financial standing, possibly by attracting investors
- A marketing plan
- And above all: Happy customers.

In order to safeguard these in the longer term every ski resort needs to assess periodically whether any of these elements are facing risks and hence whether elements of these need to be updated or replaced with new, innovative solutions.
Innovation audits assess the innovation potential of skiing areas or skiing operators. Based on this assessment, tailor-made recommendations can be identified for improvement and enhancement of innovation capacities. The innovation audit serves as a tool for skiing operators, local authorities with skiing areas within their boundaries, regional development agencies or other stakeholders with strategic interests to identify drivers and needs for innovations and to support planning and develop processes.
PESTEL and SWOT are two tools commonly used in this context. Whereas the PESTEL looks at the context rather than the actual organisation, resort or project, SWOT considers the qualities of the entity to be analysed. PESTEL is a simple stock-take of contextual factors, without initially judging them, while the SWOT analysis may look at the same contextual factors, but places judgement in terms of whether they are threatening or beneficial.
Theoretically, the tools can also be used to compare different skiing areas and allows for benchmarking. However, due to the diverse nature and unique local characteristics of ski areas this this is not seen as the predominant use for the tools, which will be introduced in the following paragraphs.

6.4.1.1. Status Quo Assessment SWOT

The SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. A SWOT Analysis [15] is a technique for assessing these four aspects of a business or the entire ski-resort.
The SWOT Analysis can be used with a view to make the most of the existing strengths and to use these to the resort's best advantage. The aim of a SWOT is to reduce the chances of failure of the organisation or business, by understanding shortcomings, risks and barriers, and eliminating these by being prepared.
The tool is well suited to reveal needs and opportunities to innovate and to underpin a strategy that distinguishes the resort, the organisation or the product offering from competitors, thus to compete successfully in the market. The template below provides some typical trigger-questions to stimulate discussions:

Strengths	**Weaknesses**

[15] Humphrey, Albert (December 2005). "SWOT Analysis for Management Consulting"

• What do you do well? • What unique resources/ assets can you draw on? • What will others perceive as your strengths?	• What could you improve? • Where do you have fewer resources / assets than others? • What will others perceive as weaknesses?
Opportunities • What opportunities are open to you? • What trends can you take advantage of? • How can you turn your strengths into opportunities?	**Threats** • What could harm you? • What are your competitors doing? • What threats do your weaknesses expose you to?

6.4.1.2. Identifying Innovation Drivers Using PESTEL-Analysis

Undertaking a PESTEL-Analysis involves a broad fact-finding activity. It can help a ski resort or other organisation to identify and understand the external factors that could impact any decisions made within the organisation. The PESTEL-Analysis[16] assesses these from six perspectives: **P**olitical, **E**conomic, **S**ocial, **T**echnical, **E**nvironmental, and **L**egal. The ski resort on its own typically cannot affect these factors, but clarifying the position of the ski resort within its market environment will show external drivers for innovation - in which areas innovations are plain necessary or where innovation opportunities arise. The PESTEL-Analysis can be used as a tool to assess the status quo or likely future of the skiing operator or related company and that of its market environment, including competitors. On the other hand, a PESTEL-analysis might be undertaken to understand the environment of a project, rather than to analyse the organisation. In this case it will reveal the dependencies for the project, as well as likely risks and potentials, which may shape its development.

The focus on low-carbon innovations, the environmental and political perspective may be of particular interest, while being juxtaposed by the others. Environmental issues such as climate change adaptation are increasingly pressing topics for the long-term planning for skiing areas, requiring a thorough assessment of possible impacts, opportunities or risks, on the business case. Further impacts, such as demographic change within alpine areas and conflicting interests between tourists and permanent residents can also be extracted. In so far, the PESTEL-Analysis allows a broad picture and may be used to compare different future scenarios with different requirements for innovation.

In the following examples for the different dimensions of PESTEL are given in order to help with the identification of possible influence.

[16] Dr. John V. Richardson (2017) A Brief Intellectual History of the STEPE Model or Framework—(i.e., the Social, Technical, Economic, Political, and Ecological), UCLA https://pages.gseis.ucla.edu/faculty/richardson/STEPE.htm, accessed May 2020

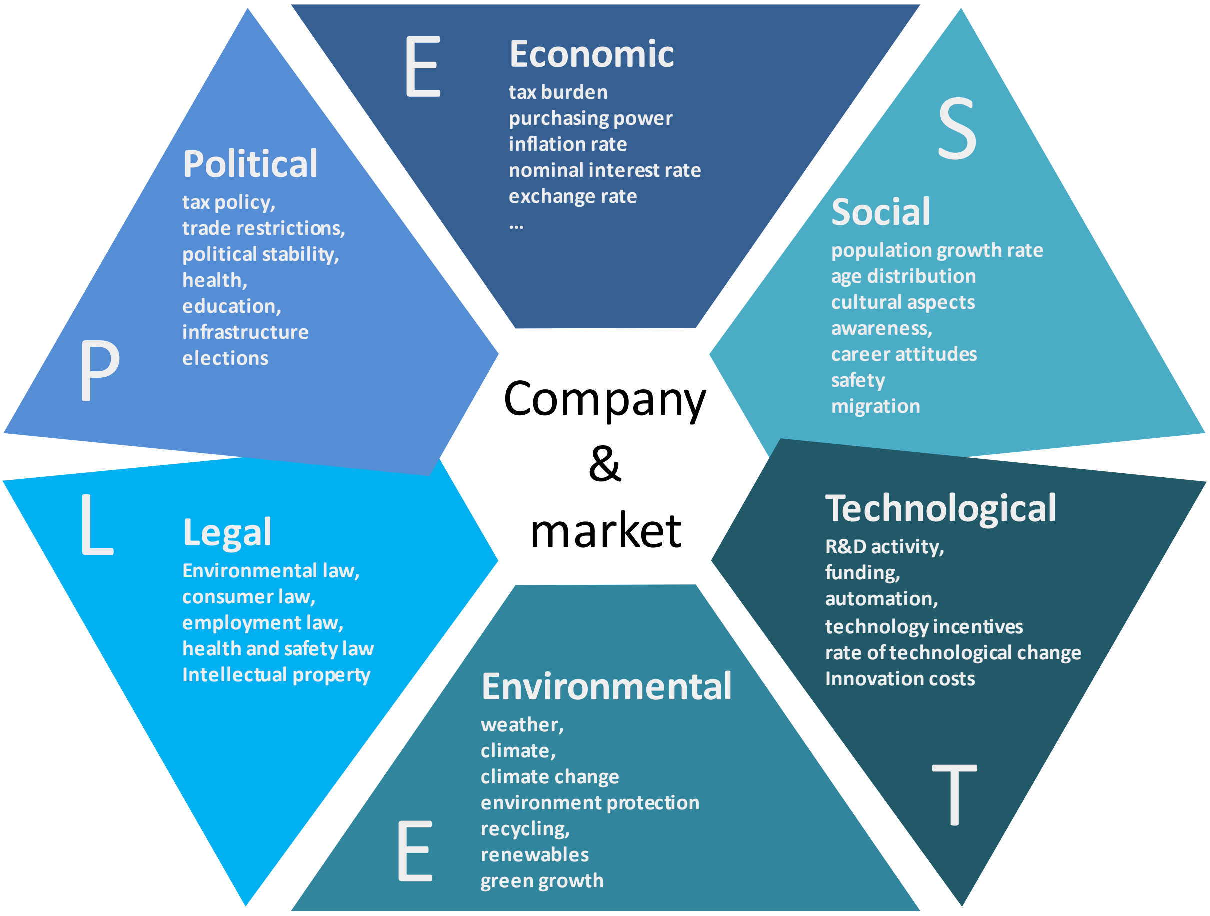

Figure 73: PESTEL

6.4.1.2.1. Political Perspective

Political factors to be taken into account relate to local politics of the local authorities and regions the skiing area is situated in, but also need to account for global political trends, which will influence sooner or later emerging local policies. A prime example are long-term climate change mitigation targets such as those of the Paris agreement or the UN 2030 targets.

It is important that the political perspective is about strategic policies, not laws, as these are covered under "Legal Perspective". The distinction between legal factors and political factors is that the latter is concerned with government intervention in society and the economy to plan for the future, while the former relates to government intervention in society and the economy to ensure fairness and wellbeing.

