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PILOT AREA ENERGY SYSTEM ANALYSIS

Activity A.2.1: Potential evaluation

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1. INTRODUCTION

This report comes as the first step of the shared methodology that will lead up to the uptake of local Alpine Green Hydrogen Ecosystems in pilot territories. As a starting point, to carry out a comprehensive and detailed assessment of the local energy system is crucial to imagine, plan and realize a hydrogen production-to-use supply chain that fits with the territorial economy without disrupting it, creating long-term extra value in a circular economy and sustainable perspective.

First step is to actually define the boundaries of the focus territory. It could be an alpine valley, a group of alpine valleys, a group of neighbouring municipalities, a district/province. The territory could also include non-alpine areas if they are strictly bound to the alpine valleys from an economic and social point of view. After that, a holistic assessment of all energy flows should be made, both categorized by energy vector and by end uses. Based on the energy flows, the related emissions and overall costs can be estimated. It is worth noting that almost all the costs related to fossil fuels represent a direct and constant cash flow that leaves the local economy for some major energy utility that has little relation with the area.

Alpine territories usually have few enterprises that account for a large share of the energy consumption (industries, ski resorts, etc.). To set up a local green hydrogen supply chain it is key to get some major end users on board from the very beginning, and therefore to know their processes and energy demand profiles throughout the year. Besides that, the current renewable energy production as well as the RES potential of the area should be assessed, to estimate current and future renewable electricity available for green hydrogen production.

After that, the potential interventions for local hydrogen implementation should be listed and ranked according to their complexity, cost, environmental and social impact. This way, in the initial stages of the establishment of the green hydrogen ecosystem, it will be easier to focus on the more realistic and economically viable interventions and not to waste resources on exploring too many options.

In this document, the future development of hydrogen production and use in alpine pilot territories is described, it lists relevant stakeholders and roughly estimates the production and environmental impact of such long-term projects. The following steps will be the engagement of stakeholders, the definition of the pilot location, the initial production and end-use, the respective roles and a risk analysis of the project with the development of a suitable strategy to address and mitigate their likely effects.

This project is co-financed by the European Regional Development Fund
through the Interreg Alpine Space programme

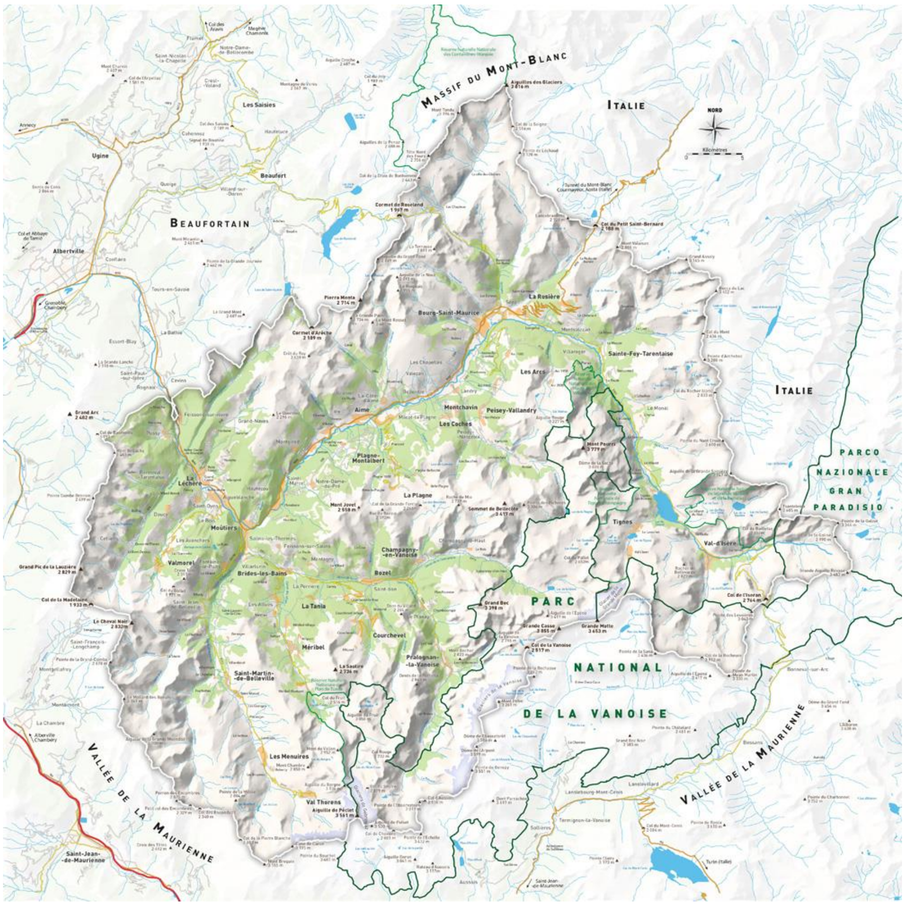
2. PILOT TERRITORY OVERALL ANALYSIS

Auvergne-Rhône-Alpes

- **Description of the area**

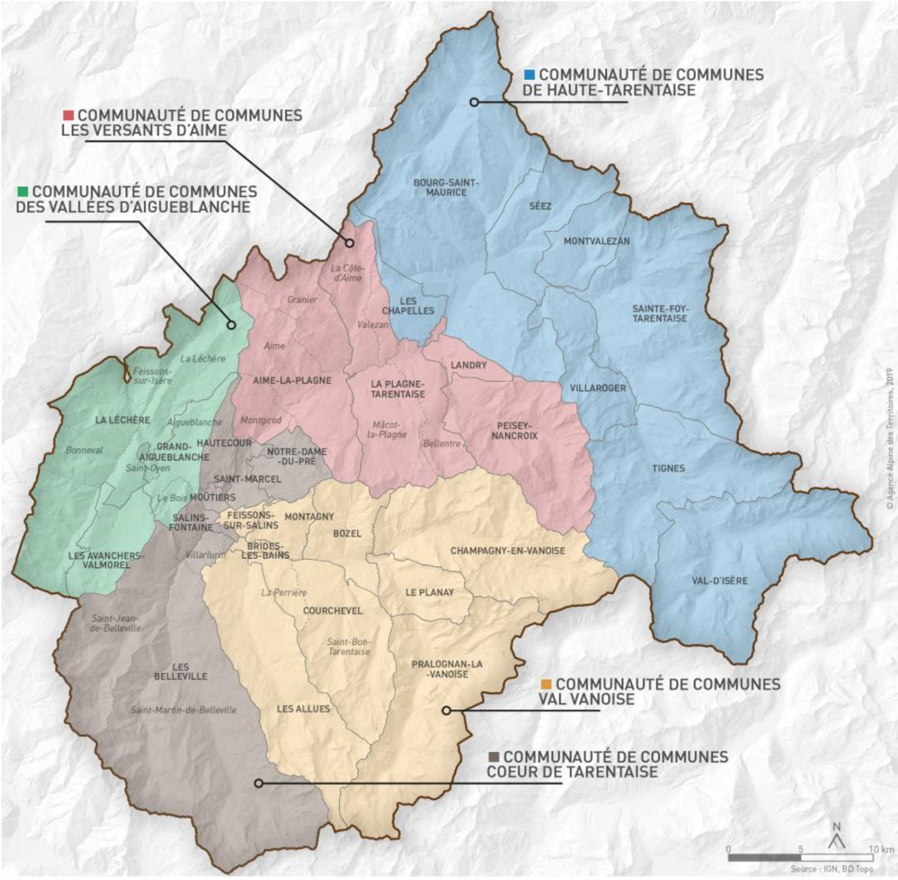
The pilot area selected in Auvergne-Rhône-Alpes is made up of two territorial entities, the Pays Tarentaise Vanoise (APTV) and the Communauté d'agglomération ARLYSERE.

This area brings together 6 EPCIs (public establishments for cooperation between local authorities), 5 of which are federated within the Pays Tarentaise Vanoise.



APTV identity sheet:

- Surface area: 1 705 km2
- Minimum altitude: 400 m at Feissons-sur-Isère
- Maximum altitude: 3,852 m at Grande Casse
- 30 communes (as at 1 January 2019) and 5 communities of communes
- 50,983 inhabitants
- 15 million overnight stays in winter, 4 million in summer.



ARLYSERE identity sheet :

- A new local authority, created on 1 January 2017
- 39 municipalities
- Compulsory powers: economic development, regional planning, social balance of housing, urban policy, reception of travellers, collection and treatment of household and similar waste.
- ARLYSERE joined the Espaces Valléens Alpine network in 2015. This programme, set up by the European Union, the French government via the Commissariat de Massif des Alpes and the Auvergne-Rhône-Alpes and Provence-Alpes Côte d'Azur regions, supports the regions of the Alpine arc in developing their summer tourism strategy. The aim for ARLYSERE is to strengthen the diversification of 4-season tourist activities.

The ARLYSERE area has been included in the scope of the pilot area because the local authority is involved in the Zéro Emission Valley regional hydrogen project led by the Auvergne-Rhône-Alpes Region and has an industrial activity that represents an interesting and strategic potential for H2 production and use.

The region is a major tourist attraction, especially in winter. It is home to a large number of ski areas of varying sizes, which attract local, French and European customers, thanks in particular to rail links via Thalys and Eurostar.

➢ H2 potential in the region

There are currently several hydrogen projects, initiatives and studies underway in the region.

In the Haute-Tarentaise region, a potential study was carried out in spring 2023. It should lead to a technical feasibility study for a mountain hydrogen ecosystem. However, the scope of a single local authority does not seem appropriate. It has been identified that AMETHyST could play a key role in creating links, coherence and the pooling of uses and infrastructures.

ARLYSERE and the Communauté de Communes Cœur de Tarentaise are also involved in the ZEV project, and in 2022 the commune of Moûtiers welcomed the region's 2ème hydrogen filling station. This infrastructure has been in service since May 2023.

ZOOM on the ZEV project

The project is the result of a **meeting between a number of players from industry and the public sector**, and was made possible by a **European call for projects**, CEF 2017. It is the first European hydrogen mobility project involving the simultaneous deployment of stations and vehicles. The distribution stations are powered by electrolysers and the vehicles are supported by acquisition aid.

The aim is to kick-start the hydrogen industry through decarbonised hydrogen mobility throughout the region. To date, the **Auvergne-Rhône-Alpes** region is home to more than 80% of the national players in the sector.

The **innovative aspect of** this initiative also lies in the fact that a commercial company has been set up for this project, with a public entity as its majority shareholder. It is called Hympulsion SAS.

⇨ Mobility use:

The potential for mobility via public fleets seems limited.
The competent transport authority is the region, and the H2 coaches acquired as part of the ZEV project will not be operated on these routes in the short term. Public fleets of light vehicles are too small for the investment to be sustainable at this stage.

The use of light vehicles seems interesting for electro-intensive use, particularly by taxi companies. The Region is currently running a call for projects offering financial support for the purchase of H2 vehicles, which could speed up the conversion of taxi fleets.
As regards private shuttle fleets, a survey of tourism operators (hotels, resorts, etc.) is planned as part of the AMETHyST project.

The use of snow groomers is currently under review, but the estimated additional operating cost of €90,000 per year seems untenable at present. A snow groomer will be tested at Alpe d'Huez in winter 2023, and French ski areas, including those in the Tarentaise, are awaiting feedback.

⇨ **Production and storage**

Mountain areas are seen as potential producers of significant amounts of RES (via hydroelectric or solar energy). Storage could therefore be an interesting option, even if the profitability of these solutions is currently not optimal.

➢ **The role of the AMETHyST project in the region**

The AMETHyST project will make it possible to draw up an inventory of public and private initiatives, studies and projects in the area, and to create links between these currently isolated initiatives.

Support in 6 stages :

1. Inventory of studies, projects, facilities, etc.
2. Building and monitoring multi-energy dashboards
3. A showcase for the region's projects and ambitions, and exchanges at Alpine arc level
4. Ongoing advice on local energy strategy and mobilisation of public funding
5. Links with private hydrogen players
6. Helping a region to build a hydrogen ecosystem (*identifying the players, coordinating the various projects and studies, identifying potential and uses, discovering technologies, finding funding, etc.).*)

The aim is to support the emergence of a mountain hydrogen ecosystem, by creating links between public and private players and between potential hydrogen users and producers, and by creating coherence between the various initiatives.

Friuli Venezia Giulia

The selected pilot territory is the upper section of the Bût valley, which consists of 5 small alpine Municipalities (i.e. Paluzza, Sutrio, Ravascletto, Cercivento, Treppo Ligosullo) for a total of about 5 thousand inhabitants. The territory is a typical alpine valley territory, with steep mountains covered in forest and a flat valley floor where residential areas and industrial/commercial activities are concentrated. The forestry and mining sector have strong relevance in the area, as resources are abundant. In particular the forestry sector received a strong push in the last few years after the Vaia storm and the bark beetle epidemy, which made available a large quantity of wood to be retrieved within a short period of time. Private heating in residential buildings often relies on wood chunks or wood pellets, but also natural gas plays an important role. In the industrial area of Sutrio, one small company, thanks to a favourable incentive scheme awarded by the National Authority, built a cogeneration biomass plant. In the neighbouring Municipality of Arta Terme there is a large cogeneration biomass plant, which consumes large quantities of wood residuals. SMEs are concentrated in two main industrial areas; wood furniture and woodworking and construction represent a large part of those activities.

Besides that, the area has a strong touristic attitude both in summer but especially in winter time. The Zoncolan ski resort is the biggest commercial activity in the area, which guarantees many jobs to local workers both directly as well as through linked activities such as the accommodation and food sector, ski schools and refuges. Zoncolan is the most popular ski resort in the region, with a ski season that spans usually from early December to the end of March and counts almost 200 000 seasonal users. The energy demand of the resort itself is very relevant compared to the rest of the area, where besides the electricity used for the lifts, over 1600 MWh are used for producing artificial snow and 120 000 liters of diesel are used for snowgroomers.

But from the ski resort, the largest energy consumer is the pumping station of the SIOT-TAL oil pipeline that runs through the valley. The pumping station consists of 4 electrical pumps of 2MW each, for an annual consumption (above 8000 full load hours) of 70 GWh.

A key feature of the pilot area is the presence of an historical Hydroelectrical Cooperative (SECAB) that owns the distribution grid of the five municipalities and several hydropower plants. The cooperative has been operating for more than a hundred years and the members are local citizens. The goal is to redistribute the value extracted from local streams to the territory by means of lower electricity bills. SECAB is already selling its electricity to the ski resort and the pumping station. During most of the year, SECAB's local production exceeds the consumption loads and the excess power is sold to the national grid. Relying only on hydro, during winter months (December to March) it happens that SECAB has to buy electricity from the national grid to feed its customers. Currently, SECAB is building a 600 kWp solar power plant, that will help reducing the purchase from the national grid over winter and will create an additional surplus over the rest of the year.

Currently, there are no H2 projects implemented in the area and not even at regional scale despite the formal set up of the North Adriatic Hydrogen Valley promoted by Friuli Venezia Giulia, Slovenia and Croatia. The step ahead within the AMETHyST project is that it tackles this situation and aims to establish a small local green hydrogen supply chain and usage. The idea is to use the production surplus from hydropower and photovoltaic from spring to autumn to produce hydrogen to run the snowgroomers. If the entire snowgroomer fleet gets converted to hydrogen, the Zoncolan ski resort could be the first zero emission ski resort in the Alps, as the electricity currently provided is already 100% green.

As the surplus during summer is relevant and hydrogen storage may present some issues, it is important to find more end-uses that can better match the yearly green hydrogen production. The most likely expansion foreseen from APE FVG is to extend the hydrogen usage to public transport (buses) that runs through the valley. Later, a fuelling station for private cars and trucks can also be envisaged. It is harder to foresee consistent use of hydrogen in the local industry and SMEs as their needs and energy demand profiles are not known yet. There is surely potential for working vehicles and machineries for forestry and mining.

Trentino Alto Adige – Fondazione Bruno Kessler

The Madonna di Campiglio ski-area is a well-known ski resort in Trentino (north-eastern Italy), included in the most important ski area within the Province of Trento, the Campiglio Dolomiti di Brenta ski area, together with the Pinzolo and Folgarida-Marilleva ski resorts. Since the second half of the 19th century, Madonna di Campiglio has been a renowned holiday destination. Before joining the AMETHyST project, Madonna di Campiglio was one of the four living labs of the project Smart Altitude, a project supported by the Alpine Space Interreg Programme from 2018 to 2021, with the aim to activate and accelerate the implementation of low-carbon policies in winter tourism regions by demonstrating the efficiency of a step-by-step decision support tool for energy transition. Within this living lab, an integrated energy management system (IEMS) was developed and tested to facilitate and support ski area operators in the continuous analysis of energy, environmental and economic performance of the resort, thus paving the way for increased awareness and targeted interventions.

Funivie Madonna di Campiglio S.p.A. is the company that manages the ski resort, which has 60 km of ski slopes with an altitude range between 1513 and 2501 m. During the winter season, the average operating days are 156, from the beginning of November until mid-April. Concerning skier days, these average 1.2 M throughout the winter season, supporting a turnover of 25 M€. In general, 19 ski lifts are operational, supporting a transport capacity of 39,000 passengers/hour and providing approximately 10 million admissions per winter season. A modern snow production system guarantees about 1.1 Mm^3 of snow per winter season, using 629 snow lances and 117 snow guns, with a water demand of 500,000 m^3. The snow production system is supported by water storage basins, with a total volume of 240,000 m^3. The main basin is called "Lake Montagnoli", which is an artificial lake built in 2014 with a volume of 200,000 m^3. Moreover, 20 diesel-fueled snow groomers work for a daily regular preparation of the slopes, and buildings serve for technical and managerial operations.

