WP T3 Smart Altitude Toolkit

A.T3.1 Decision-making criteria

D.T3.1.3 Real-time dynamic display of energy and greenhouse gas emission reduction in public information platforms

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1. Introduction

This deliverable describes the real-time dynamic display of energy and greenhouse gas (GHG) emission reduction, performed by the four Smart Altitude Living Labs, in a public information platform.
Each Living Lab is equipped with monitoring systems, relating to the operation of the infrastructures (snow production, snow grooming, ski lifts, operational buildings), the presence of skiers, climatic conditions, etc.
These monitoring systems allow on the one hand the analysis and optimization of operating conditions, on the other the evaluation of energy consumption from which to deduce the efficiency achieved by the introduction of new technologies, the degree of integration of renewable sources, the GHG emission reduction.
This deliverable allows to validate the activities carried out in the four Living Labs. The reductions in energy consumption and GHG emissions are shown on a seasonal basis, with reference to the 3 winter seasons affected by the Smart Altitude project (2018/2019, 2019/2020 and 2020/2021). The public information platform for viewing this data is represented by the Smart Altitude Online Toolkit, in the dedicated monitoring page (https://smartaltitude.eu/tools/monitor/). In particular, the reductions made by a specific mitigation action, compared to a previous situation or a technological standard, are detailed.
Each Living Lab is responsible for providing the data.

2. Mitigation strategies

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. 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 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. Energy demand in the winter tourism industry is rapidly increasing because, in addition to consumption for ski lifts, snow groomers and operational buildings, the implementation of snow making systems is at present the most widely utilized adaptation strategy. 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.
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).
The implementation of 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. 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 1.

Table 1: 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

3. The four Smart Altitude Living Labs

The implementation of Smart Altitude interventions is conducted by four Living Labs (Les Orres in France, Madonna di Campiglio in Italy, Krvavec in Slovenia, Verbier in Switzerland, see Figure 1), based on the engagement of relevant stakeholders. The Smart Altitude Living Labs represent lighthouses of innovative and high impact low carbon interventions in ski resorts, in several topics (advanced energy efficiency, integrated energy management systems, RES integration, smart grid), in different geographic areas.