Political factors might be related to:

- International relationships
- Government targets
- Government sanctions
- Subsidy Programmes

6.4.1.2.2. Economic Perspective

The economic factors covered here are connected to the general state of the local, regional and national economy. In a more specific sense, they relate to goods, services and money flows related to the skiing area. There are a number of different economic factors which can affect business, including:

- Supply and demand for a certain product or services
- Impacts of particular taxes, Interest rates, inflation
- Competition from other skiing areas or alternative tourism offers
- Characteristics of local economy, including seasonal variations

6.4.1.2.3. Sociocultural Perspective

The 'sociocultural' factors, or 'social' factors covered here are connected to the general public and their behaviour (i.e. society and culture). Here are some of the social factors that might typically play a role for skiing areas, which often relate to a high divergence of interests between tourists and locals. These may be:

- Divergence in social classes and income and lifestyle
- High seasonality leading to seasonal workers and migrant workers, who do not feel responsible for the local area.
- Lack of perspective and inflated property prices driven by tourists, causing young locals to move away

6.4.1.2.4. Technological Perspective

Technological factors are those which "relate to the existence, availability, and development of technology". These may relate to technologies and technological issues specific to skiing areas, such as snow-making equipment, snow-grooming and lift operation, but may also encompass wider trends such as digitalisation. To give but a few examples, the following technological trends may have future impacts in a wider sense:

- The development of robots
- Internet connectivity
- Security in cryptography
- New energy storage technologies including power-to-gas.

6.4.1.2.5. Legal Perspective

Legal factors are external factors which influence business operation and potentially also customer behaviour. Some examples of legal factors which may typically play a role for skiing operators are:

- Health and Safety Laws
- Environmental protection laws

- In a wider sense technical standard which ensure compliance with the above

6.4.1.2.6. Environmental Perspective

Environmental factors, also referred to as ecological factors, refer to the variables pertaining to the physical environment we live on. A few examples are:

- Climate change impacts of operations, especially those related to energy use, but also potentially to loss of forest
- Impacts of changing climate on business (less natural snow)
- Negative impacts of ski slopes and tourism on bio-habitats, wildlife and eco-system services (for example CO2-sequestration or rainwater retention of a forest)
- Other types of air pollution, e.g. particulate emissions from traffic, log fires and winter barbecues
- Noise pollution from après-ski parties
- Impacts on water courses due to artificial snow making
- Positive impacts resulting from protective measures

6.4.2. Value Chain Analysis

New ideas, products or innovations should be examined in the context of the value chains to understand their impacts and eventually exploit their full potential. The value chain refers to the activities a firm engages in when transforming inputs into outputs. The primary and support activities should be analysed which add value to the final product or offering. They can then be analysed with an aim to reduce costs or to increase differentiation.

The value chains of skiing areas have a number of typical elements and stakeholders. To assess the value chain as a way of evaluating and finetuning new ideas, strategies, products or service offerings, the value chain analysis tools provide an overview over relevant aspects and players. The value chain analysis deals with Stakeholders on the one hand and the product and the value it can offer on the other. These will be described in further detail below.

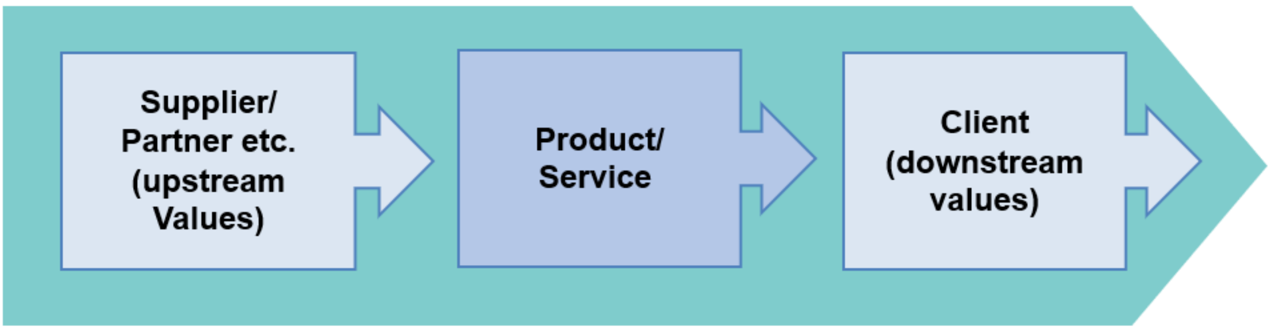

Figure 74: Value Chain

6.4.2.1. Identify the Product

The "product" can be an idea for a new service, process or product in a skiing area along the entire value chain, a unique selling point which can be turned into a service offering to skiers and non-skiing tourists, an (existing) service or a physical product to improve and/ or extend the portfolio of the ski resort. At this stage of the Value Chain Analysis, one must develop a clear understanding of the characteristics and objectives of the product. It should relate to the product owner (e.g. how does it fit into the general offering of the ski resort), the identity of the resort (e.g. portfolio and vision), and how does the product fit into the market.

How and why can the product meet or exceed expectations when used in a specific location, for specific end users, when addressing one of the challenges previously identified. In the meantime, the product is being analysed in terms of its Technology Readiness Level (TRL) and in relation to customer needs.

6.4.2.2. Identification of the Key Stakeholders

Once the product or innovation has been defined, its users and other important stakeholders have to be understood. The focus is on the value they either bring to the project or receive from it. They fall roughly into the buyer (or beneficiary) side and supplier side, supplemented by other who may support or hinder implementation.

A typical set of stakeholders for ski resorts is set out in the following paragraph, yet their level of influence will vary between resorts. For identifying which are the most relevant of these stakeholders, a set of five questions can be used to facilitate this process, roughly following Kenny (2014)[17]:

1. Can you expect a fundamental impact on the performance of your organization or your innovation project by involving this stakeholder?
2. What is your specific expectation from the stakeholder for your innovation project?
3. Do you want the relationship with the stakeholder to grow?
4. Are you dependent on the stakeholder, can you exist without or replace the stakeholder?
5. Is there an existing relationship with the stakeholder (e.g. another project, joint network etc.)?

6.4.2.2.1. Typical stakeholders of Skiing Resorts

A list of the most important Stakeholders in and around ski resorts is provided in the following. However, their relative importance and influence will vary between resorts and also in relation to the specific project which is being examined.

[17] Kenny (2014): Five Questions to Identify Key Stakeholders. Harvard Business Review. https://hbr.org/2014/03/five-questions-to-identify-key-stakeholders, accessed 28.02.2020

Stakeholders related directly to skiing

- Resort operators
- ski lift operators
- Snow makers/ maintenance of slopes
- Technical maintenance of snowmaking infrastructure
- Technical maintenance/ manufacturing of lifts
- Skiing schools, ski instructors (often not local)
- Tourists/ skiers including "Ski bums", “trust-fund babies”[18]

Stakeholder in the wider context of ski tourism

- Vendors and rental companies for skiing equipment and clothing
- owners and operators of accommodation (hotels, chalets, B&Bs, holiday apartments)
- restaurants, caterers
- Après-ski activity providers
- Suppliers to all of the above
- Marketing agencies
- Consultants (technical, marketing…)
- Local transport: Parking operators, local transport operators

Local stakeholders

- Local Authority and mayor, often as part-owner or shareholder of the operator company
- Landowners
- summer users/ farmers other competing land-users
- Nature conservation groups

6.4.2.3. Defining the Technology Readiness Levels (TRL)

Once an understanding of the most important stakeholders and their relative influence on the innovation and its value chain has been gained, it is useful to identify the level or readiness of the innovation, in order to develop an innovative idea into a market-ready product or service or operational process. The scale of technology readiness levels provides an outline roadmap through the development process. Also, depending on the Technology Readiness Level (TRL), the available support schemes through regional, national or EU-funding will differ. The following definitions apply according to the European Commission[19], unless otherwise specified:

[18] Weiermair K, Mathies C (2004) The Tourism and Leisure Industry: Shaping the Future, The Haworth Hospitality Press, p. 218

[19] European Commission (2019): Horizon 2020. Work Programme 2018-2020. https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-ga_en.pdf

TRL 1 – basic principles observed
TRL 2 – technology concept formulated
TRL 3 – experimental proof of concept
TRL 4 – technology validated in lab
TRL 5 –technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7 – system prototype demonstration in operational environment
TRL 8 – system complete and qualified
TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space) A low TRL indicates that there is still a long development path ahead, before end-users can benefit from the innovation and money can be earned, whereas a high TRL may also imply that the potential for growth is limited (e.g. when taking on a solution which was developed by others. Table 19 shows the definition for each level together with questions which help describe the relevant level.