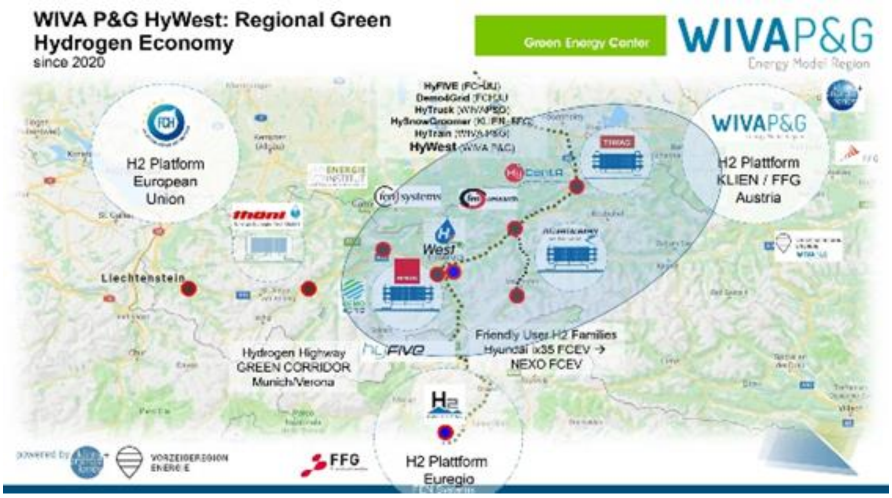
Hydrogen has the potential to make significant advancements in this pilot territory, particularly by replacing diesel-powered snow groomers with hydrogen-powered ones utilizing either fuel cell technology or hydrogen internal combustion engines. The installation of solar photovoltaic systems in the ski area could support the production of hydrogen when the electric energy supply exceeds the demand. The hydrogen produced could then be used in centralized fuel cells for generating electricity to operate the ski lifts. This approach creates synergies with the ski resort's seasonal patterns. Excess energy produced during the low-season summer months could be stored as hydrogen and utilized to meet the high energy demands of the winter high-season, ensuring a more sustainable and efficient energy supply, although very large volumes would be needed for the storage.

Trentino Alto Adige – Autonomous Province of Trento

The Autonomous Province of Trento is located in northern Italy and borders to the north with the Autonomous Province of Bolzano with which it forms the Trentino - Alto Adige Region, to the east and south with the Veneto Region and to the west with the Lombardy Region. Situated on the southern side of the chain of the Alps, Trentino's territory is characterised by the presence of valleys where most of the population and industrial activities are concentrated, and by plateaus and purely Alpine mountainous contexts that are more sparsely inhabited but characterised by a wide range of tourism in both summer and winter. It is precisely in these mountain tourist contexts that the pilot project was planned to be located, i.e. in a context that can also be replicated in the remaining part of the Alpine arc. The pilot project aims to implement hydrogen mainly as an energy vector to satisfy the heating needs of the users present in the contexts that will be identified. Therefore, considering the characteristics of the pilot, the boundary of the pilot territory was identified with that of the Province.

The energy economy of the Trentino region is described in the Provincial Environmental Energy Plan (PEAP). The most recent PEAP, adopted in June 2021 by the Autonomous Province of Trento, starts from the energy consumption balance 2014-2016 and outlines the planning of energy interventions up to 2030. The 2021-2030 PEAP and the subsequent monitoring, dated 2022, revealed the strengths and weaknesses of the Trentino energy system, which tend to be confirmed also for the three-year period covered by this document, i.e. that from 2017 to 2019. The main strength is undoubtedly the abundant hydroelectric production, which generates a surplus of renewable sources compared to demand. In this context, a profound decarbonisation of Trentino's energy system can only pass through electrification solutions, the so-called 'sector coupling', which would allow Trentino's 'green' electricity to be used also in the thermal (heat pumps) and transport (electric mobility) sectors. On the consumption side, as far as the civil sector is concerned, there is a downward trend in the consumption of climate-changing fuels, against an increase in gas consumption, and at the same time a slight increase in electricity consumption in the residential sector against a contraction in the tertiary sector. It should also be emphasised how national incentives linked to tax deductions for energy bonuses have contributed to an increase in the spread of biomass boilers, heat pumps and hybrid systems (gas boiler combined with heat pump) for residential users. With regard to the industrial sector, there is evidence of a constant overall use of electricity against an increase in natural gas consumption. Also evident is an increase in production from photovoltaics and a higher percentage of internal consumption. For the transport sector, there is a decrease in LPG and diesel consumption and a constant consumption of petrol. On the front of energy production from renewable sources, there is an increase in electricity production from photovoltaics and constant production from hydroelectric power.

Tirol



The pilot region stretches from Völs near Innsbruck to Kufstein in the Inntal and the Zillertal from Jenbach to Mayrhofen.

Wiva P & G, HyWest – The national R & D flagship project aims at the establishment of the first sustainable, business case driven, regional, green Hydrogen economy in Europe: This project is mainly based on the logistic principle and is a result of synergies between three ongoing complementary implementation projects.

- **Green Hydrogen for MPreis => Demo 4grid**

Demo4Grid

Construction of an alkaline pressure electrolysis plant to produce green hydrogen and regulation of the power grid

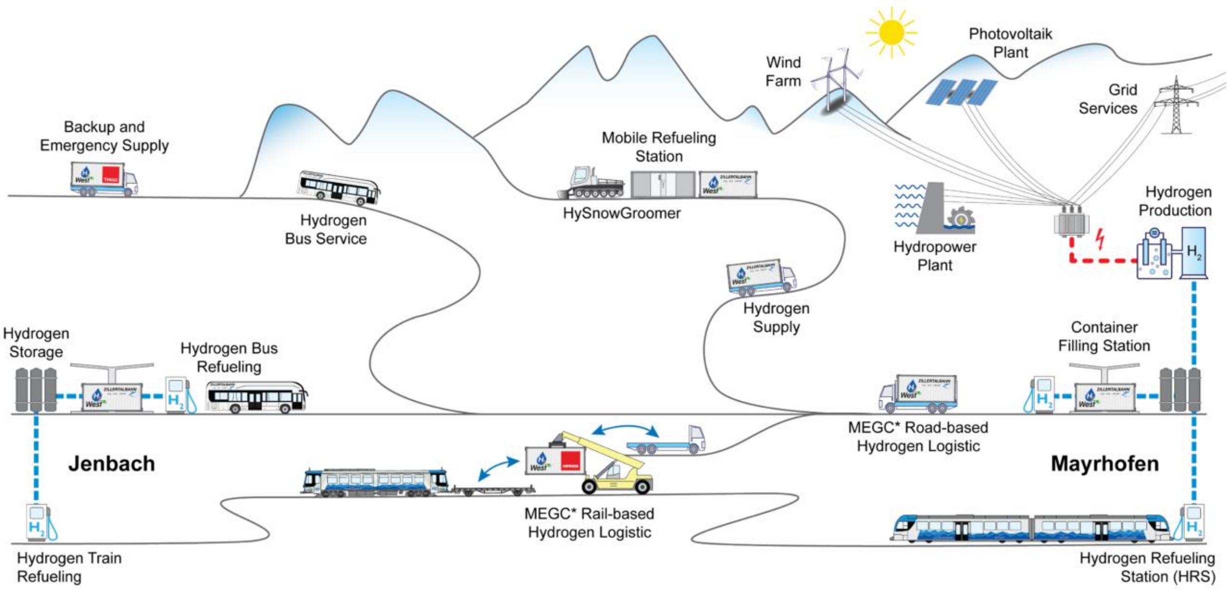
The aim of the EU project “Demo4Grid” is to build a PAE electrolysis plant (Pressurized Alkaline Electrolyser) to research and demonstrate power grid balancing services under real operating and market conditions while simultaneously producing green hydrogen to green industrial processes. The system was built at the production and logistics center of the local food supplier MPREIS in Völs near Innsbruck and is the spearhead for the development of a green regional hydrogen economy in Central Europe. The HyWest research center is the catalyst and the Green Energy Center Europe in Innsbruck is the distribution point for this pioneering hydrogen project - for the conversion of the energy system to climate neutrality and autonomy.

- **Hydrogen Valley Zillertal => starting with Zillertalbahn 2020+ energy autonomous**

HyTrain – Zillertalbahn 2020+ energy autonomous with hydrogen

The "Zillertalbahn 2020+ energy autonomous with hydrogen" project has been developed since 2016 as part of the green hydrogen economy that is currently being developed in Central Europe. The activities required for this are bundled in numerous research competition projects in the "HyWest" hydrogen center at the Green Energy Center Europe in Innsbruck.

Since 2020, the Climate Protection Ministry has also been supporting the development of a hydrogen train through the Climate and Energy Fund, which is set to become a reality with the Zillertalbahn 2020+, the first hydrogen-powered narrow-gauge railway in the world. The project costs for the relevant lighthouse project of the hydrogen initiative model region Austria "WIVA P&G HyTrain" are 5.03 million euros. A funding budget of 3.19 million euros is available for this purpose. The national lighthouse project includes the development of a hydrogen drive train including the refuelling of the train set with green hydrogen, for which a holistic infrastructure program was also developed in the context of the overarching project. The focus of the lighthouse project is to research the parameters for risk minimization and quality assurance of the procurement, acquisition and operational management processes. To this end, the project consortium must develop, test and evaluate a drive train for the hydrogen train with the associated hydrogen supply.



- **Power2X Kufstein**

"Power2X Kufstein – Innovative sector coupling system with hydrogen center" from TIWAG-Tiroler Wasserkraft AG

TIWAG -Tiroler Wasserkraft AG - as the largest energy supply company in Tyrol - relies on new technologies and is planning to build a hydrogen center in the south of Kufstein (Tyrol/Austria), integrated into an innovative sector coupling system. The project with the short name “Power2X Kufstein” is a significant contribution to the climate, energy and resource strategy “Tirol 2050-enegieautonomous” and the associated optimization of the “Power On Demand” and “Power to Hydrogen” processes, which are necessary for the Complete restructuring of the energy system is absolutely necessary. The TIWAG project is part of the national research project WIVA P&G HyWest and the associated development of a regional green hydrogen economy, which has been systematically developed at the HyWest hydrogen research center for years and is gradually being developed and expanded as part of the Codex partnership of the Green Energy Center Europe. The spearhead of this development is the recently started production of green hydrogen for MPreis, Tyrol and Europe.

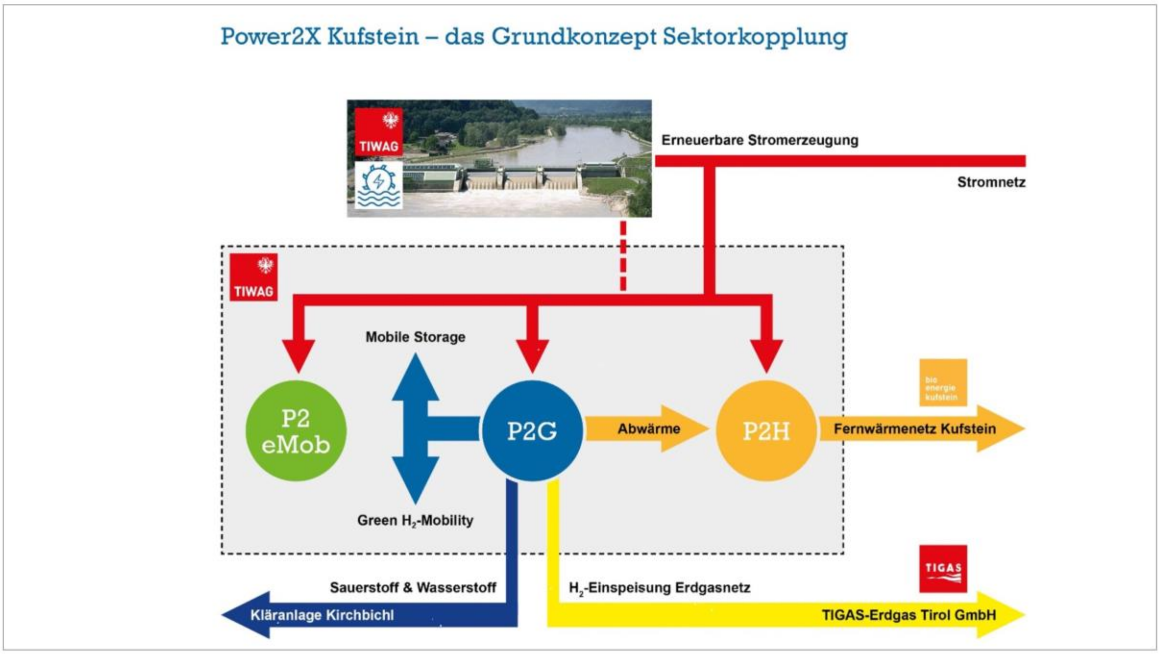
The TIWAG project “Power2X Kufstein”, which was presented to the media in July 2019, envisages the construction of an innovative, unique sector coupling plant with a hydrogen center. Sector coupling (P2X) - as a key technology in the context of the energy transition - connects the electricity, heat and gas networks as well as the mobility sector and thus creates an important prerequisite for a sustainable, future-proof and economically oriented energy system.

The P2X concept takes into account a demand- and requirement-based connection of electricity, gas and heating networks in conjunction with emission-free mobility from electricity and hydrogen over an area of approx. 9,500 m 2. The high level of innovation of the planned system is based on the use of a modern, modularly expandable system for converting electricity into hydrogen, considering the further use of the resulting waste heat.

Modern proton exchange electrolysis (proton exchange membrane, PEM for short) is used. The system configuration tailored to needs and requirements enables a production output of up to approx. 900 t of renewable hydrogen per year. In combination with low, medium and high-pressure storage, it is possible to deliver renewable hydrogen directly to vehicles (trucks, cars, buses), fill it in mobile storage (trailer) or feed it into the natural gas network of TIGAS-Erdgas Tirol GmbH.

In addition, the waste heat generated in the electrolysis process is raised to the temperature level of the Kufstein district heating system using highly efficient heat pump systems and used there accordingly (Power2Heat). It also creates the opportunity to use the hydrogen and oxygen produced during electrolysis in the nearby sewage treatment plant. With these demand and process combinations, a high overall efficiency and thus resource-saving energy conversion is achieved.

This project is co-financed by the European Regional Development Fund
through the Interreg Alpine Space programme



The R&D flagship project HyWest serves as a model for the development of a largely autonomous regional green hydrogen economy. The focus is the investigation of cross-sectoral production, storage and application of green hydrogen.

Our contribution to reach the WIVA goals, i.e. which white spots do we cover?

- Production, methanation and feed-in of green hydrogen
- Fuel cell systems based on renewable energy sources
- Green hydrogen in industrial processes

CONTRIBUTION OF PARTNERS

MPREIS Warenvertriebs GmbH

Within HyWest, the food retailer and producer MPREIS initiates the transition of its logistic fleet towards emission free transport by substituting some diesel trucks with FCE trucks and conducting technical and operational research regarding the operation and the corresponding infrastructure.

ZVB, Zillertaler Verkehrsbetriebe AG

Mobility operator ZVB will implement a first FCE bus in the Zillertal valley including a novel backup HRS in Jenbach as a starting point for the project "hydrogen region H2Zillertal". This effort is supported by the ongoing projects HyTrain and HySnowGroomer.

TIWAG, Tiroler Wasserkraft AG

TIWAG connects sectors of electricity, heating, cooling and gas networks as well as mobility within the innovative sector coupling facility "Power2X Kufstein".

TIGAS, Erdgas Tirol GmbH

TIGAS supports HyWest within the sector coupling facility "Power2X Kufstein" with its Natural Gas infrastructure and its general expertise on gas related issues.

Energieinstitut an der JKU Linz

The research institution EI-JKU supports HyWest with socio-economic evaluations of the developed business models and analyses the economic effects regarding the hydrogen deployment.

FEN Research GmbH

The research and development company FENR deals with the multi- and interdisciplinary tasks for the development of a green hydrogen economy within the framework of the Green Energy Center Europe.

HyCentA GmbH

The research organization HyCentA supports HyWest with its long-established technical hydrogen competence and their testing infrastructure.

WIVA P&G

The WIVA P&G association is responsible for the coordination and organisation of conferences and stakeholder workshops in the showcase region.as well as project monitoring regarding the region as a whole.

In addition to this project, the H2Alpin project, in which we as the Standortagentur Tirol are project leaders, also provides valuable information for the project results in Amethyst.

- **H2Alpin**

For Alpine regions, mobility and transit represent major challenges in climate protection. In recent years, Tyrol has prepared strategy papers that also focus on hydrogen as an energy carrier für public transport and freight logistics. To implement these strategies sustainably, an integrative approach is needed to jointly solve technical, economic and organisational challenges. It is precisely these three topics that H2Alpin is addressing in order to develop system solutions for the mobility transition in the Alpine region in a large-scale interdisciplinary demonstration project.

Although there are already urban pilot projects for fuel cell electric vehicles, there is still a lack of important technical experience for alpine applications in order to further develop the vehicles and to define an optimum application for hydrogen mobility. Within the framework of H2Alpin, hydrogen-powered buses and the first trucks will be tested in alpine conditions (temperature extremes, snow, winding mountain roads, transit passes) and real data on driving behaviour, maintenance, energy consumption, etc. will be collected and analysed.