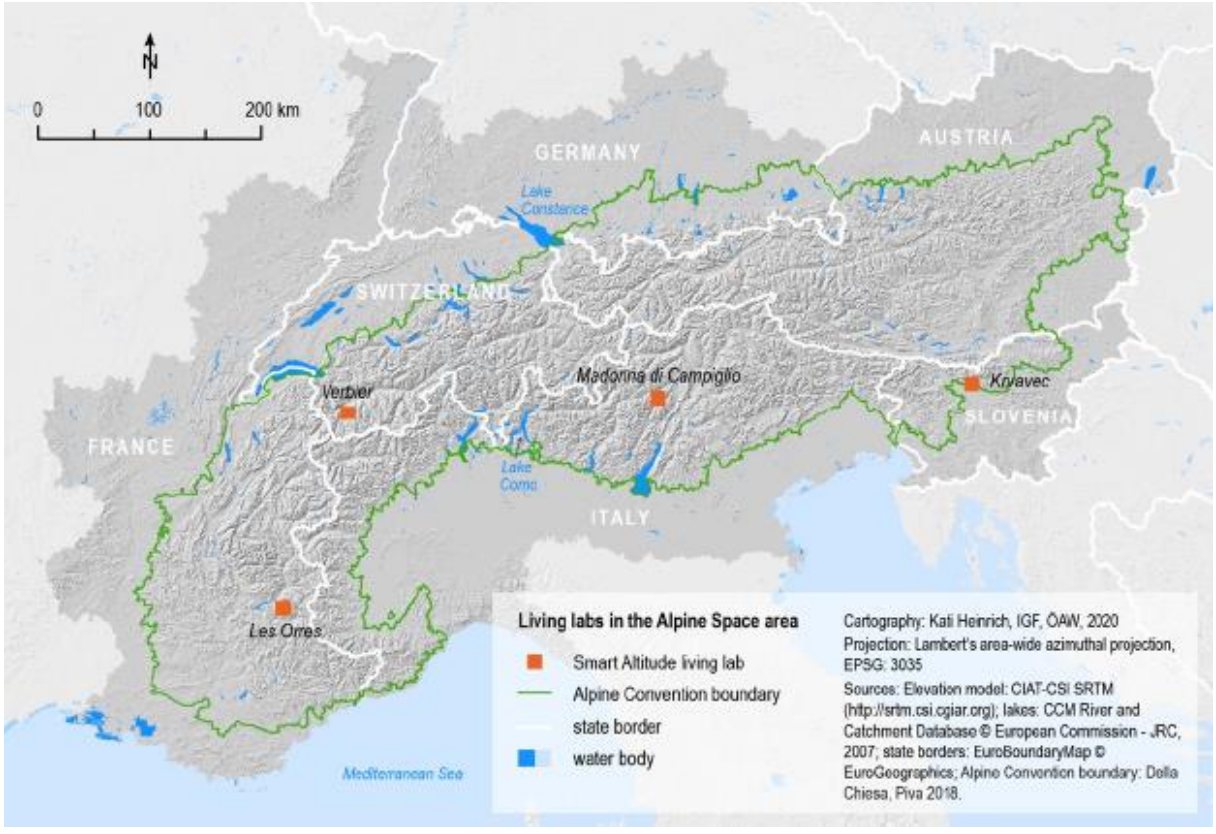

Figure 1: Smart Altitude Living Labs in the Alpine Space cooperation area (shaded in dark grey)

From the beginning of the project, the operational and energy characteristics of the Living Labs were analyzed in detail. In particular, for the Living Labs of Les Orres, Madonna di Campiglio and Krvavec, the new audit tool of the Smart Altitude project called Wi-EMT was used. Instead, for the Verbier Living Lab only a few data were collected which, however, made it possible to identify its main characteristics. The analysis result is shown in Table 2.

The energy consumption of a ski resort is very high (between 5 and 16 GWh/winter season in the Smart Altitude Living Labs) and represents an important share (between 7% and 16% in the Smart Altitude Living Labs) in the seasonal turnover. Therefore, paying great attention to the reduction of energy consumption is strategic not only to contribute to the mitigation of climate change but also to guarantee economic sustainability for the tourism. Furthermore, the use of renewable sources is often low (12-56 % in the Smart Altitude Living Labs), the decarbonisation potential is therefore manifold.
The data in Table 2 represents the starting state of the 4 Living Labs at the beginning of the Smart Altitude project, the goal of this deliverable is to ensure visibility to the evolution of these values during the Smart Altitude project, highlighting progress in energy efficiency and decarbonisation.
In this paragraph an individual description of the four Living Labs follows, with the related challenges and solutions of the Smart Altitude project.

Table 2: Characteristics of the Smart Altitude Living Labs

Characteristic	Les Orres	Madonna di Campiglio	Krvavec	Verbier [3]
Municipality	Les Orres (FR)	Pinzolo (IT)	Cerklje na Gorenjskem (SI)	Bagnes (CH)
Ski Operator Company	SEMLORE SAEM	Funivie Madonna di Campiglio S.p.A	RTC Krvavec d.o.o	Téléverbier SA
Altitudinal range (m a.s.l.)	1550–2720	1513–2501	1477–1973	1500–3300
Construction of first lift (year)	1966	1948	1973	1946
Winter season turnover (EUR)	11 million	25 million	4 million	44 million
Skier days per winter season (count)	510,000	1,222,872	205,508	1,161,554
Ski slopes (km)	48	60	30	200
Lifts (km)	15	28	13	43
Lift capacity (persons per hour)	22,398	35,533	14,121	45,980
Snow guns (count)	61	117	20	82
Snow lances (count)	125	629	90	278
Snow production per winter season (m^3)	600,000	1,140,000	200,000	720,000
Total energy consumption in winter season (kWh) [1]	6,887,686	15,094,773	5,267,260	16,223,786
Energy use for ski lifts (percentage of total energy use)	23	22	15	37
Energy use for snow production (percentage of total energy use)	27	30	34	6
Energy use for snow groomers (percentage of total energy use)	27	24	23	34
Energy use for operative buildings (percentage of total energy use) [2]	23	24	28	23
Renewable energy use (percentage of total energy use)	12	30	16	56