Table 19: Technology Readiness Levels (TRLs)

TRL	Definition	Description
9 – Proven	Actual system operated over full range, in final form	No further development required / possible?
8 – Qualified	Actual system completed & qualified through test & demonstration	End of true system development? Who qualified and tested the system?
7 – Demo operational environment	Full-scale, prototype system operated in relevant environment	Actual prototype represents full scale system? Compare relevant to actual environment.
6 – Demo in relevant environment	Pilot engineering scale system validated in relevant environment	Is prototype beyond lab-scale? Does tested demonstrate high readiness?
5 – Validated in relevant environment	Laboratory scale system, concept validated in relevant / simulated environment	Are technology components integrated in high fidelity system that match final application in almost all respects?
4 – validated in laboratory	Component & or system validation in simulated laboratory environment	Are basic components integrated in low fidelity system? Has ad-hoc testing been completed?
3 – Proof of concept	Analytical & experimental critical function shown in proof of concept	Is active research & development initiated? Dp preliminary results exist?
2 – Concept formulated	Technology concept formulated. No proof or analysis	Have basic principles been observed? Is speculative application identified?
1 – Basic	Principles observed & reported.	Have ideas for translation of

principle observed	Study of technologies basic properties.	scientific research to applied R&D been completed?

6.4.3. Defining the Value Proposition (Strategyzer ©)

Value proposition canvas is a plug-in tool for the Business Model Canvas, which will be dealt with in the following paragraph. The value proposition is the central element and starting point for the Business Model canvas. It helps to evaluate how well the value created by the product or service matches the expectations the customers will have, also describing the benefits customers can expect from products and services.
The method is based on the evaluation of the job the customers want done and the gains and pains related to this job. The so-called gain creators and pain relievers delivered by the product/service have to be examined in order to clarify their relationships and eventually defining the value proposition more clearly. The Value Proposition Canvas considers two aspects – the Customer Profile and the Value Map. The Customer Profile clarifies the understanding of the customer. The Value Map describes how we intend to create value for this customer. The aim is to achieve a "Fit" between the two by matching them closely. Both are explained in more detail in the following sections.

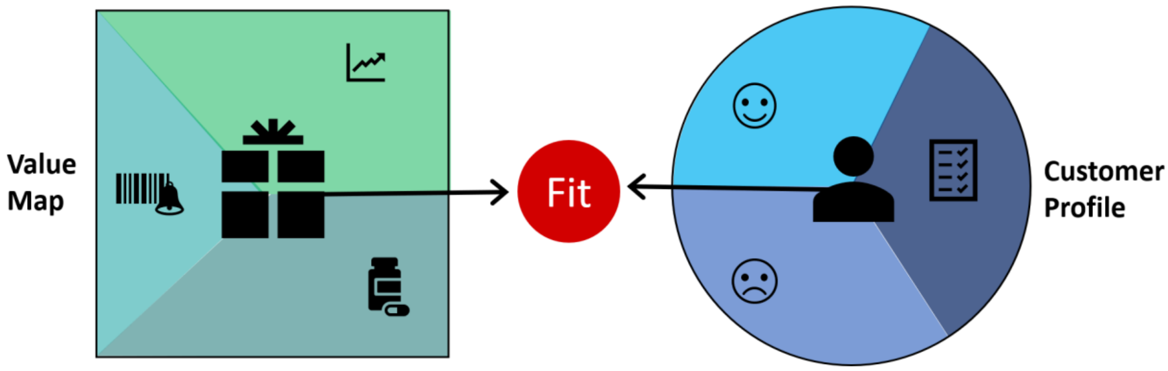

Figure 75: Value Proposition according to Strategyzer (redrawn)

6.4.3.1.1. Customer Profile

The customer profile refers to the customer segment, which has to be defined when developing the business model.

It breaks the customer perspective down into jobs, pains.

- **Customer Jobs** describe what customers are trying to get done in their professional capacity or in their private lives.
- **Customer Pains** describe bad outcomes, risks, obstacles and inconveniences related to the above customer jobs.

- **Customer Gains** describe the outcomes customers want to achieve or the concrete benefits they are seeking.

6.4.3.1.2. Value proposition Map

The Value Map describes the features of a specific value proposition of a business model in a more structured and detailed way.
It breaks the value proposition down into products and services, pain relievers and gain creators

- **Products and services.** This is a list of all the Products and Services a value proposition is built around.
- **Pain Relievers** describe how the products and services alleviate customer pains.
- **Gain Creators** describe how the products and services create customer gains.

Having thus clarified the value proposition in detail the focus for the surrounding business model becomes clear. This will be addressed in the following section.

6.4.4. Business Model, Business Plan and Business Case

In order to successfully introduce a new business idea or implement best practice solutions, impacts on the existing business model or a completely new business model need to be considered. The business case consists of the reasons and objectives for a specific project or task and should result readily from the drivers for innovation identified in the SWOT and PESTEL analyses. A successful business case will consider quantifiable and non-quantifiable reasons for a project and describe the expected benefits and opportunities. It will include the expected costs of the project, as well as the expected risks. Therefore, a cost-benefit analysis is required revealing the financial and non-financial costs and benefits. For a comprehensive picture of the project, social, societal and environmental benefits can be considered as well.
The Business Plan on the other hand presents the financial position, targets and projections of a business or venture and its plan for reaching targets, all compiled in a formal document. The business plan considers a variety of aspects and perspectives, including requirements and sources for financing, the required human resources including their cost, but would also extend to intellectual property management, supply chain management, marketing, sales etc.
A business plan would evolve over time. Seven key questions will guide the business plan

- What does the business do?
- Which is your industry, market, and competitor landscape?
- How is the business organized?
- What is your offer?
- How are you selling your product/ service?
- How much money will you need for the next three to five years?

- How will the business become profitable?

These questions give a brief overview of the aspects to be considered as part of managing innovations – there are many resources with detailed instructions on writing an actual business plan on the internet for example at www.entrepreneur.com[20]. Help can often also be obtained from business support organisations such as chambers of commerce.

The Business Model sits at a more strategic level. It describes the rationale for how a business creates, delivers and captures value. The key objective of a business model is to answer the question of how one can make money with the business idea.
The most common methodology for defining and representing a business model is the Business Model Canvas by Alexander Osterwalder and Yves Pigneur[21]. Its core element is a template which contains nine fields, which can be downloaded freely from various sources. It can be used to analyse new and existing businesses. The 9 fields cover the following topics:

- Customer Segments
- Value Propositions
- Channels
- Customer Relationships
- Revenue Streams
- Key Resources
- Key Activities
- Key Partnerships
- Cost Structure

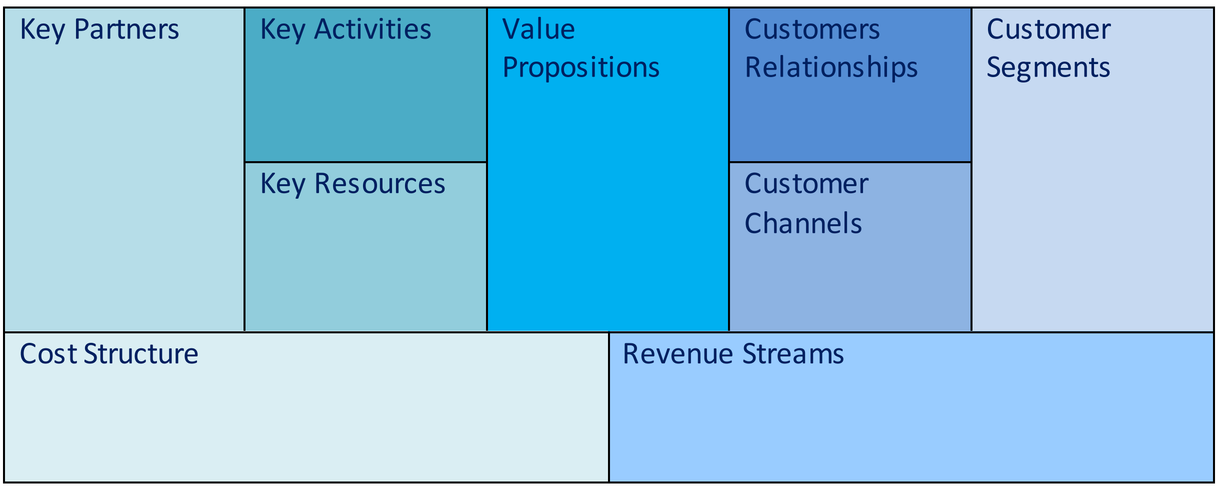

Figure 76: Business Model Canvas according to Osterwalder and Pigneur

[20] Entrepreneur Europe: How to write a Business Plan. https://www.entrepreneur.com/article/247575
[21] Osterwalder, A., & Pigneur, Y. (2010). Business Model Generation. Retrieved from https://s3.amazonaws.com/academia.edu.documents/32253198/businessmodelgenerationpreview.pdf?response-content-disposition=inline%3B%20filename%3DYoure_holding_a_handbook_for_visionaries.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53

Assistance with defining the business model for an innovation may also be available from local Chambers of Commerce or other business support organisations.
An extended version of the standard business model canvas will be introduced in the following. It is designed to emphasize and strengthen the sustainability of business ideas and hence particularly suited to low-carbon innovations.