Economic viability is still the biggest hurdle for the switch to hydrogen-powered mobility. The procurement of vehicles is difficult to afford for end users. Therefore, business models for procurement platforms are being developed and tested. Via these platforms, vehicle pools can be procured, maintained, and made available to third parties via a leasing model. The Tyrolean Mobility Coordinator will implement this for public passenger transport, a private company for freight logistics. Also, hydrogen prices play a major role for the mobility transition. To be able to offer additional attractive hydrogen prices on the market, demand and production simulations will be used by the hydrogen logistics side to design attractive supply-demand pricing models for H2 commercialisation.

To ensure a green hydrogen supply for a comprehensive mobility transition in Tyrol, it is necessary to develop accurate simulation models that map all relevant factors for a gradual transition to zero-emission mobility e.g., until 2035. In the small-structured, Alpine-tourist region of Tyrol, renewable energy is mainly available from a network of hydropower plants. Seasonal fluctuations in energy supply and hydrogen demand as well as the location on one of the strongest European transit routes must be considered.

The regional implementation plan, which is being developed in consultation with stakeholders and in compliance with current and future standards, is intended to help give both hydrogen producers and users planning security for their business models. With the measures initiated within the frame of the H2Alpin project, hydrogen-based mobility should already save around 17,700 T CO2 by the end of 2030.

Bavarian Oberland

The Civic Foundation Energiewende Oberland (EWO) is a non-profit organization to promote energy savings, energy efficiency and use of renewable energy within the region Oberland (Upper Bavaria). EWO serves as counsellor for 94 municipalities in 4 district governments, with altogether 440.000 inhabitants. The Oberland (districts of Bad Tölz- Wolfratshausen, Garmisch-Partenkirchen, Miesbach and Weilheim Schongau) was chosen as a pilot region. On the one hand, there is already a broad data basis and, on the other hand, EWO is already working on the energy strategy together with the region.

The four administrative districts have a polycentric spatial structure which is characterized by a number of medium-sized centers and, according to the regional development program (Landesentwicklungsprogramm LEP), they belong to the Oberland planning region (Region 17). The majority of the districts are classified as "rural sub-areas in the neighbourhood of large conurbations«. In addition, the southern parts of the region belongs to the area category "Alpine region", bordering Austria. In the north, the region is part of the metropolitan region Munich.

The Oberland is an dynamic economic region with a constantly growing population, in which the percentage of settlement and trafic area will increase significantly in the next 20 years. The land surface is intensively used for very different purposes, with significant, partly competitive uses being food production, energy production, tourism use, and use as settlement and traffic areas. These competing land uses are one reason why, despite the good natural potential and the large established network, the regional consumtion of renewable energies in the Oberland region is still below average (compared to Bavaria or Germany).

Energy consumption

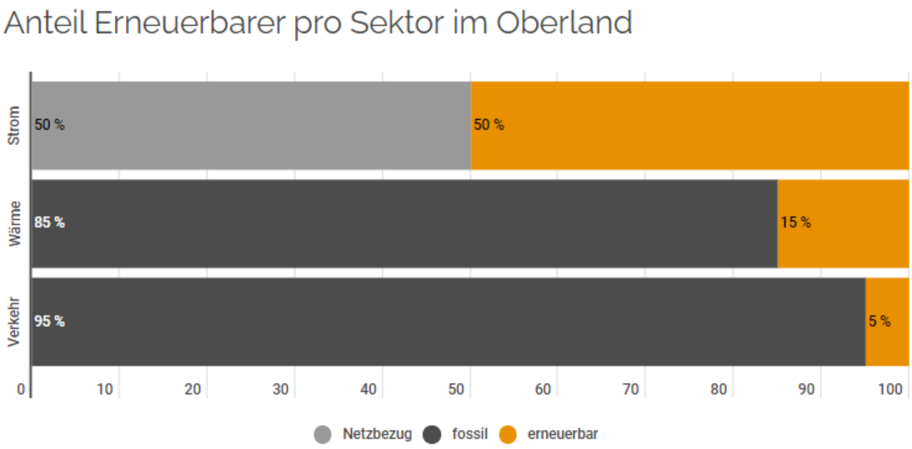


Figure 1 Region Oberland: Share of renewable energy by sector (2019) | source: Energiewende Oberland | Translation: Strom = electricity; Wärme = heating; Verkehr = mobility

In order to describe the pilot region Oberland with regards to its energy consumption and potential development, three main data sources are available:

- Firstly, Energiewende Oberland introduced a standard for energy and CO2 balancing for the administrative districts Bad Tölz-Wolfratshausen, Garmisch-Partenkirchen, Miesbach and Weilheim-Schongau including its municipalities called **Klimaschutz-Planer**[1] (developed and run by Climate Alliance) in the Region Oberland. The most current energy data from Klimaschutz-Planer describes the year 2019[2].
- Secondly, Energiewende Oberland participated on a scientific project called **INOLA**[3] from 2015-2019 and therefore possesses an in-depth analysis of the energy system, its regional actors and potential development. While INOLA serves a lot of insight about the development and usage in various sectors including economic effects and social acceptance, the data mostly reflects the energy consumption and production of the administrative districts Bad Tölz-Wolfratshausen, Miesbach and Weilheim-Schongau in the years between 2013-2016.
- Thirdly, Bavaria publishes energy data via the so called **Energieatlas Bayern**[4]. This source feeds itself from several sources and provides publicly available data, like e.g. installed photovoltaic capacity by year and kW. The latest data set available describes the year 2021.

This report uses the above-mentioned sources as coherently as possible. However, it might occur that there are slight deviations between the data as they sometimes vary in some assumptions about energy distribution among sectors (especially with regards to heating and mobility) and like in the case of Energieatlas Bayern compared to INOLA and Klimaschutz-Planer have a different geographical focus.

As shown in Figure 1, according to data from Klimaschutz-Planer, currently about 50% of total electricity consumption is provided by renewable energy, whereas the heating sector accounts for about 15%

[1] https://www.klimaschutz-planer.de/
[2] https://energiewende-oberland.de/hp8534/Energiebilanz.htm
[3] www.inola-region.de
[4] https://www.energieatlas.bayern.de/

renewable energy share and the mobility sector shows a renewable energy share of about 5%. The final energy consumption of the region is 12.773,57 GWh (2019).

Canton of Valais

The Val de Bagnes is a picturesque territory nestled in the Swiss Alps. The region's main economic players include tourism, agriculture and energy. Tourism plays a central role, with renowned destinations such as Verbier, attracting visitors from all over the world for its ski resort and mountain activities. In the low season, the resort has a population of 10,000, rising to 50,000 in the high season, mainly during the winter.

The local economy is supported by a variety of businesses linked to the tourism industry, including hotels and restaurants. Agriculture is also important, as the commune boasts 98 farmers.

In terms of energy flows, Val de Bagnes draws most of its electricity from renewable sources, notably hydroelectricity from the Mauvoisin dam, which produces an average of 70,000,000 kWh per year. The installation of micro-turbines on the commune's various penstocks also supplies around 10,000,000 kWh, while solar panels produce 996,463 kWh per year. In addition, the municipality's wastewater treatment plant produces energy from biomass, equivalent to 506,654 kWh per year. Today, hydroelectric power is estimated to account for 90% of total optimization.

There is also a solar park project to increase the share of renewable energy. The project is currently being studied, and one of the hypotheses would be to use this energy to produce green hydrogen. If the project is approved, we'll have a solar park by 2024. At the moment, there is no hydrogen production in the region, but this technology is attracting increasing interest from the industry.

The opportunities for synergies in the region are considerable. The municipality of Verbier and local transport companies are showing a strong interest in this project. As a second solution for acquiring green electricity, a collaboration with Axpo Suisse could be envisaged. Axpo Suisse is a major company in the electricity sector and holds a majority stake in the Mauvoisin dam. The idea would be to obtain a green energy source and negotiate preferential rates for hydrogen production.

A third possibility would be to generate hydrogen from surplus electricity from energy trading or photovoltaic production. This approach could represent a significant opportunity for Val de Bagnes. It would not only contribute to the stability of the electricity grid, but also pave the way for a clean, sustainable energy storage solution.

The central objective remains the integration of hydrogen into mobility. Mountain transport, such as buses and snow grommers, could be powered by hydrogen, reducing carbon emissions while maintaining essential mobility for visitors and locals alike. Snow groomers consume 500 tonnes of diesel per year and buses 110 tonnes of diesel per year. This transition would also reinforce Val de Bagnes' position as a sustainable and innovative tourist destination, which is the resort's primary objective.

In conclusion, Val de Bagnes offers fertile ground for exploring innovative and sustainable energy solutions. The potential synergies between abundant renewable energy sources, the dynamic tourism industry and the introduction of hydrogen pave the way for a cleaner, more resilient economy. By exploiting these opportunities, Val de Bagnes could play a pioneering role in the energy transition, while enhancing its appeal as a sustainable tourism destination. Val de Bagnes could also become the springboard for implementing hydrogen in other Swiss alpine areas.

Trentino Alto Adige – Agenzia per l'Energia Alto Adige - CasaClima

The pilot area object of this description is the Pustertal Valley, or Val Pusteria, in the north Italian province of Bolzano. The main town Bruneck/Brunico lies at an altitude of 850 m asl, the pilot location "Arieshof" is located at an altitude of approximately 900 metres. The climate can be considered warm-summer humid continental climate (Dfb according to Köppen classification), with warm summers and chilly winters, precipitations predominant in the warmer season. Its alpine geography heavily contributes to its weather, as it brings large diurnal temperature variations. The area of the Pustertal is characterised by a rural landscape, but the tourism sector plays an important role in summer as well as in winter. The area counts 6 million booked nights per year (2022, Source SWZ). Guests visit one of the many skiing resorts or popular hiking areas in the nearby Dolomites. Over the past years, there has been a strong tendency towards the establishment of high-quality / luxury accommodation.

The tourism sector will be required to make an important contribution to the decarbonisation of the entire Province according to the Provincial climate strategy (Klimaplan Südtirol 2040): "Reduce energy consumption in tourism by 25% by 2030 and 35% by 2037. Fossil energy consumption is to be reduced by 40% by 2030 and to 20% by 2037."

Description of energy economy of the territory

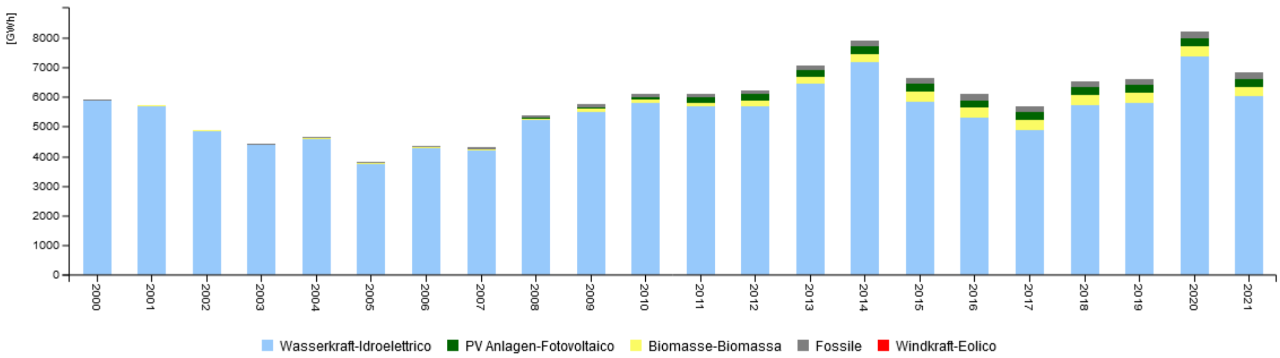
Electricity generation in the province comes from various energy sources, almost exclusively renewable energy sources:

- Hydropower: 29 large-scale plants account for 81% of the entire production from hydropower. The remaining 19% is produced by more than 1,000 small and medium-sized plants;
- photovoltaics;
- biomass;
- fossil fuels.

Hydropower covers the predominant share. New hydropower plants, however, are the exception, as they are difficult to realise under current legislation and regularly meet strong opposition from local communities. The generation of electricity from fossil fuels is due, exclusively, to CHP generation from biomass-natural gas district heating. Wind power is currently irrelevant in the territory.

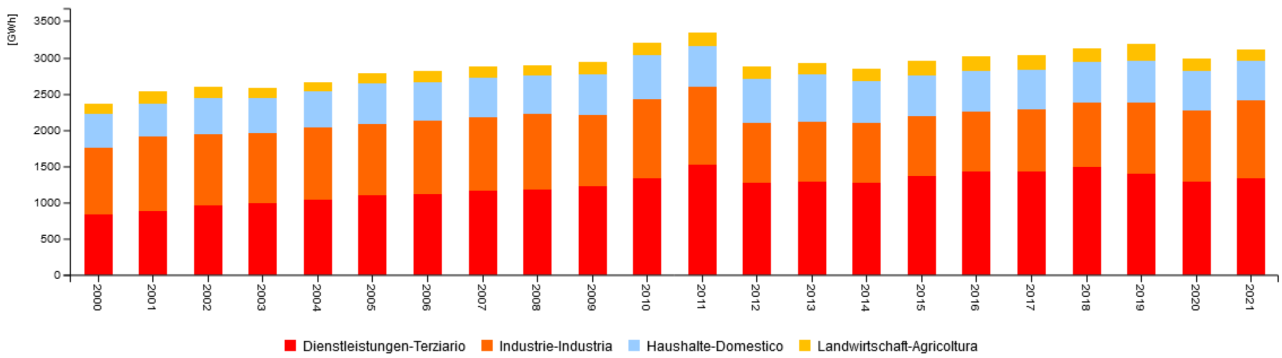
The graphs in this chapter illustrate the development of total electricity generation over the years and the distribution among the different energy sources.

Fig. 1: Production of electricity in the province in 2021:



Source: *https://umwelt.provinz.bz.it/energie/energiebilanz-suedtirol.asp*

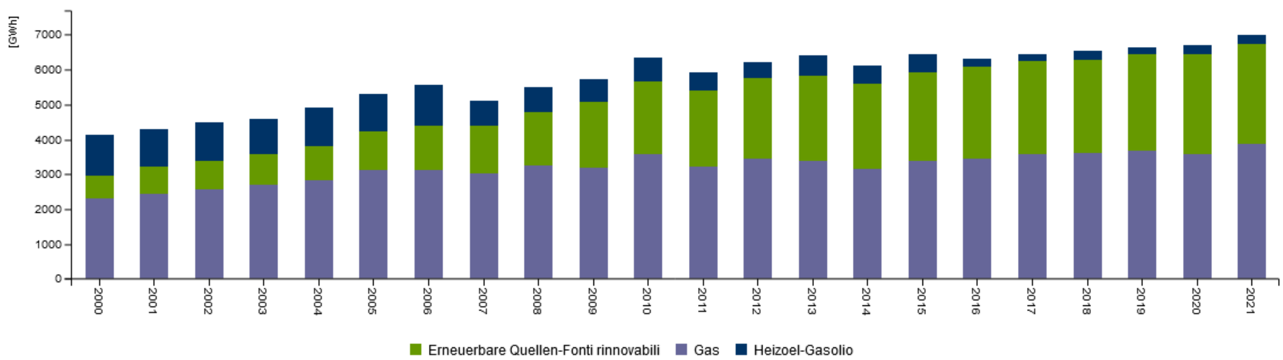
Fig. 2: Consumption of electric energy in the province in 2021:



Source: *https://umwelt.provinz.bz.it/energie/energiebilanz-suedtirol.asp*

Since the turn of the century, there has been a strong increase in heating demand. The following graph highlights the evolution of heating energy sources since 2000. The reasons for this are many, from demographic growth to changes in family composition and altered living standards, to and increased demand in businesses and tourist accommodation premises. Reducing the consumption of fossil fuels for heating will be a central element in the local decarbonisation strategies from here on.