[1] Relates to the total energy consumption of the ski area operations. [2] Operative buildings are at the service of the ski slopes management (e.g., ski pass sale, warehouses, control room; does not include hotels or residential buildings). [3] Data are not validated by the Winter tourism Eco-energy Management Tool (Wi-EMT).

3.1. Les Orres/France – Smart Mountain Grid

Les Orres is a sports and leisure resort in the Hautes-Alpes department in south-eastern France. In winter, the ski resort offers 48 km of slopes. In summer, the area provides multiple opportunities for hiking, biking, well being and relaxation in nature.
In 2014, Les Orres set up an energy management system that reduced energy consumption by 20%, green-house gas emissions by 100 t CO2 and the station's energy bill by 25%. However, the power capacity of the resort's private electricity grid represents less than half of the total installed capacity: 4.5 MW for a total of 14 MW. The smart grid model can be a solution for managing the energy balance of all components of the ski resort.
In the Smart Altitude Project, Les Orres will build and test an integrated smart grid model. The consideration of geographical and climatic specificities will allow to design the smart grid model to the stakes of balancing networks, reducing consumption and enhancing energy autonomy of the ski resort.
Complementary and integrative to the main goal of the Smart Mountain Grid, the following key activities are highlighted:

- Energy balance system: test an energy supply-demand balancing system
- Renewable energy: integrate the renewable energy production of the territory (hydroelectric, PV, …)
- User engagement: influence individual user behaviour.

3.2. Madonna di Campiglio/Italy – Integrated Energy Management System

Located in the heart of the Brenta Dolomites, Madonna di Campiglio is called the "Pearl of the Dolomites" for the unique beauty of its landscapes, mountains and nature. Madonna di Campiglio is the largest ski-area in the western Dolomites, offering several opportunities for skiing, snowboarding but also for hiking, ice-climbing, dog-sledding and wellness. Madonna di Campiglio's mission is to achieve zero CO2 emissions by 2026, the year of the XXV Winter Olympic Games hosted in Italy. To this end, it aims to improve energy efficiency, optimize the use of water and integrate renewable energy.
In the Smart Altitude Project, Madonna di Campiglio will test an integrated energy management system. The system will monitor ski-lifts, snow groomers, snow production, skier days, operative buildings, meteo and electric grid. The focus of the monitoring is on the consumption of energy and water on the entire ski area. It will generate reports with aggregated data and information to support ski managers in taking eco-sustainable decisions.
Complementary and integrative to the main goal of the Integrated Energy Management System, the following key activities are highlighted:

- Reservoir lake: monitor reservoir lake "Montagnoli"
- Renewable energy: integrate PV on ski lifts and geothermal heat pumps for snow groomers' garage
- Smart meters: add new smart meters for energy monitoring.