6.4.5. Sustainable Business Model Canvas

The sustainable business model canvas was developed by the consultancy Border step to reflect a given business model from the point of view of sustainability and to readjust or refine it in order to improve its sustainability. It can also be used to develop alternative or complementary business models for an existing business. It builds on the traditional Business Model Canvas described above, but adds an additional field for the vision of the business. It also differs in as far as that customer segments, relationships and channels are summarised in one field. Instead it includes competitors and other stakeholders, thus considering the wider context of the business model and capturing outcomes which may have been identified using the PESTEL, SWOT and Porters 5 Forces. Also, it comes with a set of questions to drill into the sustainability aspects of each of the traditional fields. For example:

- In how far are the sustainability principles of efficiency, consistency and sufficiency, play a role for your vision? Commonly these are understood to be
    - Efficiency: reducing the input required to achieve a given output.
    - Sufficiency: reducing the total levels of need, decreasing total overall production and consumption
    - Consistency of resource use: how and where a scarce resource can be used optimally, impacting on nature as little as possible e.g. through circular economy principles
- How can these principles bring advantages such as lower costs, lower risks, competitive advantage?
- What benefits for the environment and society does your value proposition entail?
- How can you compensate for areas where you compromise sustainability?
- What additional benefits arise for the customer from your sustainability features?
- How can you communicate sustainability benefits effectively?
- Which stakeholders are instrumental to the sustainability of your business idea?

A detailed description can be found in Tiemann, I. & Fichter, K. (2016): Developing business models with the Sustainable Business Canvas: Manual for conducting workshops, Oldenburg

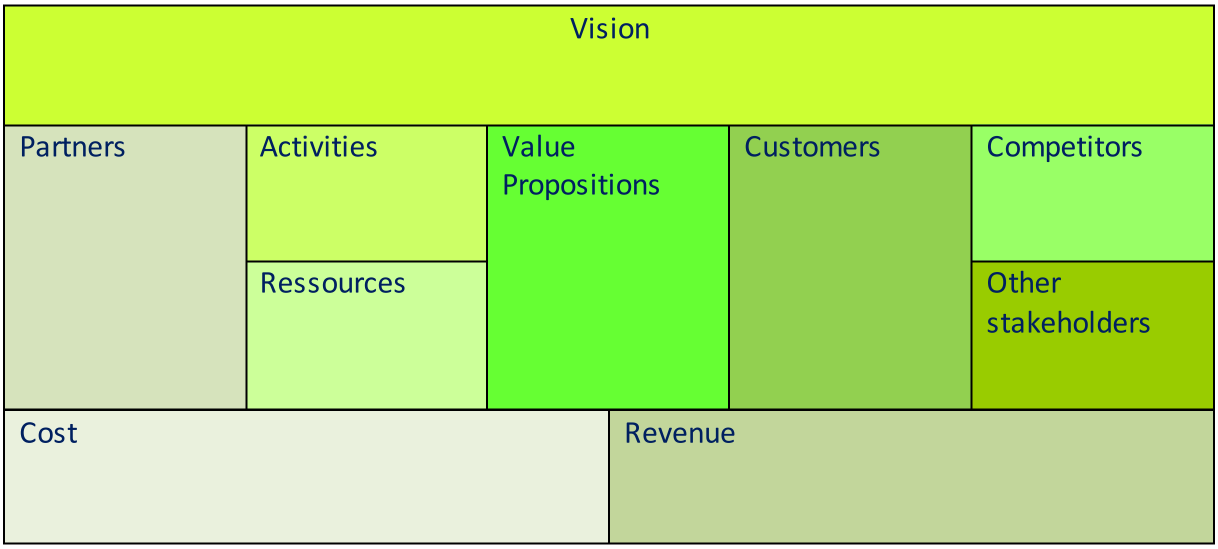

Figure 77: Sustainable Business Model Canvas according to Border step

6.4.5.1. Green-Check Your Idea

The online-tool "Green Check your Idea"[22] supports idea creators to check their ideas and turn them into green products or solutions. It can help answer the following questions:

- What do you need to turn your innovative idea into a "green product" or a "green solution"?
- How can the environmental impacts of your idea be assessed and optimized?

The tool will provide information on sustainability, Life Cycle Assessments (LCA) and Ecodesign principles and help generate new ideas or to improve idea.

6.4.6. Assessing the Market – the Five Forces of Porter

Porter´s Five Forces is a tool helping to understand the strengths and weaknesses of a business environment and the competitive position of the company[23]. With this tool it is possible to describe, where the threats of new entrants or substitute products are and what the bargaining power of suppliers or buyers is. This analysis will enable the company to take advantage of its strengths and improve its weaknesses. Five factors are considered:

- intensity of competition from existing competitors
- threat of substitutes
- threat of new entrants
- bargaining power of suppliers
- bargaining power of buyers

For ski resorts innovation in other resorts can be classified as new entrants. The power of suppliers is also important to consider, as there may be limited choice of suppliers due to the

[22] https://www.green-check-your-idea.com/start

[23] Porter, M. E. (2008). The five competitive forces that shape strategy. In Harvard Business Review - HBR's Must-Reads on Strategy (pp. 25-40).

remoteness of some resorts and extreme mountainous locations requiring highly specific solutions, which are not readily available. Additional constraints are dictated by the skiing season and climatic conditions. Businesses and suppliers often rely on particular equipment manufacturers for decades or even generations, leading to long-term cooperation and trust. Thus, switching-costs might be high and substitutes not available.
New innovative technologies in digitalization may however lead to substantial changes in the supply chains. Costs of switching may be equally substantial and be accompanied by compatibility issues. Nevertheless, new approaches especially through changing structures (e.g. demographic changes, urbanisation of resorts, digitalization, etc.) may have the potential to lower the switching barriers. Traditional value chains are altered by changing demands of skiing tourists and changing climatic conditions. Equally, circular economy strategies may change the sector.
The rivalry among competing accommodation providers can be disruptive in a field where ownership structures are changing and corporates are entering the usually family-business driven markets. Schemes where these small family owned businesses pool together under local associations and umbrella organisations may bring benefits to each individual small business. These are some of the aspects which may be considered when examining the strategy for low-carbon innovations using the Five Forces Model.

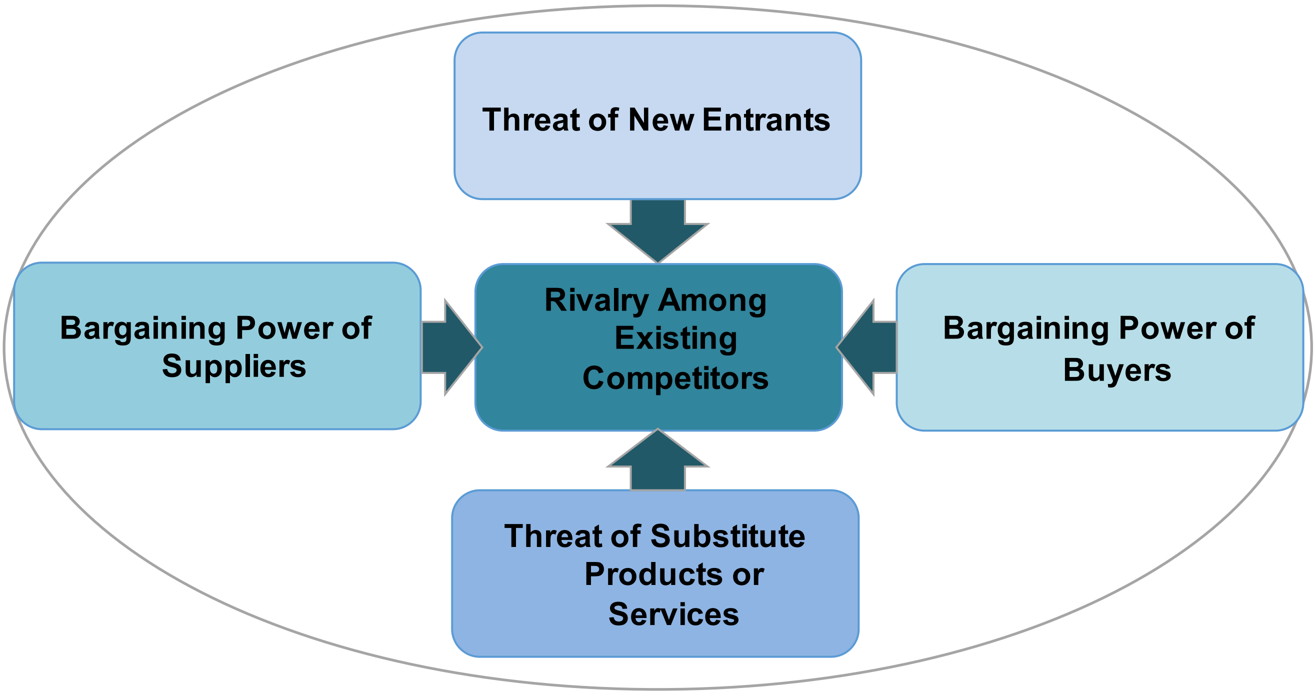

Figure 78: The Five Competitive Forces that Shape Strategy according to Porter (Own representation)