Fig. 3: Energy sources for heating in 2021



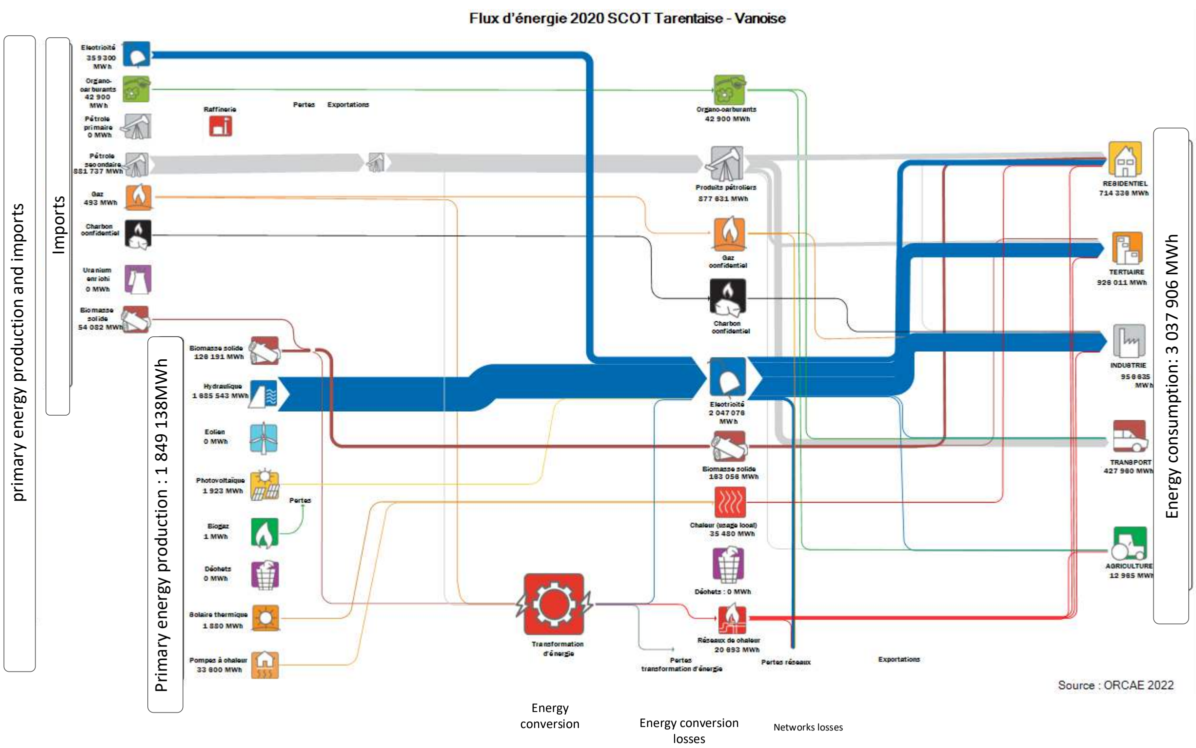
Source: *https://umwelt.provinz.bz.it/energie/energiebilanz-suedtirol.asp*

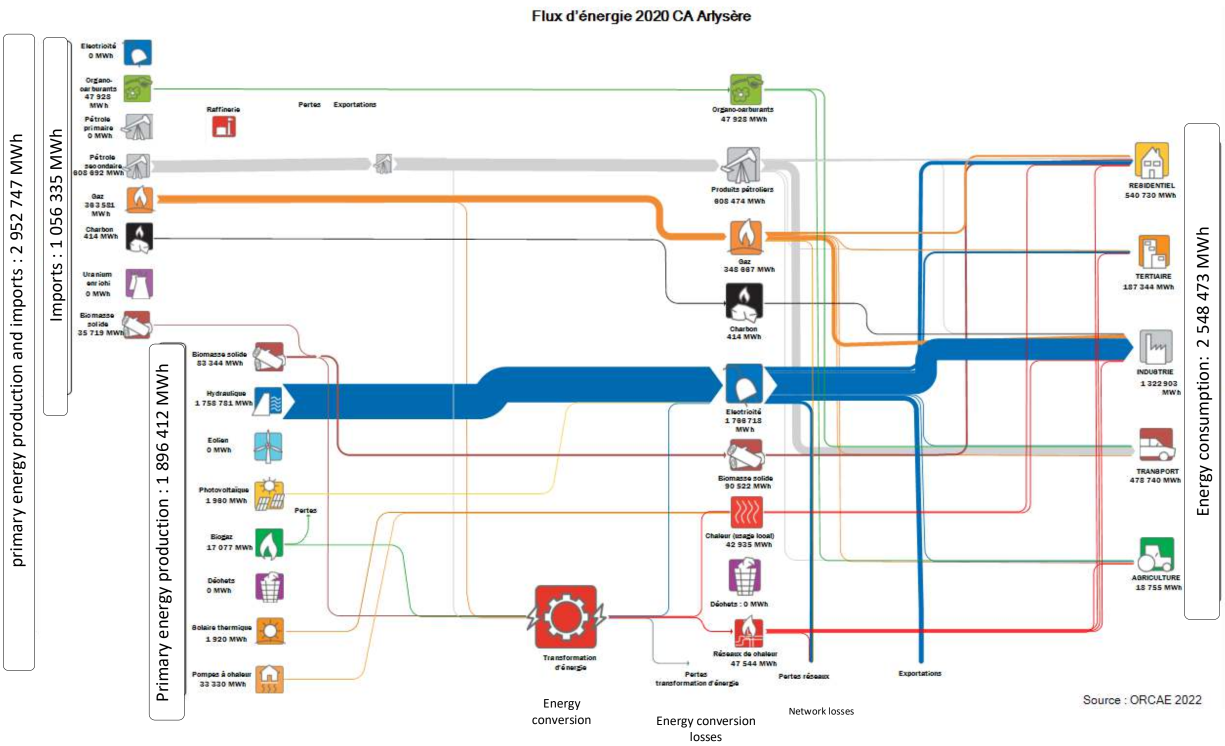
It is notable that the utilization of biomass grew considerably due to the proliferation of district heating plants using biomass; however, fossil fuels remain the predominant energy source for residential and commercial heating.

3. HYDROGEN PRODUCTION AND USE POTENTIAL

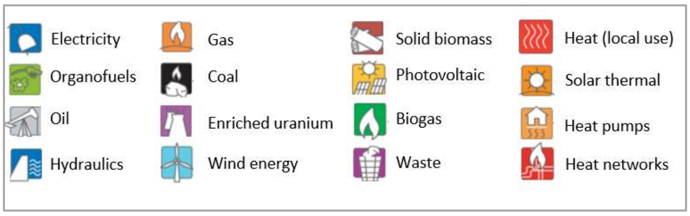
Auvergne-Rhône-Alpes

CURRENT KEY ENERGY FLOWS





This project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme

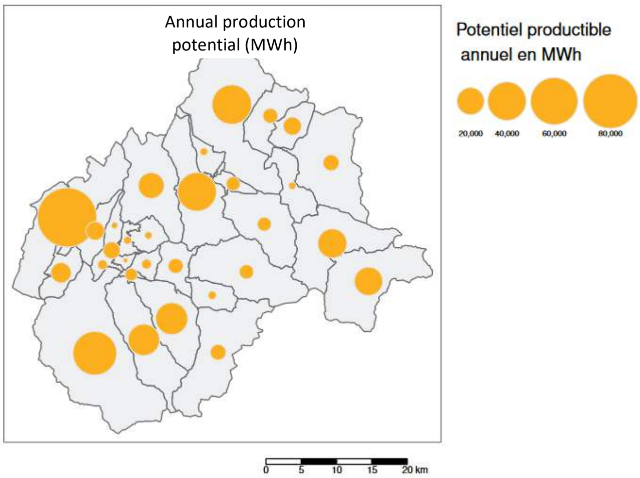


There is considerable industrial potential in the region and the study of the link between RES production and H2 storage should be considered as it seems to represent an interesting potential.

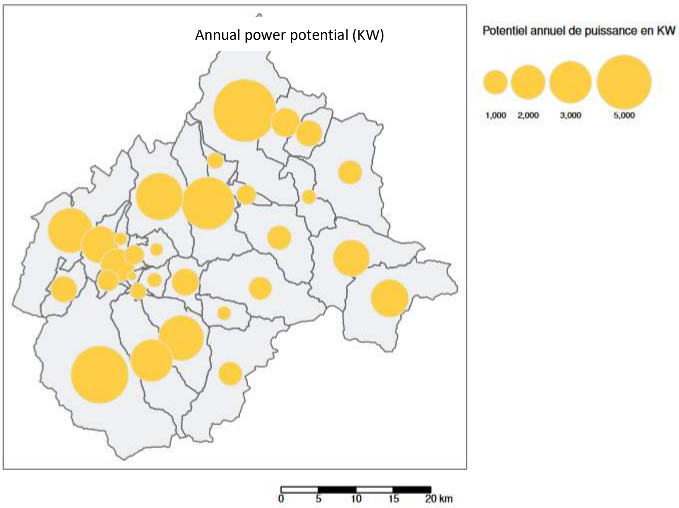
RES PRODUCTION POTENTIAL

The most significant potential RES is solar.

With regard to solar thermal energy: the total annual production potential remaining in the region is 443,125 MWh.



Photovoltaic solar energy: total annual production potential in the region: 464,709 MWh.



Note: competition between solar thermal and photovoltaic is not taken into account in these figures.

This project is co-financed by the European Regional Development Fund
through the Interreg Alpine Space programme

It is interesting to note that stationary use could also be studied.

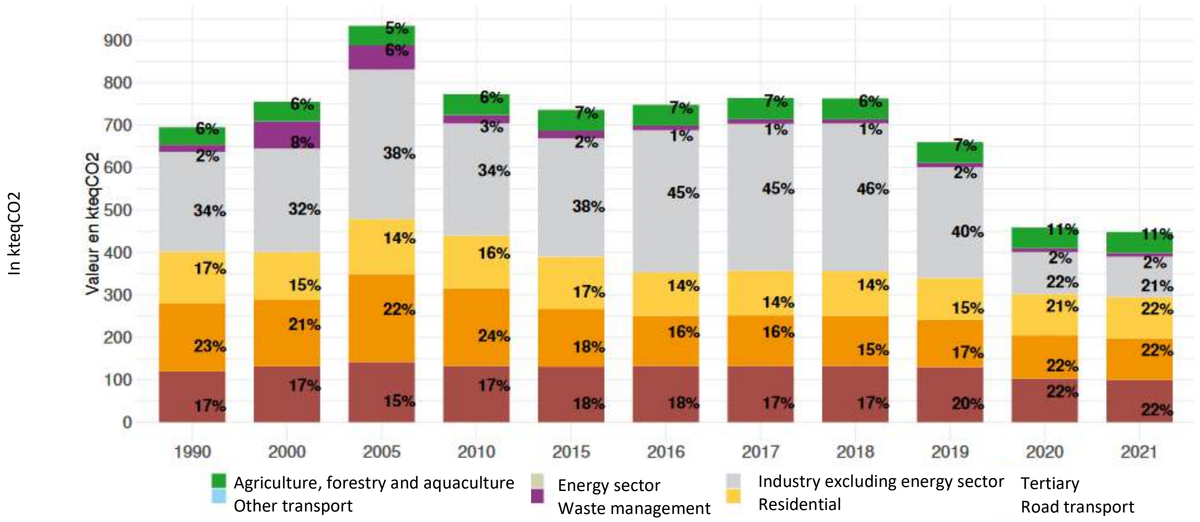
DECARBONIZATION AND LOCAL IMPACT

The first major impact of hydrogen is the decarbonization of the energy system. In the pilot area, we are looking specifically at public and private transport, as well as snow groomers for ski resorts.

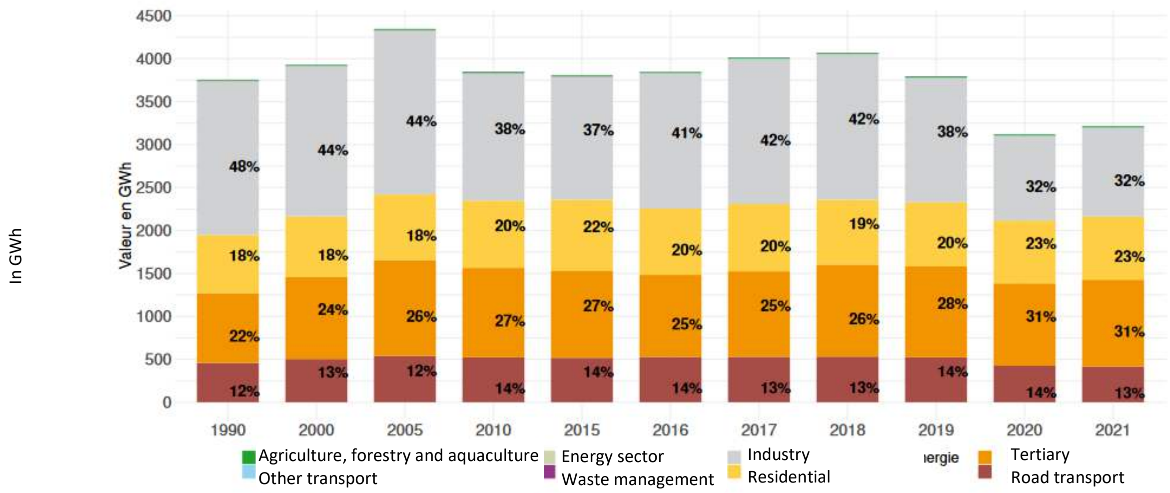
The second major impact of a local hydrogen ecosystem is that hydrogen could be produced and consumed in a local loop. This would give local public and private players a very strong energy sovereignty and a more obvious link to the RES strategy.

Industrial use seems to represent a significant, complementary and stable potential, which would make it possible to offset part of the strong seasonal demand for mobility.

Evolution of total GHG emissions by sector



Evolution of the share of final energy consumed by each sector



Friuli Venezia Giulia

CURRENT KEY ENERGY FLOWS

There is no large industry in the area that could be a simple target for hydrogen usage. In the next years the opportunity for synergy with some SMEs will be explored but energy profiles must be retrieved and studied in detail. Apart from the ski resort, the largest energy consumer is the pumping station of the SIOT-TAL oil pipeline that runs through the valley. The pumping station consists of 4 electrical pumps of 2 MW each, for an annual consumption (above 8000 full load hours) of 70 GWh.

The largest electricity production source is hydro. SECAB owns 6 power plants in the area for a total capacity of 10,8 MW and a yearly production of around 44 GWh. All the plants are run-of-river plants, with no reservoirs or pumping technology. Therefore, the yearly production varies depending on rainfall pattern and on the snow accumulation during winter. Production varies over the year due to seasonal behaviour, but it can be considered quite stable on a daily or weekly timeframe. In the following chart, the average monthly production of the hydro plants over 2013-2018 is depicted. It can be seen that during winter, since most of the precipitation consists of snow and rivers partially freeze, the production is at its minimum. From April to June the production is at its maximum thanks to the snow melting. During summer and autumn, the production is quite stable thanks to the rivers and the rainfall trends. Also, the other power plants follow more or less the same behaviour.

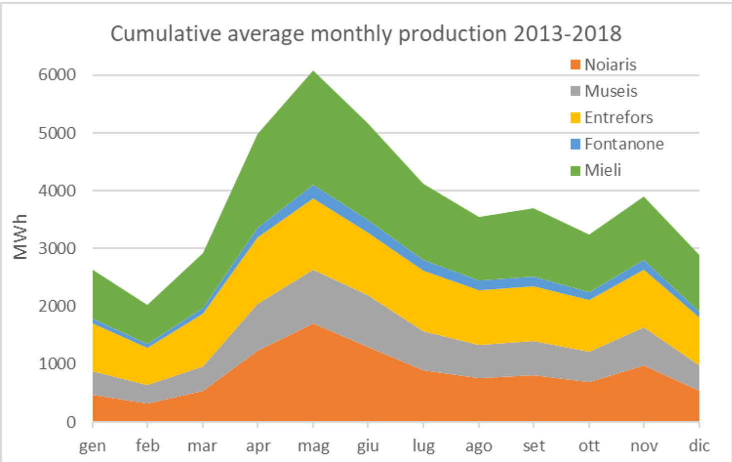


Figure 2: SECAB average 2013/18 hydro monthly production

Regarding fuel usage for transport, there are few gas stations, but since trucks mainly follow other routes, they mostly supply private cars or small vans/trucks. Over the entire area, the yearly consumptions are: 1 052 255 liters gasoline and 1 449 732 liters diesel.

Snowgroomers operate daily from the beginning of December throughout March, 7,5 hours per day. The Zoncolan ski resort has 6 snowgroomers operating for a total of 45 hours/day, 121 days/year. The total annual diesel consumption is 120 000 liters. This is equal to a daily consumption of 992 litres for the fleet, 165 litres per vehicle/day or 22 litres/hour.

Currently there is only one “large” PV plant set on the ground, it belongs to SECAB and it is operating since 2023. The installed peak capacity is 600 kWp. For this area the expected gross production, according to SolarAtlas, is about 1200 kWh per kWp per year.

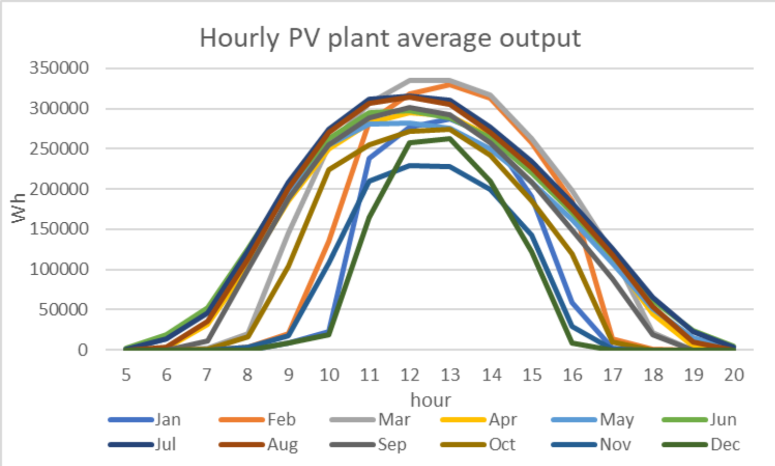


Figure 3: expected average hourly production of the new 600 kWp PV plant

Currently there is no H2 production or final use in the area, and there is no active project besides AMETHyST.

RES PRODUCTION POTENTIAL

In the following two tables the forecasted renewable installed capacity and estimated renewable production are depicted, comparing the status quo with the 203, 2035 and 2040 scenarios.

INSTALLED CAPACITY [kW]	**CURRENT**	**2030**	**2035**	**2040**
PV > 20 kW	1 133	2 000	2 500	3 000
PV < 20 kW	257	500	1 000	1 500
HYDRO	10 800	11 000	11 000	11 000
BIOMASS	999	0	0	0
WIND	-			
OTHERS	-			

INSTALLED CAPACITY [kW]	**CURRENT**	**2030**	**2035**	**2040**
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HYDRO	10 800	11 000	11 000	11 000
BIOMASS	999	0	0	0
WIND	-			
OTHERS	-			

DECARBONIZATION AND LOCAL IMPACT

The first major impact of hydrogen implementation is the decarbonization of the energy system. In the Alto But pilot area we are looking specifically at transport, private and public, as well as snow groomers for the ski resort. Private transport accounts for about 6071 tonnes of CO2 per year, while public transport for about

637 tonnes. Regarding snow groomers, the yearly consumption of 120000 litres of diesel adds up around 351 more tonnes of CO_2.