3.3. Krvavec/Slovenia – Energy Savings

The Krvavec Ski Resort is the second-largest Slovenian ski resort, located in the beautiful and wild Kamnik-Savinja Alps. Krvavec has a long-standing tradition in winter tourism, with more than 30 km of ski-slopes that make it the most popular ski resort in Slovenia. In the summer, Krvavec becomes a green oasis for families, hikers and cyclists. Krvavec's mission is to save energy by optimizing energy consumption, for a better, more sustainable and eco-friendly management of the ski resort. However, it is characterized by a low altitude that challenges the availability of natural snow and forces it to make intensive use of technical snow-making.
In the Smart Altitude Project, Krvavec will gain new equipment for snow-making and new systems to accumulate and manage water. It will compare and use the results of the other Living Labs to design eco-friendly development strategy and to market new offers for eco-tourism.
Complementary and integrative to the main goal of the Energy Savings, the following key activities are highlighted:

- Ski infrastructure: replace old ski lifts with new energy efficient ones
- Snow making: add energy-efficient snow cannons to improve snowmaking
- Reservoir lake: build a new reservoir lake to optimize water management.

3.4. Verbier/Switzerland – "Cité de l'énergie" gold label

Linked to the 4 Vallées, Verbier and La Tzoumaz form part of Switzerland's largest ski area with 410 km of slopes. With activities such as ski touring, heli-skiing, and freeride, Verbier provides a full range of opportunities to skiers and snowboarders. In summer, the area becomes a Mecca for mountain biking and hiking.
Verbier has a low carbon policy for reducing its carbon footprint, complying with the ISO 50001 certification. Verbier is harmonizing the energy saving policy and actions across its territory and the municipality of Bagnes to reach the gold label "Cité de l'énergie". To this end, Verbier is implementing low-carbon measures related to its installations, buildings and mobility and keeps improving its energy management platform.
In the Smart Altitude Project, Verbier will work on innovative measures for monitoring, optimizing and managing energy-consumption of the overall ski infrastructure. A new concept will be tested based on the valorization of waste heat released by the ski lifts motor, wood fire burner for heat generation and PV solar panels for electric needs.
Complementary and integrative to the main goal of the "Cité de l'énergie" gold label, the following key activities are highlighted:

- Smart low-carbon building: design and test of a new concept for the energy-management of buildings in the ski-resort
- Energy Management System: improve the system to go towards the energy management system certification according to the standard ISO 50001
- Heat valorisation: extend the concept of the heat pump system for waste heat valorisation to a second ski lift.

3.5. Monitoring systems

This paragraph shows Table 3 indicating the characteristics of the monitoring systems in the 4 Smart Altitude Living Labs.
As you can see, three of the four case studies are equipped with an Integrated Energy Management System (IEMS), capable of collecting and analyzing data from the Energy Management System (EMS) of different sectors of the ski resort. Les Orres and Verbier were equipped with an IEMS already at the beginning of the Smart Altitude project while Madonna di Campiglio adopted it starting from the second winter season (2019/2020).
The energy management of a ski resort can be divided into four sectors: ski lifting, snow making, snow grooming and operational buildings. The degree of monitoring of these sectors is not uniform in the four Living Labs, it is of high quality in Les Orres, Verbier and Madonna di Campiglio while it is of medium quality in Krvavec.
The current low integration of renewable sources and storage systems, with monitoring, unites the four cases.
In ski lifting, Smart Altitude case studies include monitoring of the number of entrances, of the ski lifts speed and of the electricity consumption.
In snow making the monitored parameters concern water (storage, consumption, temperature), compressed air (consumption), outdoor climatic characteristics (temperature, humidity), electrical consumption.
In snow grooming, operational data (km, h), snow thickness and energy consumption are monitored.
Finally, in operating buildings, attention is paid to data collection dedicated to indoor parameters (temperature, humidity ...), energy consumption for heating, energy consumption for electricity, heat recovery.