6.4.7. Intellectual Property Rights (IPR)

Where the implementation of low-carbon solutions depends on innovations developed by others, these can be subject to Intellectual Property Rights (IPR). Besides soft IP, which can

be summarized as trade secrets, know-how and confidential information, questions of ownership and property can arise for these innovations. Therefore, a careful analysis of the situation is required prior to planning implementation. A rough overview of types of IPR is provided in Table 20 and the different types of IPR protection will be explained in the following paragraphs.
Owners of an innovation should not only ensure that the solution is protected (e.g. as a patent, an industrial design or a trademark), but also ensure that the IPR are managed and enforced. Whereas it is in the interest of the owner of the innovation to transfer the innovation, to stimulate cooperation around it, eventually it is in their interest to enforce IPR. This is demanding in terms of time and resources. Hence a sound strategy on how to disseminate and exploit the innovation is required.
In cases where the local knowledge of a foreign company is required in order to define applications of the innovation in a ski resort or other contexts abroad, a cooperation agreement should be considered to foster the knowledge exchange for cooperation. If IPR has been registered already for an interesting innovation, one might implement it in a new market by becoming a licensee.
In order to define the right strategy, the definitions and characteristics of IPR have to be understood. The European IP Helpdesk[24] provides valuable information and support free of charge. Further, other H2020 such as VIP4SME[25] or KnowingIPR[26] offer support and tools for IPR management.

Table 20: Overview of protection types of Intellectual Property Rights (IPR). Own representation based on European IP Helpdesk

IPR	What for?	Registration?
Patent	New inventions	Registration is required
Utility model	New inventions	Registration is required, but conditions are less stringent than for patentability
Trademarks	Distinctive signs	Registration is required
Industrial design	Appearance of products	Registration is usually required, but it is possible to acquire an unregistered design right
Copyright	Literary, artistic and scientific works	Not required, but it can be registered in some countries
Confidentiality	Confidential business information/ trade secrets	Not required, but internal protection measures needed (i.e. NDAs)

[24] European IP Helpdesk: http://www.iprhelpdesk.eu/
[25] VIP4SME: Value Intellectual Property for SMEs (VIP4SME). http://www.innovaccess.eu/vip4sme-project
[26] Knowing IPR -Fostering Innovation in the Danube Region through Knowledge Engineering and IPR Management. http://www.interreg-danube.eu/approved-projects/knowing-ipr

6.4.7.1. What can be Patented?

Before considering patenting or registering IPR, a number of criteria have to be met. According to the European Patent Convention[27], patentable innovations can be described as follows: "European patents shall be granted for any inventions, in all fields of technology, provided that they are **new**, involve an **inventive step** and are **susceptible of industrial application** (i.e. can be used in any kind of industry, including agriculture).." The European IP Helpdesk as well as regional or national Patent and Trademark offices provide support in identifying the freedom to operate and facilitate the process of IPR registration.

6.4.7.2. Cooperation Schemes

For the implementation of the types of innovations typical for ski resorts, several stakeholders need to be involved in order to jointly develop and adapt existing solutions for the local context, thus forming a project consortium. Assessing know-how, trade secrets and confidential information is very difficult though, as involved stakeholders have their own interests. Hence, a clearly structured cooperation is key to success. Figure 79 shows usual stakeholders for innovation projects that collaborate at project level. These stakeholders can feed various inputs into a project (see *Figure 80*). While bringing in knowledge might be a fairly clear process, the step of jointly developing is more complex.
In the case of transferring a low carbon solution, such as those showcased in SMART ALTITUDE as a project consortium with a clearly defined framework is important. Each of the partners must be clear about their own role to reduce and eliminate difficulties along the implementation process. Therefore, a legally binding document, either a consortium agreement or an additional IP-agreement captures the expectations for inputs and outputs. The role and responsibility of each partner can be defined operationally, technically, and financially. In the case of intellectual property rights (IPR), the targets and exploitation rights can be defined in advance. This also applies to local consortia implementing each pilot. These consortia consist of local suppliers, consultants, project managers etc. and are outside of the structure of the EU-funded project, though aligned with it.

[27] European Patent Convention, Article 52: Patentable Inventions. https://www.epo.org/law-practice/legal-texts/html/epc/2016/e/EPC_conv_20180401_en_20181012.pdf

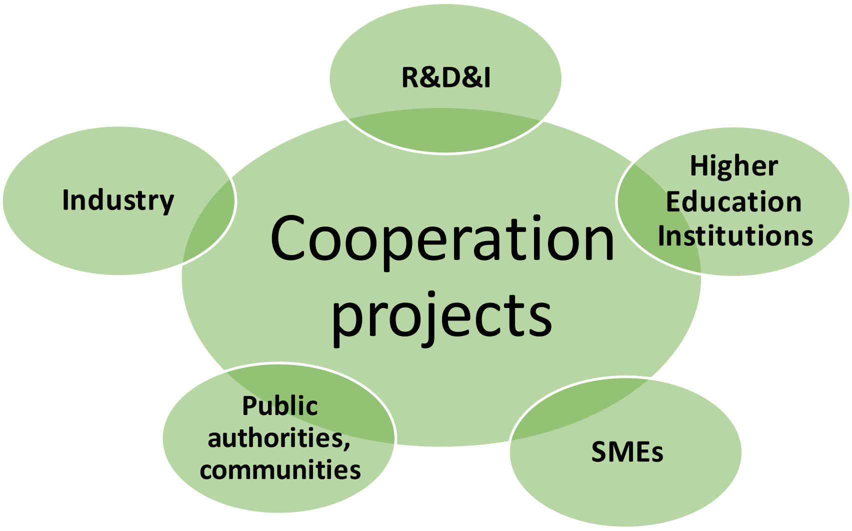

Figure 79: Overview of actors involved in cooperation projects.

6.4.7.3. Open Innovation

Especially in the context of societal problems such as demographic issues or the effects of climate change faced by resorts, **Open Innovation (OI)** can be a viable approach to jointly develop a new solution. The term Open Innovation was coined in 2003 by Henry Chesbrough and refers to an opening up of the innovation process to include customers, researchers, suppliers and partners into the innovation activities, as opposed to development of new products in secretly behind closed doors. Especially in the field of user-driven platforms, OI can unlock its full potentials. In order to develop a new solution according to the OI principles, the basic requirements can be defined as follows:

1. A strong will to cooperate and jointly develop a new solution must be present
2. There must be a reciprocal benefit and added value of jointly developing a solution
3. Mutual trust and transparency between the partners
4. Definition of the cooperation framework through a Consortium Agreement

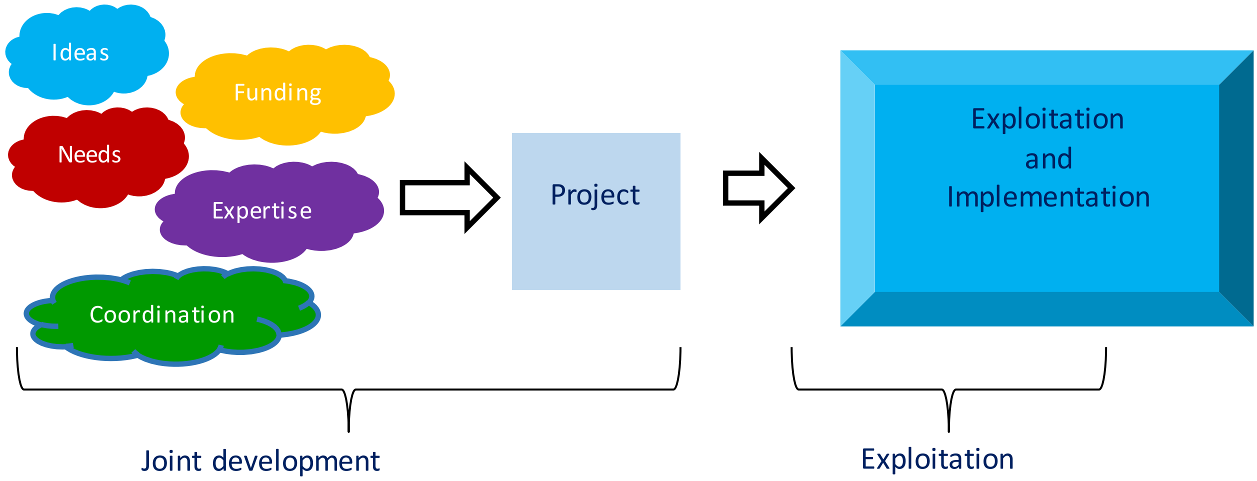

Figure 80: Overview of inputs and outputs of the projects.