The second major impact of a local hydrogen ecosystem is that hydrogen is locally produced and consumed, substituting the import of fossil fuels. This translates in avoiding cash to flow outside the valley, while instead establishing a circular economy that holds the value locally, with great benefits for the entire society. Considering again transport fuels only, the amount of money that could be hold in the local economy is respectively 3,3 million euros for private transport, 346 thousand euros for public transport and 190 thousand euros for snow groomers refuelling.

Trentino Alto Adige – Fondazione Bruno Kessler

Current key energy flows

The main energy consumptions of the pilot territory are associated with the tertiary sector and concern the use of electricity (for snow production, ski lifts and operational buildings), of woody biomass (pellets, for heating purposes), and of oil fuel (for space heating). Moreover, gasoline and Diesel oil are used as fuels for private transport (snow groomers and cars) within the ski area. Total yearly consumptions are reported in *Table 1* for years from 2015/16 to 2022/23 (considering the year starting in May with the summer season and ending in April with the winter season). Data until 2019/20 were taken from results of the Interreg Alpine Space Project Smart Altitude, while more recent data were provided directly by Funivie Madonna di Campiglio S.p.A.

Table 1 – Total yearly consumptions in the pilot territory by energy vector for years from 2015/16 to 2022/23.

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Electricity [MWh]	12044	13647	11566	14999	8837	6885	12460	12525
Woody biomass [t]	213	254	258	261	267	2118	339	286
Oil fuel [t]	12	0	0	3	0	0	0	2
Gasoline [t]	0	4	4	4	0	3	2	6
Diesel oil [t]	369	373	467	455	0	91	413	447

Table 2 shows the monthly profile, from May to April, of the total electricity consumption from 2015/16 to 2022/23. The last five years are represented also in *Figure 4Figure 4***Errore. L'origine riferimento non è stata trovata.**. It should be noted that the years 2020 and 2021 are anomalous because, due to the SARS-CoV-2 epidemic, the ski area was compelled to have extended closing periods, corresponding to low energy consumptions. Moreover, a high seasonality character in the electricity consumption can be observed, with high peaks during the winter season and much lower consumptions during the summer season.

Table 2 – Monthly, winter seasonal (November – April), and annual electricity consumption, in MWh, for years from 2015/16 to 2022/23.

Month	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
May	145	195	248	177	227	178	162	126

June	320	367	230	319	309	175	204	348
July	380	319	329	341	401	340	385	381
August	393	365	355	361	413	390	417	369
September	260	220	261	243	348	323	357	381
October	260	330	418	381	363	480	367	264
November	2.111	2.755	2.638	2.689	984	1.052	1.768	1.991
December	2.580	3.843	2.126	3.079	1.656	605	3.246	2.686
January	2.614	2.324	952	1.529	1.722	1.335	2.051	2.253
February	1.191	1.265	2.210	1.212	1.678	1.047	1.497	1.740
March	1.229	1.202	1.258	4.017	556	750	1.404	1.440
April	560	461	541	650	180	209	603	545
Total winter season	**10.285**	**11.851**	**9.726**	**13.177**	**6.777**	**4.997**	**10.568**	**10.655**
Total annual	**12.044**	**13.647**	**11.566**	**14.999**	**8.837**	**6.885**	**12.460**	**12.525**

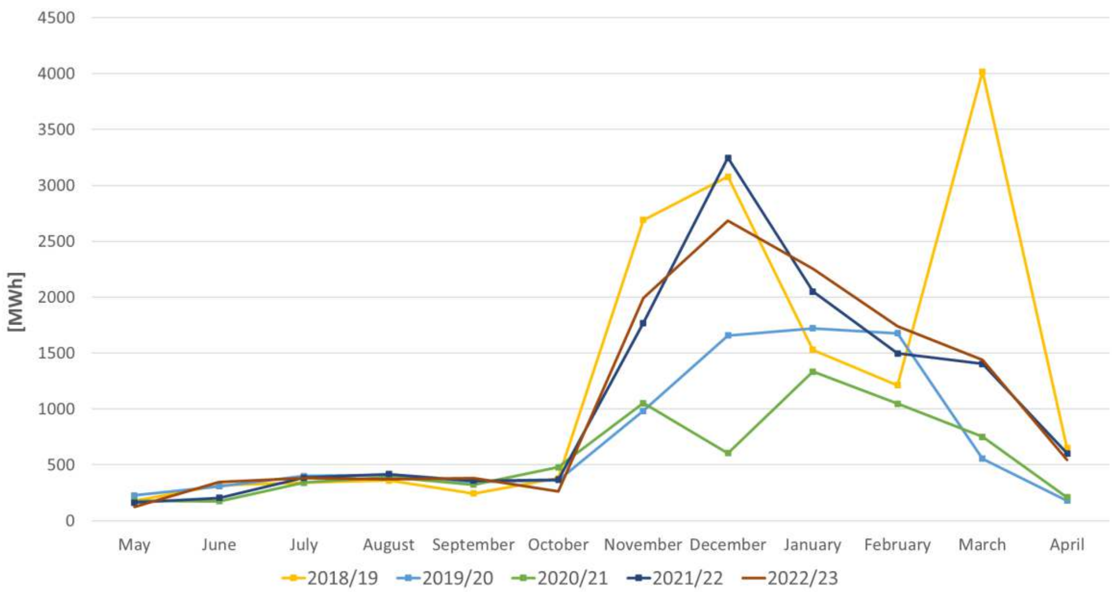


Figure 4 – Monthly total electricity consumption (in MWh) for the last five years.

Table 3 reports the electricity consumption of the ski-area only for the winter season (from November to April) divided into three categories: snow production, ski lifts, and other uses. The "other uses" category includes the electricity consumed by facilities such as offices and other buildings within the ski resort. **Errore. L'origine riferimento non è stata trovata.**For the last three years (2020/21, 2021/22, and 2022/23), in the absence of data broken down by energy end-use, the average percentages of breakdown by end-use in previous years were taken as a reference (53% of total electricity consumed for snow production, 30% for ski-lifts and the remaining 17% for other uses). *Figure 5Figure 5* visually represents the data for the last five years.

Table 3 – Winter electricity consumption broken down into different end-uses.

Winter season	Electricity consumption

(November – April)	Snow production [MWh]	Ski lifts [MWh]	Other uses [MWh]	Total [MWh]
2015/16	5.730	3.238	1.317	10.285
2016/17	7.540	3.342	968	11.851
2017/18	4.509	3.279	1.938	9.726
2018/19	5.921	3.692	3.563	13.177
2019/20	3.592	2.033	1.152	6.777
2020/21	2.649	1.499	850	4.997
2021/22	5.601	3.170	1.797	10.568
2022/23	5.647	3.196	1.811	10.655

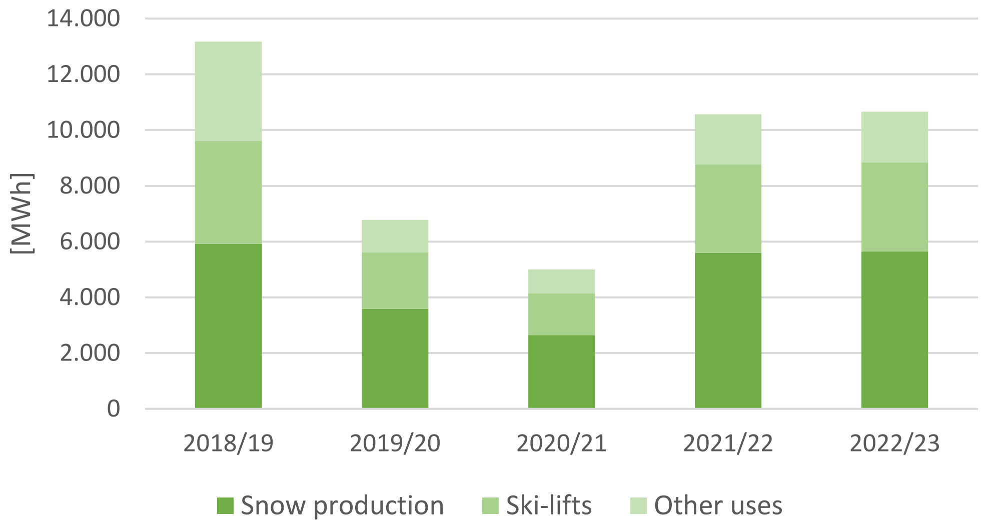


Figure 5 – Winter season electricity consumption broken down into different end-uses for years 2018/19 – 2022/23.

Table 4 focuses on private transport (mostly snow groomers, but also cars) and presents the yearly supply of Diesel oil and gasoline in liters and MWh. It is assumed that the annual supply is equal to the annual consumption. The data is also plotted for the last five years in *Figure 6* **Errore. L'origine riferimento non è stata trovata.**. The consumption of gasoline is very limited compared to that of Diesel oil.

Table 4 – Yearly consumption of Diesel oil and gasoline (in liters and in MWh) for private transport (snow groomers and cars).

Year	Diesel oil		Gasoline	
	[L]	[MWh]	[L]	[MWh]
2015/16	436.000	4.549	0	0
2016/17	441.000	4.601	5.000	44
2017/18	552.100	5.761	6.000	53
2018/19	537.800	5.611	5.000	44
2019/20	591.900	6.176	10.000	88
2020/21	107.998	1.127	3.953	35
2021/22	487.800	5.090	3.000	26
2022/23	528.363	5.513	7.693	67

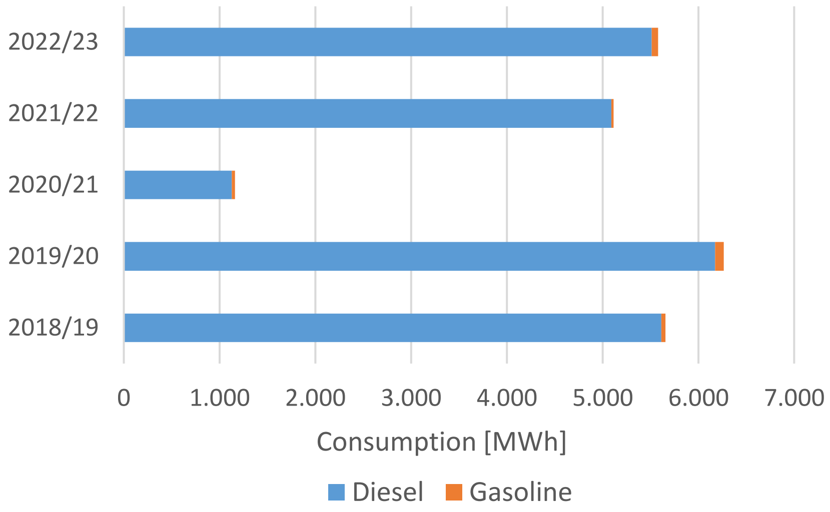


Figure 6 – Yearly consumption of Diesel oil and gasoline in the last five years, expressed in MWh.

In **Errore. L'origine riferimento non è stata trovata.** the annual supplies of woody biomass (pellets) and oil fuel for space heating (in tons/liters and MWh) are reported. As for the supply of fuels for snow groomers and cars, it is assumed that the annual supply of oil fuel for space heating is equal to the annual consumption. *Figure 7* displays the data for the last five years (from 2018/19 to 2022/23).

Table 5 - Yearly consumption of pellets (tons and MWh) and oil fuel (liters and MWh) used in the ski area for space heating.

Year	Pellets		Oil fuel	
	[t]	[MWh]	[L]	[MWh]
2015/16	213	1.038	12.120	135
2016/17	254	1.235	0	0
2017/18	248	1.206	0	0
2018/19	261	1.266	3.000	34
2019/20	267	1.296	0	0
2020/21	218	1.059	0	0
2021/22	339	1.647	0	0
2022/23	286	1.389	2.200	25

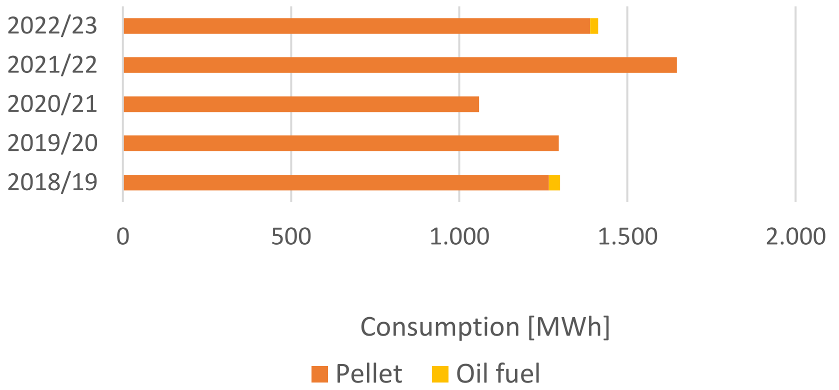


Figure 7 - Yearly consumption of pellets and oil fuel in the last five years, expressed in MWh.

RES production potential

Exploring the RES potential in the ski area, it is most likely that in the next years Funivie Madonna di Campiglio S.p.A. will install photovoltaic panels (PV), so PV installation was considered over the years with the following assumptions:

- PV panels are placed on the roofs of buildings owned by Funivie Madonna di Campiglio in the area, assuming that the area available is half of the total roof area (available area = total roof area / 2 = 5.352 m^2)
- To optimize the annual production the following are considered:
  - Tilt angle = 36°
  - Azimuth angle = -11° (obtained through PVGIS)
- No system losses
- Equivalent number of operating hours equal to 1327 h/y (obtained through PVGIS),
- Area power density equal to 220 W/m^2.

In addition, a gradual increase in the installed capacity was assumed, corresponding to a gradual increase in the coverage of the available area (10% in 2030, 75% in 2035, 100% in 2040). *Table 6* and *Table 7* report the estimated potential installed capacity and production, respectively, with projections for 2030, 2035, and 2040.

Table 6 – RES potential (in terms of installed kW) from the current situation until 2040.

Installed capacity	Current	2030	2035	2040
PV < 20 kW	0	589 kW (with 50% available area coverage)	883 kW (with 75% available area coverage)	1.178 kW (with 100% available area coverage)

Table 7 – Forecast of RES production (in MWh) from the current situation until 2040.

Production	Current	2030	2035	2040
PV < 20 kW	0	782 MWh	1.172 MWh	1.563 MWh

Decarbonization and local impact

The use of electricity and fossil fuels implies emissions that can be estimated applying to each energy vector the corresponding emission factor. For pellets, being the carbon dioxide derived from combustion of biomass of biogenic origin, an emission factor equal to zero is considered. Emission factors used in the analysis of the pilot territory energy flows are reported in Table 8. The emission factor associated with the electricity used depends on the energy mix used for its production and may vary each year. For an estimate of the emissions associated with the electricity used in the ski area, the emission factors determined by ISPRA[5] (Istituto Superiore per la Protezione e la Ricerca Ambientale) for different years were considered. In Table 9 the yearly total emissions, expressed in tons of equivalent CO_2 are reported per each energy vector used.

Table 8 – Emission factors of energy vectors considered in the analysis of the pilot territory.

	Emission factors	
Electricity	dependent on energy mix used for production of electric energy	tCO2e /MWh
Woody biomass	0	tCO2e /t
Oil fuel	3,518	tCO2e /t
Gasoline	3,140	tCO2e /t
Diesel oil	3,347	tCO2e /t

Table 9 – Emissions by energy vector expressed in tons of equivalent CO_2.

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Electricity	3.796	4.188	3.493	4.264	2.375	1.687	3.053	3.069
Woody biomass	0	0	0	0	0	0	0	0
Oil fuel	42	0	0	10	0	0	0	8
Gasoline	0	12	14	12	0	9	7	18
Diesel oil	1.235	1.249	1.563	1.523	0	306	1.381	1.496

Most of the emissions are ascribable to the large electricity consumption, but also Diesel oil consumption entails a large share of CO_2 emissions.

The costs associated with each energy vector were also determined. In **Errore. L'origine riferimento non è stata trovata.** the costs related to the different energy carriers are shown, considering that:

- For electricity, the PUN averages[6] (in €/MWh) between May and April of the following year were considered.
- For Diesel oil, gasoline, and heating oil fuel, averages of fuel prices between May and April were used[7].

[5] Indicatori di efficienza e decarbonizzazione del sistema energetico nazionale e del settore elettrico, ISPRA, Rapporti 343/2021, ISBN: 978-88-448-1049-8
[6] Gestore Mercati Energetici (GME). https://www.mercatoelettrico.org/it/. Accessed: 08/09/2023.
[7] Ministero dell'Ambiente e della Sicurezza Energetica. Statistiche energetiche e minerarie. https://dgsaie.mise.gov.it/prezzi-annuali-carburanti. Accessed: 08/09/2023.

- For woody biomass, prices were provided by Funivie Madonna di Campiglio S.p.A.

Table 10 – Costs of energy used within the pilot territory expressed in k€.