Table 3: Characteristics of the monitoring systems in the 4 Smart Altitude Living Labs

Monitoring System		Les Orres			Madonna di Campiglio			Krvavec			Verbier		
		2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021
Overall ski resort	Integrated Energy Management System (IEMS)												
Ski lifting	Monitoring dedicated to n. of entrances												
	Monitoring dedicated to the speed												
	Monitoring dedicated to electric consumption												
	Monitoring dedicated to RES integration												
	Monitoring dedicated to energy storage integration												
Snow making	Monitoring dedicated to water storage												
	Monitoring dedicated to water consumption												
	Monitoring dedicated to water temperature												
	Monitoring dedicated to outdoor air temperature and humidity												
	Monitoring dedicated to compressed air consumption												
	Monitoring dedicated to electric consumption												

	Monitoring dedicated to RES integration												
	Monitoring dedicated to energy storage integration												
Snow grooming	Monitoring dedicated to operational data (km, h)												
	Monitoring dedicated to snow depth												
	Monitoring dedicated to energy consumption												
	Monitoring dedicated to RES integration												
	Monitoring dedicated to energy storage integration												
Buildings	Monitoring dedicated to indoor parameters (temperature, humidity ...)												
	Monitoring dedicated to energy consumption for heating												
	Monitoring dedicated to energy consumption for electricity												
	Monitoring dedicated to RES integration												
	Monitoring dedicated to heat recovery												
	Monitoring dedicated to energy storage integration												

4. Real-time dynamic display of energy and GHG emission reduction in a public information platform

The reductions in energy consumption and GHG emissions, performed by the four Living Labs, are shown on a seasonal basis, with reference to the 3 winter seasons affected by the Smart Altitude project (2018/2019, 2019/2020 and 2020/2021). The platform for viewing this data is represented by the Smart Altitude Online Toolkit, in the dedicated monitoring page (https://smartaltitude.eu/tools/monitor/). In particular, the reductions made by a specific mitigation action, compared to a previous situation or a technological standard, are detailed.

Each Living Lab is responsible for providing and updating the data. When this deliverable is written, July 2020, only estimates are available (Table 4 and Table 5) which will be validated at the end of the project (April 2021) with a detailed analysis of the monitoring data.

Let's start with the reductions in energy consumption (Table 4).

Three of the four Living Labs, Les Orres, Madonna di Campiglio and Verbier, have adopted a very advanced energy monitoring and Integrated Energy Management System, for the entire ski resort, from the overall data analysis it is possible to reduce 10-20% energy consumption, identifying losses, inefficiencies and unnecessary uses. Les Orres and Verbier were in possession of this measure already at the beginning of the Smart Altitude project while Madonna di Campiglio adopted it starting from the second winter season (2019-2020).

In ski lifting, monitoring and EMS are adopted by Les Orres, Madonna di Campiglio (SKIDATA and grid electric consumption) and Verbier with the potential to reduce energy consumption by 10-20% by identifying losses, inefficiencies and unnecessary uses. Since 2019 Téléverbier is testing an automatic regulation of lift's speed thanks to cameras and in 2020 it is start the implemention (with the company Sisag) of an automatic system regulating the speed according to n. of entraces, with energy savings of 2-5%. Replacement of old ski lifts with modern technologies is adopted by all Living Labs with particular commitment by Krvavec and Madonna di Campiglio (the latter with new Nube d'Oro and Fortini ski lifts with Doppelmayr Direct Drive energy-saving technology), for this measure the energy savings for the overall consumption of ski lifting is between 1 and 5% (the values are low because the interventions are only on a few ski lifts compared to the total).

Turning to snow making, all four Living Labs are very attentive to optimal water management, including pump analysis, with energy savings of 10-20%. Particular commitment is expected from Krvavec with the new reservoir lake. Replacement of old snow-making systems with modern technologies is adopted by all Living Labs with particular commitment by Krvavec, for this measure the energy savings for the overall snow making consumption is between 1 and 5% (the values are low because the interventions are only on a few snow-making systems compared to the total). Finally, the implementation of an automated snow making system (e.g. TechnoAlpin Liberty in Madonna di Campiglio) and the