So, for ski resorts this may mean to define a framework to engage with the local community, tourists and local businesses in order to re-invent the resort as a low-carbon resort.

6.4.8. Driving Innovation through Sustainable Procurement

A green procurement strategy can be a powerful instrument for procuring innovative low carbon solutions. For it to be successful the strategy needs to be formalised and recognised at the top management level as part of the overall strategic orientation of the organisation. Setting performance targets is one of the most important instruments to implement the strategy into practice. Eco-labels or energy ratings can often act as a proxy for targets and can be easier to specify. Difficulties arise when there are many different labels and when criteria or quality assurance of these are not clear. Sometimes sustainable procurement is driven by suppliers who proactively promote eco-innovations, rather than by the buyer. Also, innovative low-carbon solutions can be developed jointly within long-term relationships with suppliers.

Important tools for implementing green procurement

- ✓ *green/ sustainable procurement strategy in place*
- ✓ *setting of performance targets*
- ✓ *asking for eco-labels, energy ratings or similar*
- ✓ *suppliers proactively promoting eco-innovations*
- ✓ *long-term relationships with suppliers to develop solutions*
- ✓ *interaction with research organisations/ universities*

The interaction with research organisations/ universities can play an important role in increasing knowledge on sustainable, low carbon solutions and developing solutions jointly, thus representing a particular way of procuring these solutions. In fact, this route has proven to be the most powerful for the pilots involved in Smart Altitude.

The way procurement of businesses or organisations is organised can also have a powerful impact on innovation and act as an influential policy instrument. Procurers – be it a resort operator, a lift operator or the local authorities acting as an important shareholder of the resort - can define their needs in a way that can trigger market innovation, and at the same time ensure that users are ready to adopt the procured innovation.
In the context of procurement, innovation can be seen as the implementation of a new or significantly improved good or service or process. It entails activities which are either new to the organisation, or new to the market as a whole. The concepts of sustainability and innovation are often linked in procurement.
For public bodies the concept of using procurement processes to drive innovation is gaining considerable support and becoming a focal point for policy at local, national and European level. As the local authorities and resort operators are often closely interlinked, green procurement can have considerable leverage.
There are strong links between innovation and more sustainable performance – for example where new technology extends the lifetime of a product, or where better access to information means services to people can be targeted more precisely to demand and customer preferences.
Whenever technical specifications, selection or award criteria are not explicitly asking for new, more sustainable ways of doing things, bidders are unlikely to propose these. On the other hand, innovation can be placed centrally in order to procure more sustainable and environmentally friendly solutions.
Innovation involves changes to business-as-usual. This means that new procurement and contract management approaches are required to support innovation, even though performance-based specifications may already be routine for some organisations. Such specifications are a typical instrument for driving innovation through calls for tender.

Key principles to observe for sustainable procurement are[28]:

- ✓ That the products and services achieve value for money on a life cycle cost basis
- ✓ That they generate benefits not only for your organisation, but also for the environment, society and the economy
- ✓ Conditions have to equally apply to purchasing of goods, services or works
- ✓ Conditions apply regardless of the type of contract or form of procurement procedure followed (e.g. service contracts, centralised framework agreements

Procuring in a sustainable way involves looking beyond short-term needs and considering the longer-term impacts of each purchase. Sustainable procurement is used by both public

[28] Clement, S; Watt, J.(2016) The Procura+ Manual - A Guide to Implementing Sustainable Procurement, 3rd Edition, ICLEI – Local Governments for Sustainability, European Secretariat https://procuraplus.org/fileadmin/user_upload/Manual/Procuraplus_Manual_Third_Edition.pdf accessed February 2020

and private sector organisations to ensure that their purchasing reflects broader goals linked to resource efficiency, climate change, social responsibility and economic resilience.
Pooling demand of several operators in one region (e.g. all lift operators in one resort) can broaden the impact of sustainable procurement, with useful added benefits to the local economy.
The guide "The Procura+ Manual - A Guide to Implementing Sustainable Procurement provides a good starting point for sustainable procurement".

6.4.8.1. Procurement of Innovations in the Pilots

SMART ALTITUDE pilot Maria di Campiglio procure innovations either directly from relevant suppliers of snow-production equipment (e.g. TechnoAlpin and Demaclenko), ski-lifts (eg. Doppelmayr and Laitner) and snow groomers (eg. Prinoth) or through continuous relationships with local agencies such as Trentino Sviluppo and Assindustria Trento (Assoenergia). This is supported through ad-hoc interaction with research centres such as FBK or indirect support through project partners, as in the case of Smart Altitude
In the case of Verbier it is its charter on sustainable development which is most instrumental as driver for sustainable procurement, as it encourages the resort to plan actions and anticipate investment ahead. Anticipatory planning allows them to collaborate with universities or other organisations to study new opportunities and solutions. On the other hand, suppliers, such as Garaventa – Doppelmay, Leitner or other, offer proactively eco-innovations.
In Krvavec, the interaction with suppliers of the equipment implemented as part of the SMART ALTITUDE Project is also perceived favourably, as they have proven to have the required expertise and knowledge and are interested in pursuing the goals of the project.
For pilot Les Orres the participation in the Flexgrid initiative provided access to collaboration with large industry players such as EDF, ENEDIS, VEOLIA, ORANGE, SFR, etc., and also to collaboration with top-level R&D institutions such as CEA-Tech and CNRS/Aix-Marseille University, furthermore also with innovative start-ups and SMEs of the Capenergies cluster. Les Orres also benefits from the OCOVA forum, which brings together solution providers, R&D developers, mountain communities and territorial policy makers to exchange current thinking on the future of mountain resorts. Les Orres is therefore a good example on how active participation in projects and networks facilitates the exploration of innovations and eventually their procurement.

6.4.8.2. Attracting Small and Medium Enterprises

When talking about the procurement in particular of public bodies, which as stated previously, may be responsible for parts of the ski resort operation, procedures are governed by strict public procurement rules. Public procurement processes are generally more accessible for large companies with a well-established market presence and the resources to submit a tender, even if the market outcome is uncertain. SMEs sometimes feel that they have too little legal and administrative capacity to engage in procurement contracts. However, it is Start-ups and small and medium enterprises SMEs which can offer

more innovative products and services. While larger companies may have the financial capacity to keep entire innovation departments and call in consultants, they still struggle to match the creativity and innovative thoughts of SMEs driven by a lack of resources on the one hand and passion on the other. With organisational hierarchies slowing down decision-making, and salaries and service providers creating a substantial costs base, large companies cannot compete with start-ups and SMEs on either cost or execution basis. Hence cooperation with SMEs can offer more innovative solutions for ski resorts. If these are local SMEs the cooperation will also feed into the local economy with social benefits attached.
For example, in Krvavec it is the ski-resort operator who takes on a leading role in safeguarding livelihoods of related small businesses. (mainly hotels, service providers, maintenance companies, discos, bars restaurants)
In summary, engaging local SMEs can have a number of advantages for resorts:

- They may be able to respond to the actual local needs better and more timely, due to their proximity and understanding of local contexts
- They will bring a positive impact on the local economy and in turn on the local community.
- The resort can benefit from the more innovative approaches SMEs may offer.
- There may be local or national subsidy programmes for SMEs which the resort can tap into and which compensate for the limited access to finance for SMEs with risky R&D projects.