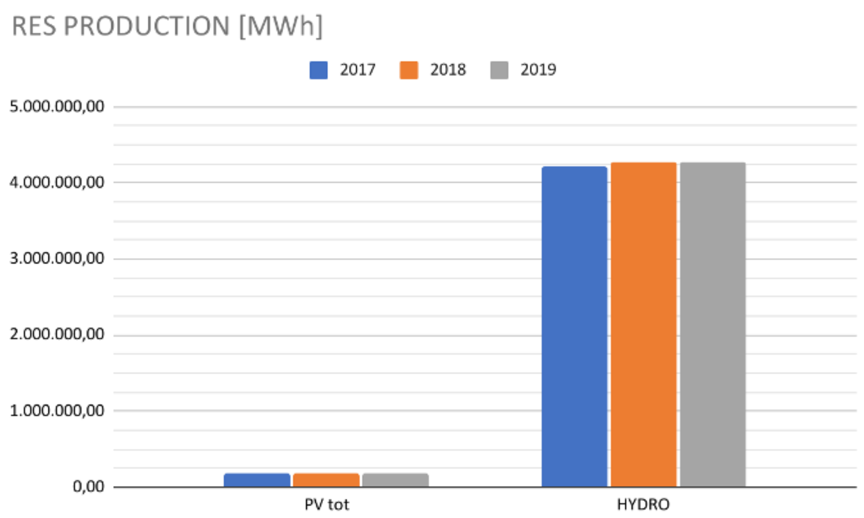
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Electricity	577	657	621	943	398	327	2329	3395
Woody biomass	45	50	52	63	65	519	83	70
Oil fuel	14	0	0	4	0	0	0	4
Gasoline	0	7	9	8	0	6	5	14
Diesel oil	583	591	771	807	0	142	786	967

Trentino Alto Adige – Autonomous Province of Trento

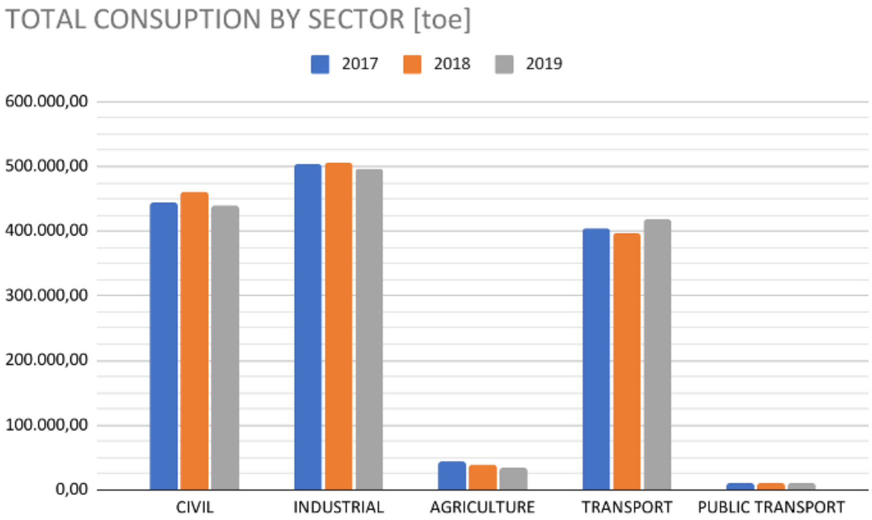
CURRENT KEY ENERGY FLOWS

Below are the energy production and consumption data for the years 2017, 2018 and 2019, which will be used as the three-year reference period for this document. These years were chosen for two main reasons. On the one hand, we wanted to have the best possible data availability, but on the other hand, we did not want to have a database that would be affected by the drop in consumption from 2020 due to the COVID-19 emergency.

Renewable energy generation in the province is characterised by the presence of a preponderant and increasingly constant hydropower production (about 4.2 TWh per year). Production from photovoltaics in the three-year reference period is stable (about 190 GWh per year) but shows a positive trend in subsequent years (207 GWh per year in 2021). As far as biomass is concerned, no data is available for the three-year reference period; what is known is the figure for the three-year period 2014-2016, which was around 1.7 TWh per year of thermal energy produced. Finally, wind energy production is not significant. Below are the figures for electricity production from photovoltaics and hydroelectric power.



As far as energy consumption is concerned, the data for the civil, industrial, agricultural and private and public transport sectors are given below, expressed in toe. The data reported are partial since it was not possible to find, for example, the data associated with the consumption of woody biomass for domestic use (still relevant in the Trentino context) and the consumption associated with certain types of fuel for the industrial sector (LPG, Diesel, Fuel Oil).



The three most energy-intensive sectors are civil, industrial and transport, with values ranging between 400 and 500 ktoe.

RES PRODUCTION POTENTIAL

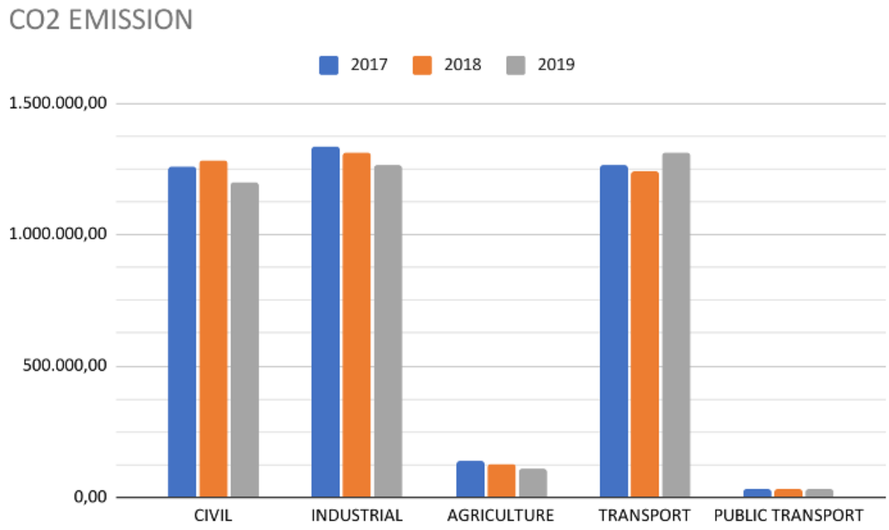
The issue of supply and production of the hydrogen vector remains of crucial importance, especially for territories like Trentino, which is excluded from the scenarios envisaged by the European Hydrogen Backbone (EHB) initiative, and where almost all renewable energy comes from hydroelectric basin power plants (the overproduction situations that might occur with photovoltaics will not occur in the future).

The availability of electricity from renewable sources generated through existing hydrogen plants could come mainly from hydropower. The hypothesis here could be to reserve part of the electricity production of one or more existing power plants for hydrogen generation. To facilitate this hypothesis, a rewarding mechanism could be introduced in the renewal procedures of hydroelectric concessions for those who would thus favour hydrogen production.

Focusing instead on the future development of energy production facilities from renewable sources, one could consider the construction of new hydroelectric power plants dedicated to hydrogen production or the construction of dedicated photovoltaic fields.

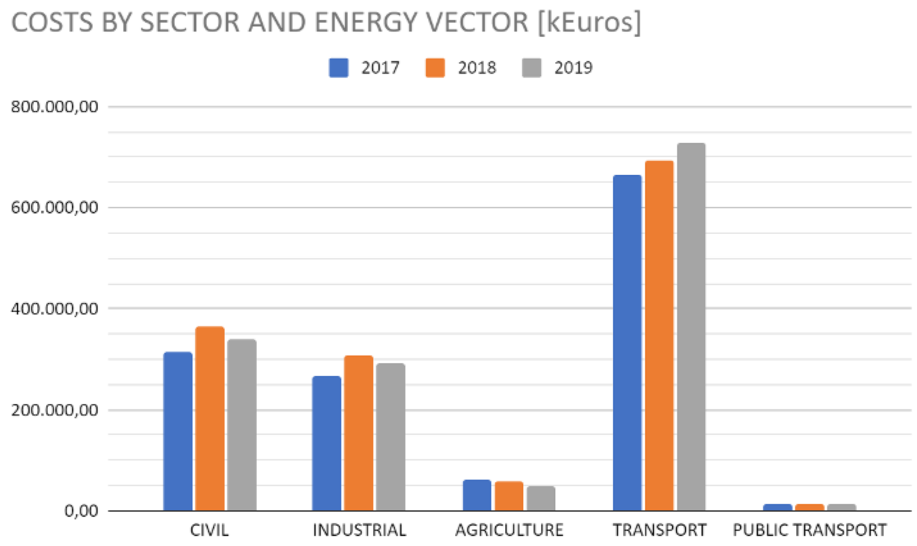
DECARBONIZATION AND LOCAL IMPACT

Starting from the consumption data given in Chapter 1, broken down by sector, the corresponding estimated CO2 emissions are shown.



With the implementation of green hydrogen in Trentino, we could contribute to the decrease of the reported values by acting on the various consumption sectors identified. With regard to consumption linked to the use of methane gas, mainly used in the civil and industrial sectors, the possibility of implementing hydrogen blending on the gas distribution network is envisaged to meet part of the provincial heat demand and thus contribute to the direct decarbonisation of methane. This scenario was analysed with the 2021-2030 PEAP and, assuming 5% blending with the configuration and consumption expected in 2030, avoids the generation with methane of about 250 GWh per year of heat energy, equivalent to about 50 tonnes of CO2 per year. As far as the transport sector is concerned, the implementation of hydrogen is planned on an experimental basis to 2030, while only in the following decades will there be a significant contribution to the reduction of fossil fuel consumption for the sector. It should be noted that in this context, the Autonomous Province of Trento is also involved in the H2 Corridor Brenner/o working group that deals with heavy transport on this important road axis.

As far as energy costs in the three most energy-intensive sectors, i.e. civil, industrial and transport, are concerned, the expenditure for energy supply is around €300 million for the first two and around €700 million for transport. Below is the relevant explanatory chart.



As mentioned in the previous section, as far as thermal power generation is concerned, mainly in the civil and industrial sectors, the main area in which hydrogen could become established in the next few years is the blending into the natural gas grid. The expected savings from the non-purchase of methane gas must, however, be compared with the cost of the new energy carrier, which is not comparable to date.

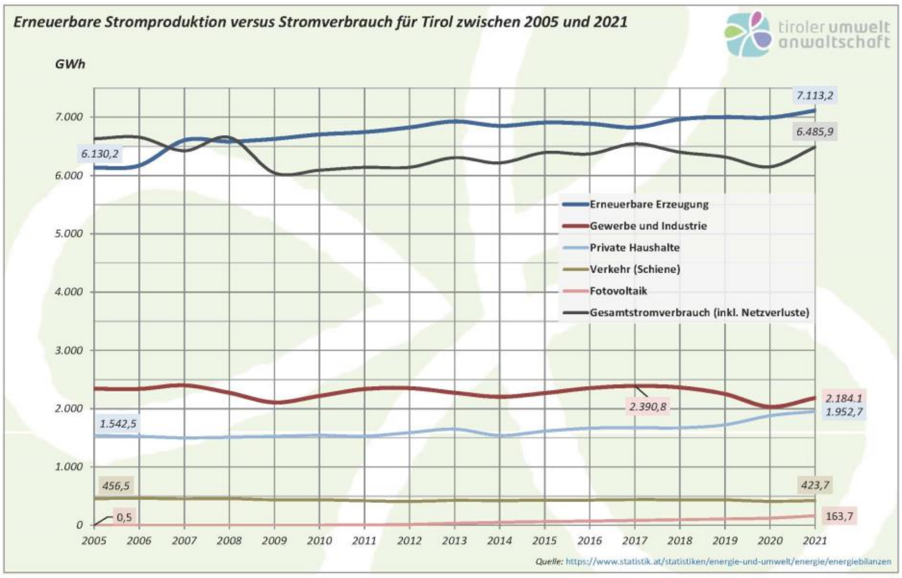
Tirol

CURRENT KEY ENERGY FLOWS

The regional implementation plan, which is being developed in consultation with stakeholders and in compliance with current and future standards, is intended to help give both hydrogen producers and users planning security for their business models. With the measures initiated within the frame of the H2Alpin project, hydrogen-based mobility should already save around 17,700 T CO2 by the end of 2030.

In 2021, a total of 7,113.2 GWh (gigawatt hours) of electricity was produced from renewable sources in Tyrol. Around 95 percent of this electricity was provided by hydropower, only a small share was generated by burning biogenic materials. Electricity generation from photovoltaics amounted to 2.30 per cent this year 1.

The pure production of electricity from hydropower in Tyrol is dominated by 22 large power plants, which generate 71.99 percent of the total amount of electricity. In contrast, 728 micro power plants (output below 500 kW) produce only 3.77 percent 1.



RES PRODUCTION POTENTIAL

TASK 6 UNTAPPED RES POTENTIAL – **COPY/PASTE TABLES** – how much of this production could be available for hydrogen production?

INSTALLED CAPACITY [MW or kW]	CURRENT	2030	2035	2040
PV > 20 kW				
PV	*12637*	*17500*	*20000*	*25000*
HYDRO	*64130*	*70000*	*72000*	*75000*
BIOMASS	*296*	*300*	*300*	*300*
WIND	*2,3*	*5*	*10*	*20*
OTHERS				

Power2XKufstein => up to 900 t of Green Hydrogen / year

Power2X Jenbach => up to 900 t of Green Hydrogen / year

Demo4grid => up to 420 t of Green Hydrogen / year

Plansee-Reutte: Electrolyse with Renewable Energy by Grid.

H2Alpin => hydrogen-based mobility should already save around 17,700 T CO2 by the end of 2030.

This project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme

Bavarian Oberland

CURRENT KEY ENERGY FLOWS

In order to visualize primary energy sources and final energy consumption by sector, the follow graph shows where energy comes from and how it is use in the region Oberland. The data is based on Klimaschutz-Planer (2019).

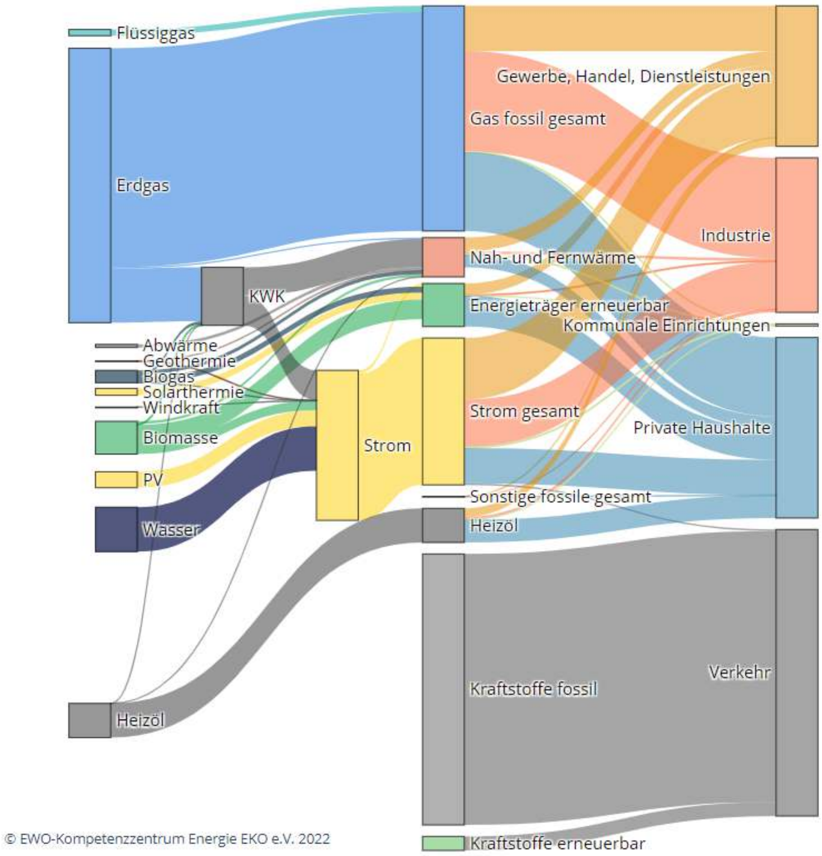


Figure 8 Primary energy and final energy consumption flow by sector in the Region Oberland (source: Energiewende Oberland)

As depicted in Figure 2 CNG (Erdgas) is the main energy source in the region supplying trade and commerce, industry and households. The electricity consumption (Strom) of the region Oberland accounts for 2.454 GWh. The largest renewable energy source is hydropower by supplying 744 GWh, followed by photovoltaics (266 GWh) and bioenergy (157 GWh). Wind energy and geothermal energy play minor roles in the region, although there is natural potential.

Mobility (Verkehr) is the largest final energy consumption of the region with 4.789 GWh. Private households (Private Haushalte) use 3.016 GWh, industry (Industrie) 2.583 GWh and trade and businesses (Gewerbe, Handel, Dienstleistungen) 2.347 GWh from dominantly fossil sources like CNG (Erdgas) and oil (Heizöl).

According to INOLA/Klimaschutz-Planer, the extrapolated heat demand of the region is currently about 5.5 TWh_{th} (private households (45%), economy (55%)). The economic sector implies consumption of municipalities, commercial and industrial sectors.

INOLA examined larger industrial consumptions in the region Oberland. Important to note is that the total electricity consumption of the district Weilheim-Schongau is nearly half of the overall energy consumption of the region: the largest consumer by far is the municipality of Schongau with 736 GWhel, due to the UPM Kymmene paper mill and other large companies, such as the Hoerbiger company and the Hochland company. Within the district of Bad Tölz-Wolfratshausen, total electricity consumption is 451 GWhel. The municipality of Geretsried, with 101 GWhel, has the highest electricity consumption in the district. Rudolf GmbH, an industry focused on customer-oriented development of new textile auxiliaries and speciality chemicals, is located here with 260 employees. In addition, Geretsried is a location for various logistics companies, including GLS, DPD, DHL and Hermes. The municipality of Wolfratshausen also has a high energy consumtion, with 77 Gwhel (Eagle Burgmann Group and Haupt-Pharma) as well as Bad Tölz, with 70 Gwhel (Moralt AG).