plan of which kind of snow making system is the most effective for the ski resort are adopted by all four Living Labs with energy savings of 10-20%.
As for snow grooming, Les Orres, Madonna di Campiglio and Verbier are particularly active, with careful management of the snow groomers' park and snow groomers' routes, with expected energy savings of 10-20%. In Madonna di Campiglio the snow groomers' fuels consumption is monitored by AMA, the snow groomers' operational data by Prinoth and Kassbohrer, the snow depth by Snowsat, Leica and Snowhow. To these potential savings can be added the replacement of old grooming machines with newer ones (1-2%, the values are low because the interventions are only on a few snow groomers compared to the total).
Finally, operational buildings also determine large energy consumption (electricity and heating) for which various efficiency measures can be adopted. Les Orres and Verbier are particularly active in the evaluation of energy consumption and in the improvement of the heating and ventilation system from the beginning of the project, with potential for energy savings between 10 and 20%, Madonna di Campiglio and Krvavec are at work on these measures with the aim of adopting them by the end of the project. The replacement of indoor and outdoor lighting with energy-efficient lightbulbs and an automated lighting control is adopted by all four Living Labs, with potential savings of 5-10%. Finally, Verbier is committed to recovering heat from the engines of the ski lifts with energy saving potentials of between 1 and 5% (% of the overall operation buildings consumption).
Let's move on to the GHG emission reductions (Table 5).
Three of the four Living Labs, Les Orres, Madonna di Campiglio and Verbier, have adopted a very advanced monitoring and Integrated Energy Management System, for the entire ski resort, from the data analysis it is possible to reduce the 15-25% of the GHG emissions, identifying losses, inefficiencies, unnecessary uses and optimizing the integration of renewable sources. Les Orres and Verbier were in possession of this measure already at the beginning of the Smart Altitude project while Madonna di Campiglio adopted it starting from the second winter season (2019-2020).
In ski lifting, monitoring and EMS are adopted by Les Orres, Madonna di Campiglio and Verbier with the potential to reduce GHG emissions by 15-25% by identifying losses, inefficiencies, unnecessary uses and optimizing the integration of renewable sources. Implementing renewable sources ("actively" and not only through "green certificate" electrical import) is complex for all four Living Labs, mainly due to the high costs (especially in the mode integrated with the ski lifts) and the low winter yield (PV), with potential during the Smart Altitude project that does not exceed 5% of GHG emission reduction (in ski lifting). As a positive aspect for PV, despite the low yield of the winter season compared to the summer one, the energy consumption is in the daytime when the solar production is maximum, and in a mountain environment where the solar radiation is better than at the lowest altitudes as well as low temperature conditions help. Since 2019 Téléverbier is testing an automatic regulation of lift's speed thanks to cameras and in 2020 it is start the implemention (with the company Sisag) of an automatic system regulating the speed according to n. of entraces, with reduction of GHG emissions of 2-5%. Replacement of old ski lifts with modern technologies is adopted by all Living Labs with particular commitment by Krvavec and Madonna di Campiglio (the latter with new Nube d'Oro and Fortini ski lifts with Doppelmayr Direct Drive energy-saving technology), the reduction of GHG emissions for the