6.4.9. Local Innovation-Alliances

Beyond the specific interaction with SMEs (local or more remote) resorts can foster in local alliances which grow into ecosystems which are conducive to innovation.
For example, Les Orres is fully immersed in the regional energy ecosystem of innovation by being part of the FLEXGRID initiative run by the Capenergy innovation cluster and piloted by the Provence-Alpes-Côte d'Azur region. Through its organisation of the annual OCOVA forum (Communicating objects and value creation) they do not only attract big industry, research laboratories, communities and territories, but in particular also start-ups and SMEs.
For Madonna di Campiglio it is the actual Smart Altitude project which was instrumental in promoting a productive local relationship between Cable car operator Funivie Madonna di Campiglio (MdC), the local research centre (FBK), the local business development and destination marketing agency (TrentinoSviluppo) and a local start-up (Energenius). These supported Funivie MdC in the following activities:

- Identifying technologies for on-site energy monitoring
- Developing a customised solution for on-site integrated energy management
- Analysing the potential for renewable energy integration (PV and heat- pump)
- Defining a strategy for a medium-term sustainability plan ("Zero Emission 2026")

Téléverbier, the operator of the ski slopes in Verbier (CH) have a longstanding relationship with CREM, the regional association which accompanies local authorities and territories in their energy and environmental transition. Over the years a great level of trust between CREM and Téléverbier formed which facilitates close and efficient collaborations

"In Krvavec we are constantly in touch and communicating with our partners - suppliers, who are introducing us the innovations on the one hand and listening to our ideas on the other. This cooperation is continuous and produces results."

6.4.9.1. Use of Performance Targets and Labels in Tenders

In order to specify sustainability criteria in a tender, the procurer could state an obligation to declare the energy consumption in the submitted price of maintenance contracts and the obligation to use certain technologies or products (e.g. LED, sustainable timber)
An alternative to performance targets is the use of suitable labels which have inherent performance targets. They can greatly simplify the tasks of the procurer, as they avoid the need to define appropriate qualifications, award criteria and contract clauses[29]. Overall, labels and standards can be used in procurement to verify a product's 'green' credentials, as a minimum requirement, or as a method to create sustainability criteria[30]. However, one has to be aware that SMEs yet again may find it difficult to take part in the certification process for such labels. From an innovation perspective, a critical issue is whether the standards of such labels are being reviewed frequently enough to ensure technical progress and avoid the 'innovation freeze'.

Labels or energy ratings can be used as a short-cut to specifying performance targets. Some Labels which can be currently found in ski resorts, especially hotels are:

- The German Certificate „Viabono“
- The Austrian "Umweltzeichen“
- The Swiss Label „Ibex Fairstay“
- Blaue Schwalbe
- World Ski awards: World's Best Green Ski Hotel

Other labels refer to appliances or sustainable building in General. Labels with international significance for buildings are :

- LEED
- BREEAM
- DGNB

[29] OECD (2015), The Innovation Imperative: Contributing to Productivity, Growth and Well-Being, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264239814-en accessed February 2020
[30] UNEP (2013), Sustainable Public Procurement: A Global Review. United Nations Environment Programme,.

6.4.9.2. Procuring Value-for-Money

Within public procurement it is becoming more and more common to use additional criteria to define value-for-money[31]:

- The use of performance standards
- Total cost of ownership (TCO): the total of all costs resulting from acquiring a product and the costs involved in using the product during its period of use. As an example, TCO would explicitly allow comparison of two products on the basis of their associated energy consumption once in use. TCO usually relates to actual financial expenditure.
- Life-cycle costing (LCC): on top of the above LCC may include the cost of externalities (the shadow price) related to upstream and downstream activities, cost of disposal, etc. Not all of these costs would currently result in actual financial transaction. By way of an example, in the Netherlands infrastructure procurement, all tenderers use the same method to cost externalities on a life-cycle basis and to account for them in their bids. This means considering trade-offs between different types of externalities and other 'real' costs. International legal texts support this practice - for example article 68 of the EU Directive on public procurement explicitly mentions: "such costs may include the cost of emissions of greenhouse gases and of other pollutant emissions and other climate change mitigation costs"[32]. In addition, the WTO Revised Agreement on Government Procurement [33] states that "the evaluation criteria … may include, inter alia, price and other cost factors, technical merit, environmental characteristics and terms of delivery.

6.4.10. Conclusion

As any business, ski resorts need to innovate continuously in order to survive. This need is now becoming particularly pressing due to the challenges posed by physical impacts of climate change on the one hand and regulatory and legal obligations related to climate change mitigation on the other.
Successful innovation management will ensure that ski resorts continue to create value, thus safeguarding and promoting their businesses. This short guide to creating value from low carbon innovation has introduced the most important aspects and tools to consider when a ski resorts wants to innovate. Tools such as PESTEL and SWOT facilitate a sound understanding of the status quo and identification of innovation needs. In order to carefully plan for an innovation all implications on the supply-side and customer-side need to be

[31] Clement, S; Watt, J.(2016) The Procura+ Manual - A Guide to Implementing Sustainable Procurement, 3rd Edition, ICLEI – Local Governments for Sustainability, European Secretariat; p. 76
[32] European Union (2014), Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0024&from=EN accessed February 2020
[33] WTO (2012), Revised Agreement on Government Procurement, World Trade Organisation, Geneva, https://www.wto.org/english/docs_e/legal_e/rev-gpr-94_01_e.htm accessed February 2020

understood. The value chain analysis can help with this. The five forces of porter help to fine-tune the innovation and its market entry. Green r sustainable procurement can play a powerful role in fostering innovation and the most important aspects have been outlined.
The examples from SMART ALTITUDE pilots illustrate what innovation in ski resorts is possible and appropriate while also providing an understanding of barriers encountered and the contextual factors which allow for successful implementation of innovations.

7. Webinar Series

In the months of June and July 2020, five webinars have discussed the Implementation Models with the stakeholders of the Smart Altitude project, including potential replicators (Figure 81):

- **17/6/2020: About the Smart Altitude Project (including a presentation of Climate Adaptation & Mitigation):** The first webinar presents the Smart Altitude Project and the six-steps approach for dealing with climate change in Alpine ski resorts. Adaptation and mitigation strategies are discussed. The Smart Altitude Online toolkit are presented as a main resource for guiding ski-resort operators and local policy-makers in developing low-carbon measures.
- **24/6/2020: Renewable energy & Sustainable mobility:** The second webinar offers an overview of the approaches for integrating renewable energy systems, energy storage systems and sustainable mobility in Alpine ski areas.
- **1/7/2020: Energy Management System:** The third webinar presents the necessary steps to consider for building an Integrated Energy Management System (IEMS) for a ski operator. Best practices are presented by the Living Labs of Les Orres (France), Madonna di Campiglio (Italy) and Verbier (Switzerland).
- **8/7/2020: Smart Grid:** The fourth webinar aims at presenting Smart Grid models for maximizing GHG reduction, economic impact and stakeholder benefits at the level of a community of energy consumers and producers. The general concepts of a Smart Grid are described, focusing on flexibility, reliabilty, accessibility and savings. The second part presents the best practices of the Nice and Les Orres Smart Grids.
- **15/7/2020: Value Creation through low-carbon innovation:** The final webinar presents a short guide to creating value from low carbon innovation by introducing the most important aspects and tools to consider in a ski resort. Tools such as PESTEL and SWOT will be presented in order to analyze the status quo of a ski resort and identify its innovation needs.

In the new Smart Altitude Online Toolkit an entire section is dedicated to the PLAN theme (https://smartaltitude.eu/tools/plan/) with the 5 downloadable Implementation Models and the 5 viewable Webinars (YouTube channel, with also the downloadable presentations).
In Figure 82, Figure 83, Figure 84 and Figure 85 the main statistics relating to the Webinar Series: participants, stakeholder composition, countries, visitors YouTube.
Overall, during the Webinar Series we had 122 different registered participants from 12 different countries, while until 07/08/2020 the 5 Webinars had 148 views on YouTube.