The total electricity consumption of the district of Miesbach is at about 445 GWhel.The largest electricity consumption occured in the three municipalities of Holzkirchen (70 GWhel), Gmund (64 GWhel) and Miesbach (city) (55 GWhel). In Holzkirchen there are, besides the headquarters of Hexal AG, many medium-sized companies. In Gmund, there is the Louisenthal paper and cardboard factory, and in Miesbach there is also the Kroha company (graphic packaging).

The administrative district of Garmisch-Partenkirchen is mostly dominated by the health and tourism industry as well as strong trade and business activities.

The region Oberland in an energy nutshell:

- The has a fairly equally distributed energy consumption throughout the sectors mobility, private households, industry and trade and businesses.
- The region's energy demand is dominantly supplied by fossil fuels (CNG, LPG, oil, diesel, gasoline)
- Renewable energy plays the biggest role in the sector of electricity supplying approximately 50% of the consumption.
- The largest share of renewable energy comes from hydropower.

AMETHyST key indicators:

Table 1: AMETHyST indicators

CONSUMPTION	MWh
RESIDENTIAL	2.761.662
TERZIARY SECTOR	2.166.073
PUBLIC LIGHTING	n.a.
INDUSTRY	2.617.684
AGRICULTURE	n.a.
PRIVATE TRANSPORT	3.458.525
PUBLIC TRANSPORT	89.975
AIR TRANSPORT	n.a.
MARITIME TRANSPORT	n.a.
RAIL TRANSPORT	38.532

Please note that the difference in the total energy consumption of 11.132,45 GWh (AMETHyST indicators) in comparison to 12.773,57 GWh (Klimaschutz-Planer) is due to different methodoligies used.

Energy flow charts of potential future scenarios

Within the research project INOLA, researchers together with energy utlities developed potential scenarios of the energy system in the year 2035[8]. Researchers identified two scenarios, which are based on different assumptions. Scenario 1 (Ausbaupfad #1: PV) estimates a high share of residential and small energy production mostly by photovoltaics. Scenario 2 (Ausbaupfad #2: PV + Wind) shows a higher share of wind energy, which decreases the volatility of the energy flow over the timespan of a year.

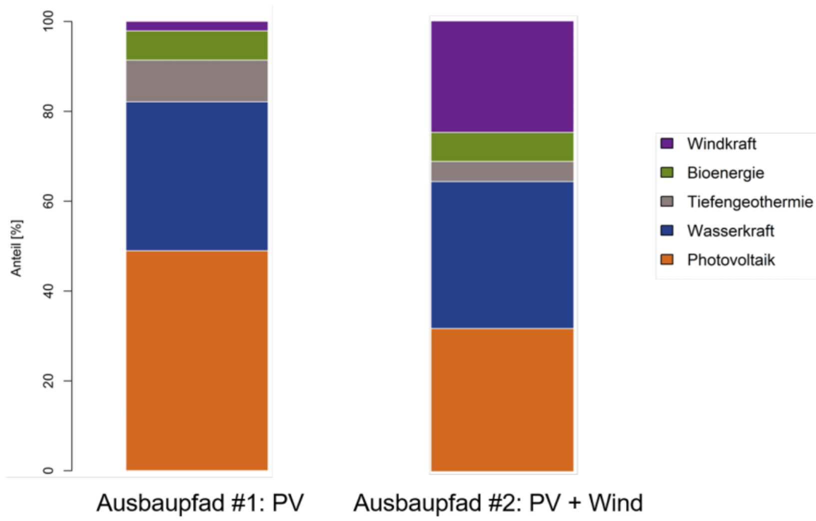


Figure 9 Scenarios for 100% renewable energy powered region Oberland | source: INOLA 2019 Arbeitsbericht Nr. 10

Figure 3 compares the share of renewable energy sources of potential scenarios where 100% of electricity consumption is produced within the region Oberland. The scenarios consist of photovoltaics (Photovoltaik), hydropower (Wasserkraft), geothermal power plants (Tiefengeothermie), bioenergy (Bioenergie) and wind energy (Windkraft).

The resulting energy flows for the region are depicted in the figures below.

[8] INOLA 2019: Arbeitsbericht Nr. 10 / https://inola-region.de/download/a4gs9u1mm0veeq58n7u0578ni7f/INOLA_Arbeitsbericht_Nr10.pdf

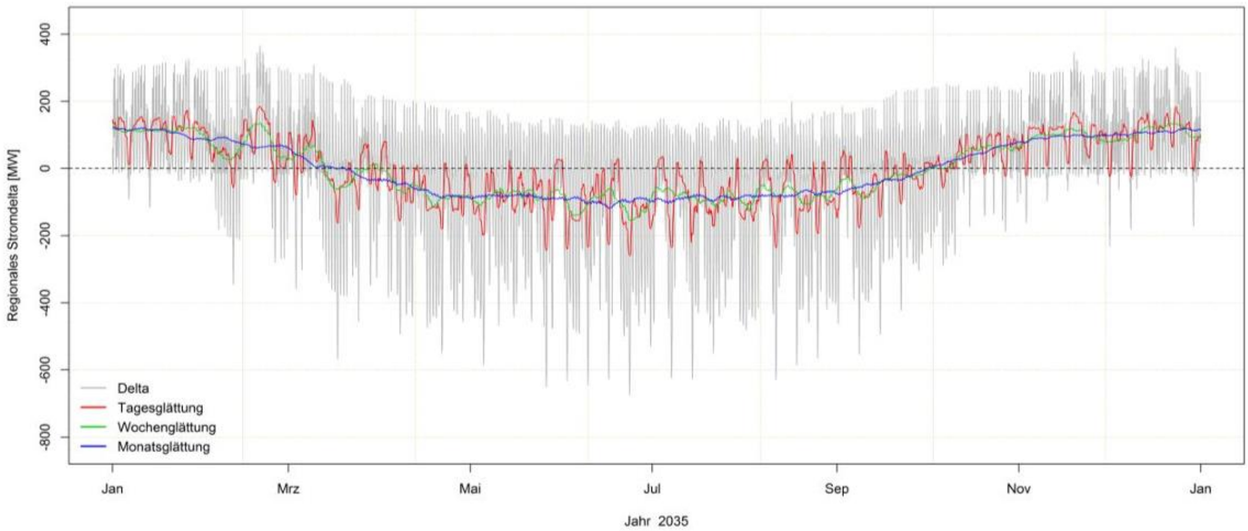


Figure 10 Time-continuous, regional electricity delta (MW) in the year 2035 created by scenario 1 based on mostly photovotaics

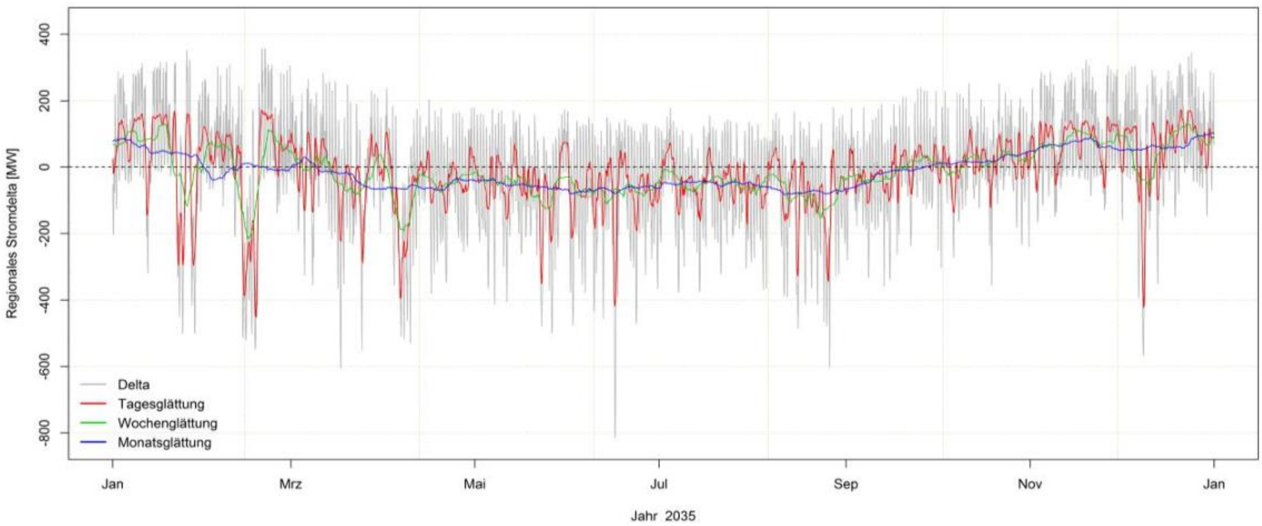


Figure 11 Time-continuous, regional electricity delta in the year 2035 created by scenario 2 photovoltaics and wind.

Figures 4 and 5 show that the rounded monthly delta (Monatsglättung) can be significantly decreased by the utilization of wind energy potentials in the region Oberland, especially in winter months. The cummulated electricity delta for scenario 1 (PV) is projected at 147 GWh compared to 75 GWh in scenario 2 (PV+Wind). The surplus energy in summer months is estimated with 204 GWh (scenario 1: PV) compared to 153 GWh (scenario 2: PV+Wind).

With regards to production of hydrogen, scenario 1 (PV) poses higher potential for the utilization of renewable energy production, but might interfere with aspects of grid capacity and stability.

RES PRODUCTION POTENTIAL

As part of the INOLA project (2014-2019) , the natural potential for renewable energy production of the districts of Bad Tölz-Wolfratshausen, Miesbach and Weilheim-Schongau was elaborated. In gray at the bottom of the graph, the electricity consumption (Stromverbrauch) in the year 2014 is shown. If all potentials for renewable energies are added up, it shows that the Oberland has more than enough potential for renewable energy to cover the current energy demand over the timespan of a year. Open space photovoltaics (Freiflächen PV) shows the largest potential, followed by hydrogen (Wasserkraft), bioenergy (Biomasse), building-integrated photovoltaics (gebäudeintegrierte PV), geothermal power plants (Tiefengeothermie) and wind energy (Windkraftanlagen).

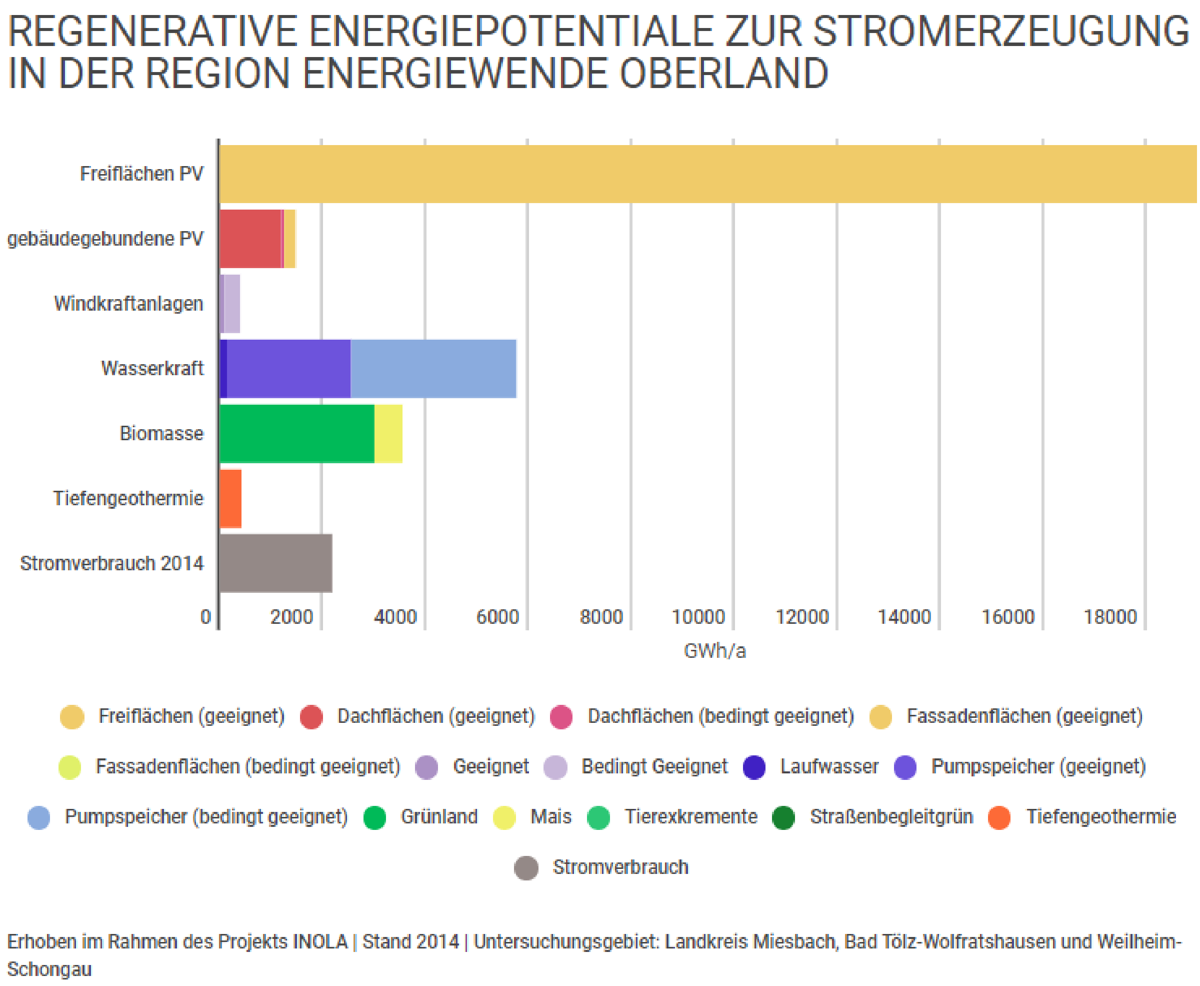


Figure 12 Natural potential for renewable energy production in the districts Bad Tölz-Wolfratshausen, Miesbach, Weilheim-Schongau | Source INOLA Arbeitsbericht Nr. 3 (2015, 2019)

The best data source for current installed capacity is the Energieatlas Bayern, as mentioned above. In order to provide the best estimation possible, the current data from Energieatlas Bayern is used in combination with scenarios from INOLA as well as current political objectives set by the German ministry for Economics and Climate Protection.

Table 2: Installed capacity and scenarios

INSTALLED CAPACITY MW	CURRENT 2021 Energieatlas	2030	2035	2040
PV > 20 kW	213	297	371	408
PV < 20 kW	160	747	934	1.027
HYDRO	230	234	293	300
BIOMASS	37	40	45	50
WIND	1	95	158	165
OTHER	4	12	20	29

Table 3: Current production and scenarios

Production MWh	CURRENT Klimaschutz-Planer 2019	2030	2035	2040
PV > 20 kW	165.426	230.432	288.040	316.844
PV < 20 kW	101.390	474.294	592.868	652.155
HYDRO	744.001	757.246	946.558	969.172
BIOMASS	198.002	212.335	238.876	265.418
WIND	609	91.350	152.250	159.500
OTHERS	8.963	29.379	49.297	71.704

Table 2 *Installed capacity and scenarios* describes the installed capacity in the year 2021 according to Energieatlas Bayern. The projection for the years 2030, 2035 and 2040 are based on existing scenarios developed by the project **INOLA for the year 2035** in conjunction with the goal to produce **80% of the electricity demand in 2030**, which is a goal set by the German Ministry for Economics and Climate Protection.

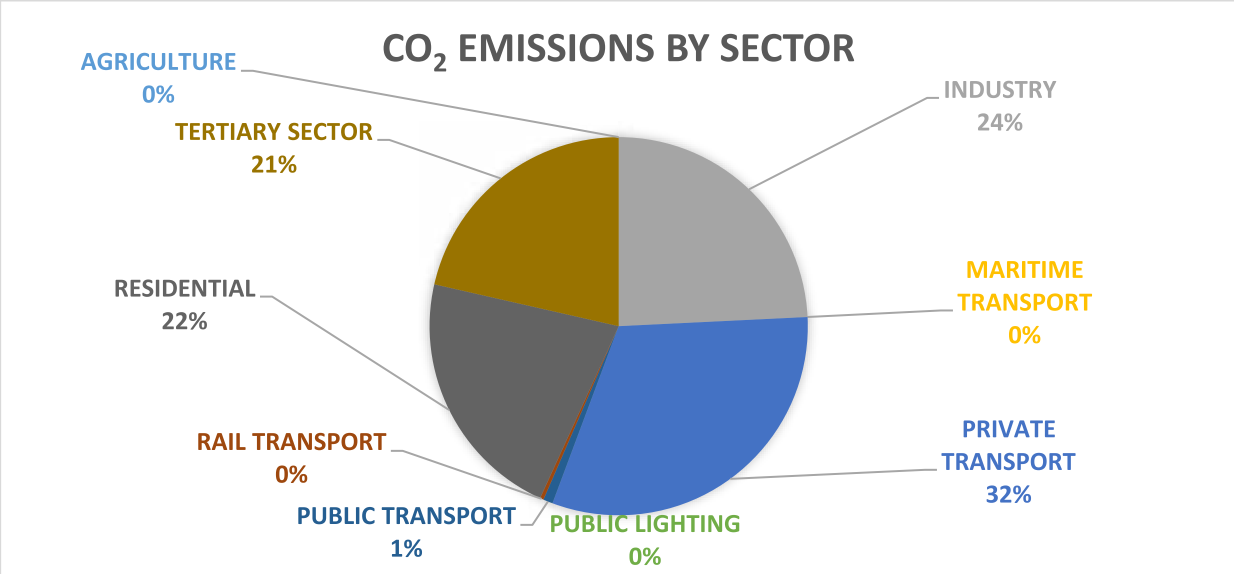
In order to create a more coherent picture with the data displayed in table 1 *AMETHyST indicators*, which are based on the data from Klimaschutz-Planer (2019), table 3 *Current production and scenarios* uses the AMETHyST indicators as a basis and projects the future production according to the relative growth of renewable energy sectors in table 2 *installed capacity.* This projection partially neglects the fact of increasing efficiency of renewable energy production.