overall ski lifting is between 1 and 5% (the values are low because the interventions are only on a few ski lifts compared to the total).
Turning to snow making, all four Living Labs are very attentive to optimal water management, including pump analysis, with a reduction of GHG emissions by 10-20%. Particular commitment is expected from Krvavec with the new reservoir lake. Replacement of old snow-making systems with modern technologies is adopted by all Living Labs with particular commitment by Krvavec, the reduction of GHG emissions for the overall snow making is between 1 and 5% (the values are low because the interventions are only on a few snow-making systems compared to the total). Finally, the implementation of an automated snow making system (e.g. TechnoAlpin Liberty in Madonna di Campiglio) and the plan of which kind of snow making system is the most effective for the ski resort are adopted by all four Living Labs with a reduction of GHG emissions of 15-25%. As for ski lifting, also for snow making, implementing renewable sources ("actively" and not only by means of "green certificate" electrical imports) is complex for all four Living Labs, mainly due to the high costs and low winter yield (PV), with potential during the Smart Altitude project that does not exceed 5% of GHG emission reduction (in snow making). In this case, mainly nocturnal energy consumption hinders integration with the PV.
As for snow grooming, Les Orres, Madonna di Campiglio and Verbier are particularly active, with careful management of the snow groomers' park and snow groomers' routes, with a reduction of GHG emissions of 10-20%. In Madonna di Campiglio the snow groomers' fuels consumption is monitored by AMA, the snow groomers' operational data by Prinoth and Kassbohrer, the snow depth by Snowsat, Leica and Snowhow. To these potential savings we can add the replacement of old grooming machines with newer ones (1-2%, the values are low because the interventions are only on a few snow groomers compared to the total). The implementation of electric snow groomers is not foreseen in the 4 Living Labs, these are vehicles still in the testing phase and first launches on the market with high costs.
Lastly, operational buildings also determine large GHG emissions for which various efficiency measures and the introduction of renewable sources can be adopted. Les Orres and Verbier are particularly active in the evaluation of GHG emissions and in the improvement of the heating and ventilation system from the beginning of the project, with GHG reduction potential between 10 and 20%, Madonna di Campiglio and Krvavec are at work on these measures with the aim of adopting them by the end of the project. The replacement of indoor and outdoor lighting with energy-efficient lightbulbs and an automated lighting control is adopted by all four Living Labs with GHG reduction potentials of 5-10%. Finally, the heat recovery is adopted by Verbier, from the engines of the ski lifts, with potential GHG emission reductions between 1 and 5% (% of the overall operation buildings consumption), while the integration of renewables for operational buildings is adopted by Les Orres (PV, 0-5%), Verbier (district heating, PV, heat pump, biomass boiler, 10-20%), Madonna di Campiglio (biomass boiler, 20-40%). Above all, for the thermal demand the integration potential of biomass and heat pumps appears remarkable and economically attractive, in this sense Verbier and especially Madonna di Campiglio represent very positive case studies.

Table 4: Real-time dynamic display of energy reduction, performed by the four Smart Altitude Living Labs, in a public information platform (estimates by the managers of the Living Labs, validation at the end of the project, data available and updated on the Smart Altitude Online Toolkit https://smartaltitude.eu/tools/monitor/)

Mitigation Measures		Les Orres			Madonna di Campiglio			Krvavec			Verbier		
		2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021
Overall ski resort	Monitoring and Integrated Energy Management System (IEMS)	10-20%	10-20%	10-20%		10-20%	10-20%				10-20%	10-20%	10-20%
Ski lifting	Monitor and implement an EMS	10-20%	10-20%	10-20%		10-20%	10-20%				10-20%	10-20%	10-20%
	Assess ski lifts energy efficiency	10-20%	10-20%	10-20%		10-20%	10-20%				10-20%	10-20%	10-20%
	Implement renewable energy sources (e.g. PV)												
	Implement speed control measures (e.g. based on the number of entrances)											2-5%	2-5%
	Replace old ski lift systems with modern technology	1-2%	1-2%	1-2%	1-2%	2-5%	2-5%	1-2%	1-2%	2-5%	1-2%	1-2%	1-2%
Snow making	Optimal water management (flow rates, height differences, main and secondary reservoirs, water concessions)	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	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	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	Replace old snow-making systems with modern technology	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	2-5%	1-2%	1-2%	1-2%