Figure 81: The Smart Altitude Webinar Series - program

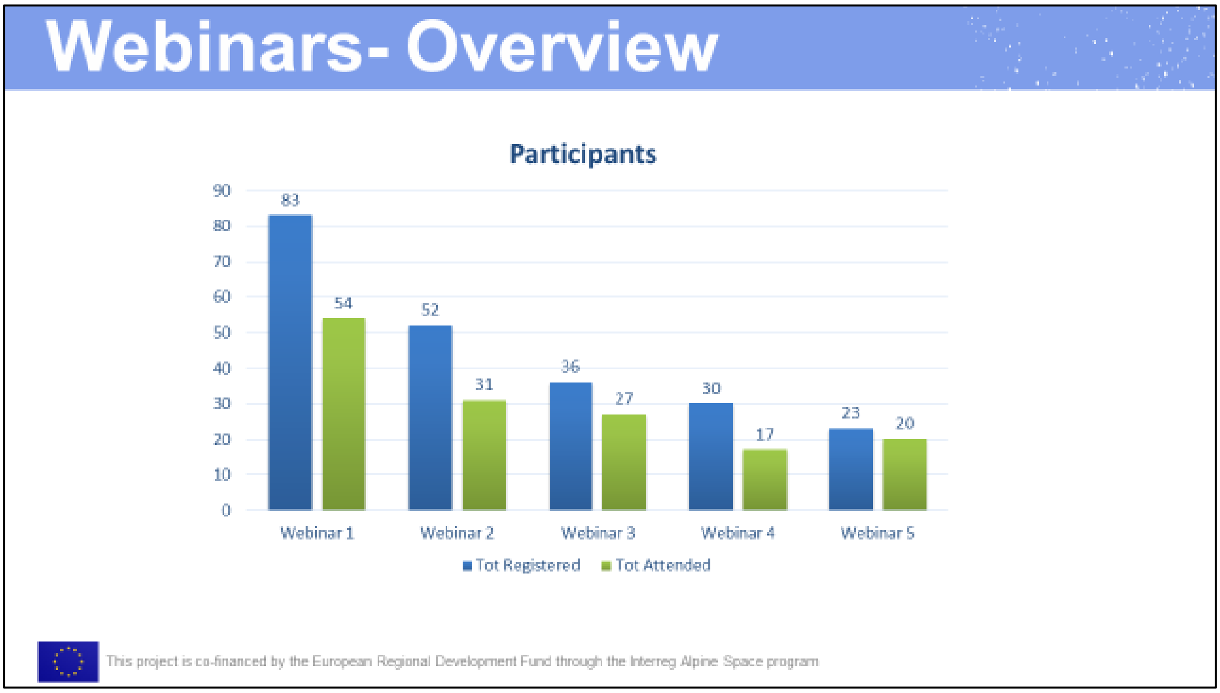

Figure 82: The Smart Altitude Webinar Series - participants statistics

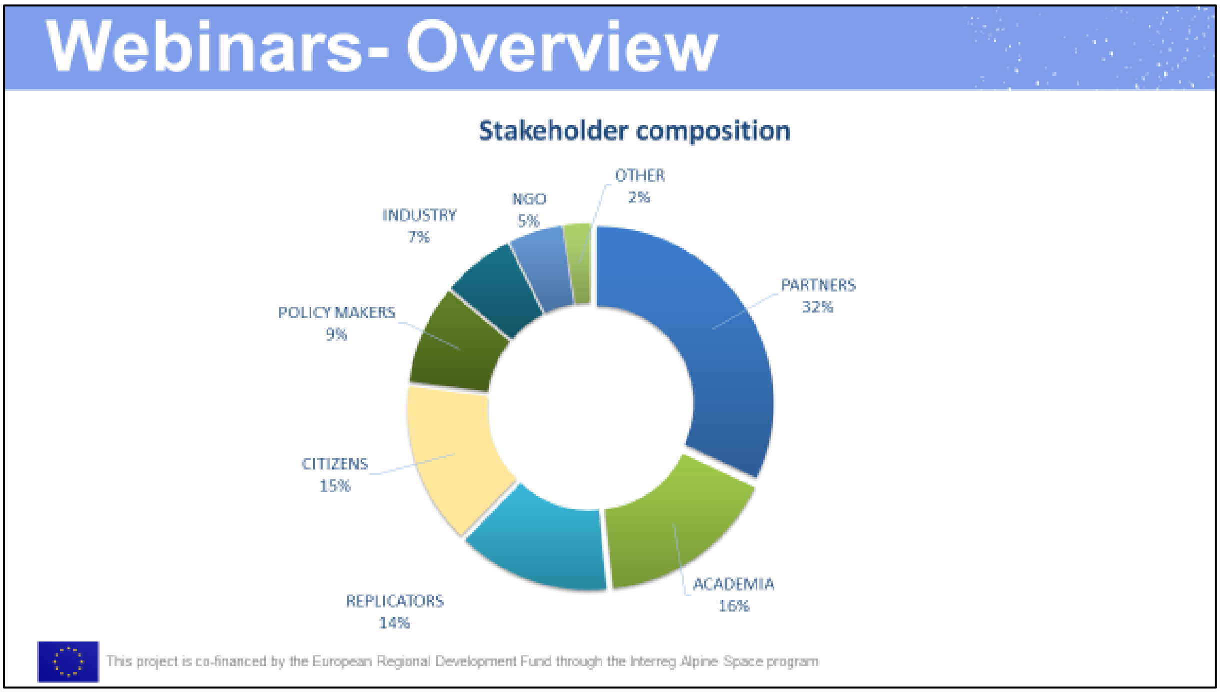

Figure 83: The Smart Altitude Webinar Series - stakeholder composition statistics

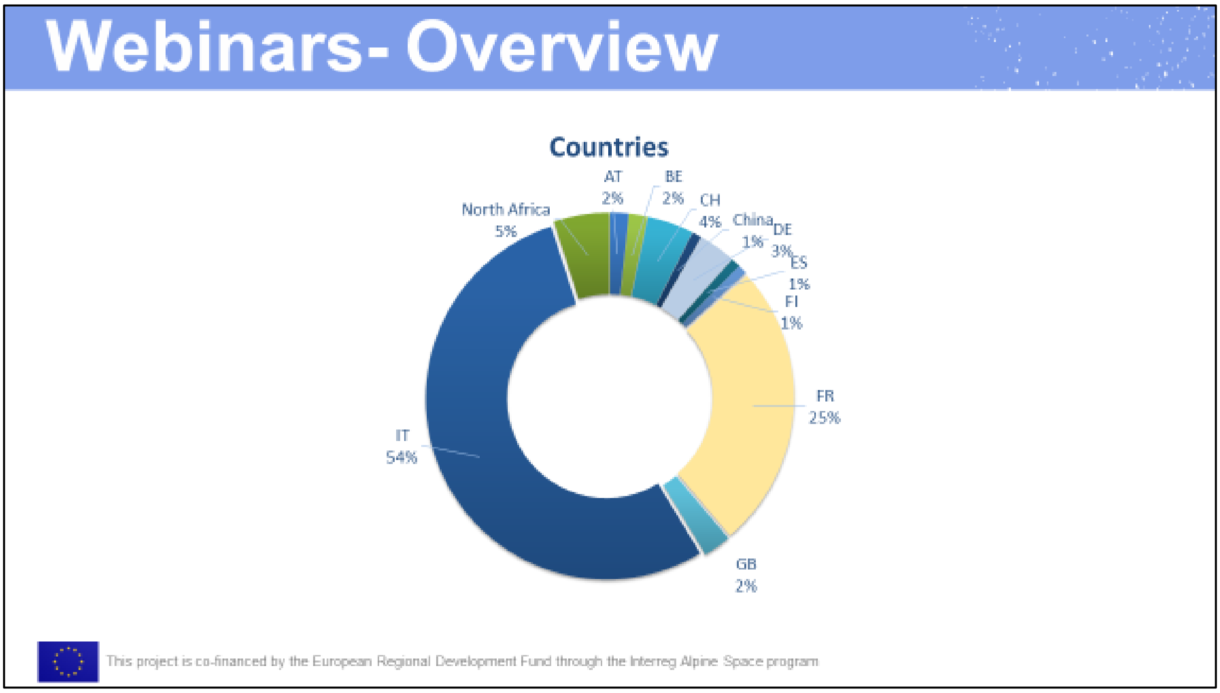

Figure 84: The Smart Altitude Webinar Series - countries statistics

Video	Visualizzazioni		Tempo di visualizzazione (ore)		Iscritti		Impressioni	Percentuale di clic delle impressioni
Totale	**170**		**7,5**		**5**		**1.770**	**3,2%**
SMART ALTITUDE | Webinar #2 Renewable energy and sustainable ...	62	36,5%	2,4	31,6%	3	60%	1.291	0,9%
SMART ALTITUDE | Webinar #1 About the Smart Altitude Project	55	32,4%	1,8	24,0%	1	20%	63	23,8%
Smart Altitude Official Video	19	11,2%	0,5	6,6%	-1	-20%	31	45,2%
SMART ALTITUDE | Webinar #4 Smart Grid	14	8,2%	0,5	6,5%	0	0%	45	11,1%
SMART ALTITUDE | Webinar #3 Energy Management System	13	7,7%	1,8	23,9%	0	0%	165	3,6%
SMART ALTITUDE | Webinar #5 Value Creation through low carbon i...	4	2,4%	0,5	6,9%	0	0%	147	1,4%
Smart Altitude | Madonna di Campiglio Living Lab	3	1,8%	0,0	0,6%	0	0%	28	10,7%

Figure 85: The Smart Altitude Webinar Series - Visitors YouTube