	Implement an automated snow making system	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	Plan which kind of snow making system is the most effective for the ski resort (Fan gun, Hybrid/tower, Hybrid/high-pressure)	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	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)	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%				10-20%	10-20%	10-20%
	Replace old grooming machines with newer ones	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%
	Implement hybrid/electric snow groomers												
Buildings	Assess the energy consumption of the ski resorts building and improve the heating system and ventilation	10-20%	10-20%	10-20%			10-20%			10-20%	10-20%	10-20%	10-20%
	Replace indoor and outdoor lighting with energy-efficient lightbulbs and an automated lighting control	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%
	Improve the energy efficiency of building envelopes												
	Implement heat recovery										1-5%	1-5%	1-5%
	Implement renewable energy sources for heating and electricity												

Table 5: Real-time dynamic display of GHG emission reduction, performed by the four Smart Altitude Living Labs, in a public information platform (estimates by the managers of the Living Labs, validation at the end of the project, data available and updated on the Smart Altitude Online Toolkit https://smartaltitude.eu/tools/monitor/)

Mitigation Measures		Les Orres			Madonna di Campiglio			Krvavec			Verbier		
		2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021	2018-2019	2019-2020	2020-2021
Overall ski resort	Monitoring and Integrated Energy Management System (IEMS)	15-25%	15-25%	15-25%		15-25%	15-25%				15-25%	15-25%	15-25%
Ski lifting	Monitor and implement an EMS	15-25%	15-25%	15-25%		15-25%	15-25%				15-25%	15-25%	15-25%
	Assess ski lifts energy efficiency	10-20%	10-20%	10-20%		10-20%	10-20%				10-20%	10-20%	10-20%
	Implement renewable energy sources (e.g. PV)	0-1%	0-1%	1-5%			1-2%						1-2%
	Implement speed control measures (e.g. based on the number of entrances)											2-5%	2-5%
	Replace old ski lift systems with modern technology	1-2%	1-2%	1-2%	1-2%	2-5%	2-5%	1-2%	1-2%	2-5%	1-2%	1-2%	1-2%
Snow making	Optimal water management (flow rates, height differences, main and secondary reservoirs, water concessions)	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	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	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	Replace old snow-making systems with modern technology	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	2-5%	1-2%	1-2%	1-2%

	Implement an automated snow making system	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%	15-25%
	Plan which kind of snow making system is the most effective for the ski resort (Fan gun, Hybrid/tower, Hybrid/high-pressure)	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
	Implement renewable energy sources	0-1%	0-1%	1-5%			1-2%						1-2%
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)	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%				10-20%	10-20%	10-20%
	Replace old grooming machines with newer ones	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%	1-2%
	Implement hybrid/electric snow groomers												
Buildings	Assess the energy consumption of the ski resorts building and improve the heating system and ventilation	10-20%	10-20%	10-20%			10-20%			10-20%	10-20%	10-20%	10-20%
	Replace indoor and outdoor lighting with energy-efficient lightbulbs and an automated lighting control	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%
	Improve the energy efficiency of building envelopes												
	Implement heat recovery										1-5%	1-5%	1-5%
	Implement renewable energy sources for heating and electricity	0-1%	0-1%	1-5%	20-25%	20-25%	30-40%				10-20%	10-20%	10-20%

5. Conclusion

This deliverable presented the way in which the reductions in energy consumption and GHG emissions, relating to the four Living Labs, are illustrated in the public information platform represented by the Smart Altitude Online Toolkit, in the monitoring page (https://smartaltitude.eu/tools/monitor/).

The aim is to show the results with a dynamism represented by the 3 winter seasons of the Smart Altitude project (2018/2019, 2019/2020 and 2020/2021).

In particular, the reductions made by a specific mitigation action, compared to a previous situation or a technological standard, are detailed.

Each Living Lab is responsible for providing the data.

Despite the monitoring systems of the 4 Living Labs are of medium/high quality, it was not possible to show real quantitative results because they are still in the analysis phase. The work was therefore limited to % estimates, with the commitment to show quantitative results by the end of the project.

The four Living Labs are particularly active in various actions to improve energy efficiency and decarbonisation, therefore reductions in energy consumption and GHG emissions are expected up to 20% and 25% respectively, between the start and the end of the project.