For example, the increase in the installed capacity of *photovoltaics >20 kW* between 2021 and 2030 equals 39% (from 213 MW to 297 MW). In parallel, the increase in production between 2019 and 2030 equals 39% (from 165.426 MWh to 230.432 MWh) as well.

DECARBONIZATION AND LOCAL IMPACT

Based on the data provided by Klimaschutz-Planer (2019) the CO_2 emissions of the region Oberland amount to 3.456.566 tonnes CO_2-equivalents.

CO2 EMISSIONS BY SECTOR AND ENERGY VECTOR [tonnes CO2]		2019
RESIDENTIAL	Electricity	269.883
	Natural gas	312.338
	LPG	14.793
	Diesel	-
	Oil fuel	120.670
	Wood biomass	6.342
	Hydrogen	-
	District heating	26.101
TERTIARY SECTOR	Electricity	480.369
	Natural gas	174.437
	LPG	13.965
	Diesel	-
	Oil fuel	45.492
	Wood biomass	699
	Hydrogen	-
	District heating	25.136
PUBLIC LIGHTING		-
INDUSTRY	Electricity	402.242
	Natural gas	414.388
	LPG	-
	Diesel	-
	Oil fuel	15.001
	Wood biomass	151
	Hydrogen	-
	District heating	4.410
AGRICULTURE	Electricity	-
	Diesel	-
	Oil fuel	-
	Wood biomass	-
PRIVATE TRANSPORT	Electricity	1.311
	Natural gas	1.260
	Gasoline	548.840
	Diesel	505.230
	LPG	10.398
	Hydrogen	
	Biofuels	18.990
PUBLIC TRANSPORT	Electricity	71
	Natural gas	98
	Gasoline	
	Diesel	27.591
	LPG	
	Hydrogen	
	Biofuels	581
AIR TRANSPORT	Kerosene	
MARITIME TRANSPORT	Diesel	-
RAIL TRANSPORT	Electricity	10.662
	Hydrogen	
	Diesel	5117



The graph above shows CO_2 emissions by sector (Klimaschutz-Planer 2019 / AMETHyST indicators). Please note that no data was available for maritime transport (not applicable in the region Oberland), agriculture, air transport and public lighting. Private transport emits most CO2 (32%) followed by the sectors industry (24%), residential (22%) and tertiary sector. Due to the fact that Klimaschutz-Planer data does not include data for agriculture specifically, the emissions from this sector are partially included in tertiary sector.

Sector	CO_2-Emissions (tonnes CO_2-equivalent)
AGRICULTURE	not available
AIR TRANSPORT	not applicable
INDUSTRY	836.192
MARITIME TRANSPORT	not applicable
PRIVATE TRANSPORT	1.086.029
PUBLIC LIGHTING	not applicable
PUBLIC TRANSPORT	28.341
RAIL TRANSPORT	10.662
RESIDENTIAL	750.127
TERTIARY SECTOR	740.098
SUM	**3.451.449**

Based on AMETHyST indicators, the total amount spent for energy and mobility amounts to a total of 1.2 billion Euros in 2019 in the pilot region Oberland (see table below).

energy vector	kEuros
Biofuels	- k€
Diesel	213.356 k€
District heating	33.150 k€
Electricity	491.661 k€
Gasoline	284.412 k€

sector	kEuros
AGRICULTURE	- k€
AIR TRANSPORT	- k€
INDUSTRY	139.578 k€
MARITIME TRASNPORT	- k€
PRIVATE TRANSPORT	489.070 k€

Hydrogen	- k€
Kerosene	- k€
LPG	9.373 k€
Natural gas	157.551 k€
Oil fuel	37.052 k€
Wood biomass	19.368 k€
Sum	**1.245.923 k€**

PUBLIC LIGHTING	- k€
PUBLIC TRANSPORT	11.018 k€
RAIL TRANSPORT	6.945 k€
RESIDENTIAL	313.224 k€
TERZIARY SECTOR	286.088 k€
Sum	**1.245.923 k€**

With regards to energy vectors, most money is spent in the region for electricity (491.611 kEuros), followed by gasoline (284.412 kEuros), Diesel (213.356 kEuros), natural gas (157.551 kEuros), oil fuel (37.052 kEuros). The cost for all above mentioned fossil energy vectors including a share of 50% electricity, which is not produced regionally amounts to 947.574 k€ in the year 2019.

cost for fossil energy	
Diesel	213.356 k€
Gasoline	284.412 k€
LPG	9.373 k€
Natural gas	157.551 k€
Oil fuel	37.052 k€
electricity 50%	245.831 k€
sum	**947.574 k€**

Canton of Valais

CURRENT KEY ENERGY FLOWS

TÉLÉVERBIER SA

Téléverbier SA, regarded as Switzerland's leading lift company, is now pursuing an ambitious goal: to become a carbon-neutral resort. Currently, the resort uses 25 diesel snow groomers to keep its slopes in perfect condition. However, it is notable that these machines consume around 540 liters of diesel for 20,000 hours of work over the course of a season.

Every year, between 2 and 3 snow groomers are replaced. This gradual replacement will make it possible to gradually replace the fleet and test hydrogen-powered snow groomers.

It's important that the hydrogen production area is close to the snow groomers parking area. For the moment, it would be located on the ski slope near the Ruinettes area.

In addition to the obvious ecological benefits, this transition could also have positive financial repercussions. Currently, Téléverbier SA is exempt from the RPLP (Redevance sur les produits pétroliers) tax. However, it is important to note that this exemption will come to an end in a few years' time.

TMR SA

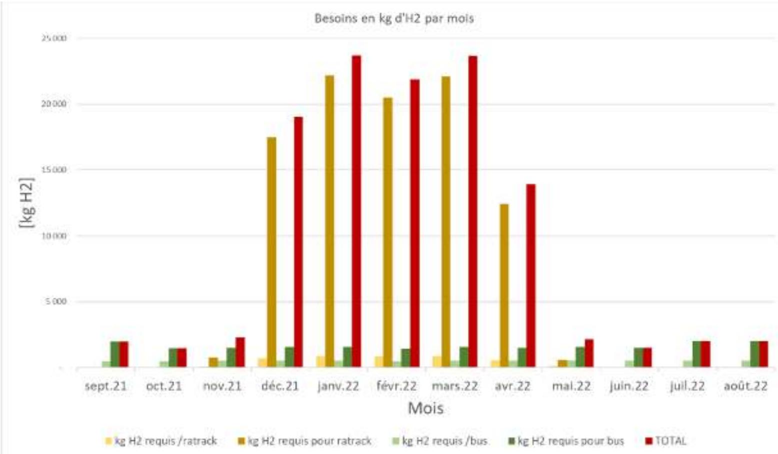
TMR SA, a company specializing in the transport sector, has four bus lines in the Val de Bagnes. The fleet currently comprises four buses, each consuming between 50 and 56 liters of diesel to cover 100 kilometers.

With a total distance covered of 500 kilometers per day throughout the year, this equates to around 195,000 kilometers per year. This consumption leads to an annual use of 98,000 to 110,000 liters of diesel. At present, the fleet is renewed every 4 years.

TMR SA is looking at options for sustainable alternatives and is considering the use of hydrogen, the challenge being the distance between the bus storage area and the hydrogen refuelling zone.

Like Téléverbier Sa, TMR Sa will have to pay the RPLP tax in the years to come.

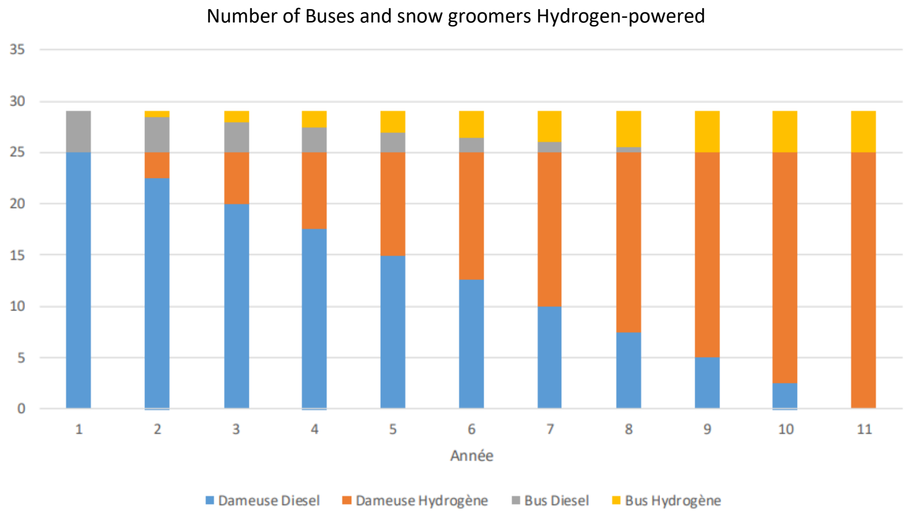
Estimated hydrogen requirements (H2)



Annual H2 requirements

- **Total: approx. 120,000 Kg**
- Total Snow groomers: 100,000 Kg
- Total Buses: 20'000 Kg

Decarbonizing mobility



According to the investment plans of TMR SA and Téléverbier SA :

- Bus fleet renewed in 8 years.
- Groomer fleet renewed in 10 years.

RES PRODUCTION POTENTIAL

In concrete terms, there are no plans to increase the share of renewable energies in the Val de Bagnes area. On the hydroelectric side, the largest producer remains the dam, with a current total output of ~70'000'000 kWh/year.

As far as microturbines are concerned, we're already at 90% of what ALTIS can optimize on its water network. The remaining 10% is not profitable, according to the company's calculations. ALTIS is the company in charge of electricity and water utility in the Val de Bagnes.

As far as photovoltaic panels are concerned, there's an idea of building a solar park. But for the moment, this idea is at the verification stage and there's no guarantee that this will happen.

Alpine photovoltaic potential is significant, with a well-balanced seasonal profile, where 55% of production is concentrated in the winter months. This characteristic offers an opportunity to harness solar energy in mountainous environments.

The theoretical annual yield is also notable, reaching 1,710 kWh per kWp. This means that each kilowatt-peak installed could potentially generate 1,710 kilowatt-hours over the course of a year. This solar energy production potential offers interesting prospects for sustainable use.

A concrete example of this potential is the Gondosolar project. It demonstrates how a thoughtful approach to solar energy in an alpine environment can generate positive results. The project offers a model for exploiting solar potential in mountainous regions, thus contributing to an energy transition.

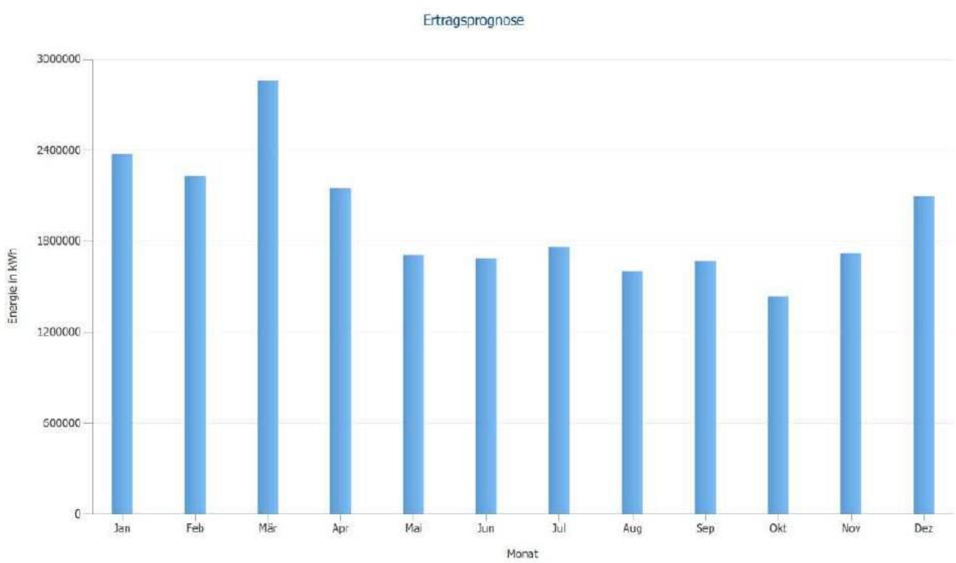


Abbildung 23: Durchschnittliche Monatsproduktionen Gondosolar, bifazial, 90 Grad, 2100 m.ü.M.

Of course, the share of private solar panels will increase in the years to come, but we are not in a position to predict this progression with any accuracy. We can envisage a further increase of 50% by 2030.

DECARBONIZATION AND LOCAL IMPACT

The primary significant impact of hydrogen implementation is the decarbonization of the energy system. In the pilot area of Val de Bagnes, we are specifically focusing on public transportation and ski resort snow groomers. Public transportation accounts for approximately 360 tons of CO2 emissions annually, while snow groomers contribute 1807 tons of CO2 emissions per year.

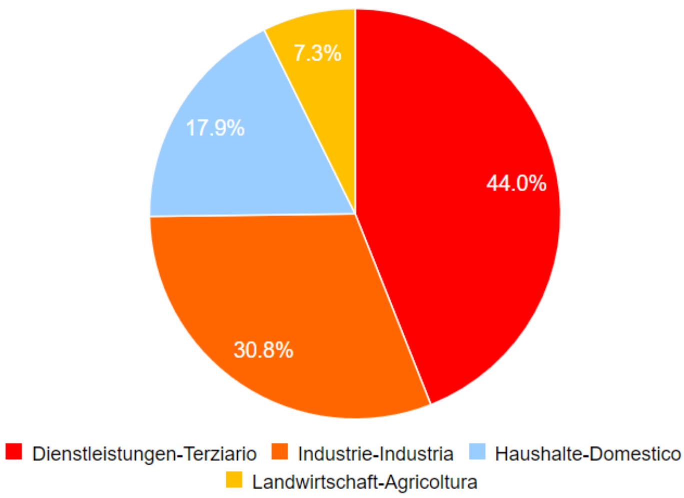
A second major impact of a local hydrogen ecosystem is the production and consumption of hydrogen on a local scale, replacing the import of fossil fuels. This approach keeps financial flows within the valley, while establishing a circular economy that retains value locally, providing substantial benefits to society as a whole. When considering fuel solely for transportation, the amount that could be retained in the local economy is €165,330 for public transport and €820,000 for refuelling snow groomers.

Trentino Alto Adige – Agenzia per l'Energia Alto Adige - CasaClima

CURRENT KEY ENERGY FLOWS

In South Tyrol, there is not a significant industrial presence that readily lends itself to direct hydrogen utilization. Rather, the economic structure of the territory sees a predominance of SMEs, also with a strong prevalence of the tertiary sector (which accounts for 44% of energy consumption), and in particular the tourism sector.

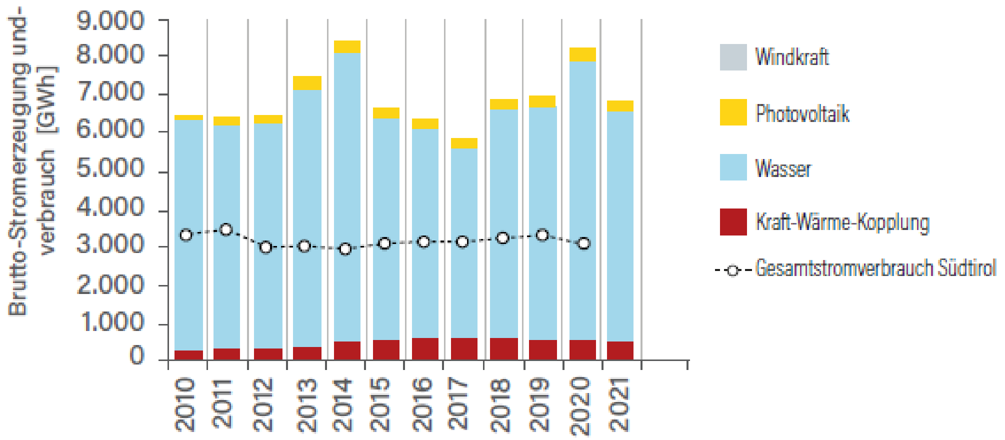
Fig. 4: Energy consumption by sector in the territory



Source: https://umwelt.provinz.bz.it/energie/energiebilanz-suedtirol.asp

As mentioned above, there is a surplus of green electricity in the territory, compared to local consumption (dotted line). Therefore, as an isolated entity, the territory would in principle be very well positioned for the large scale production of green hydrogen.

Fig. 5: Gross electricity production by source and consumption (dotted line)

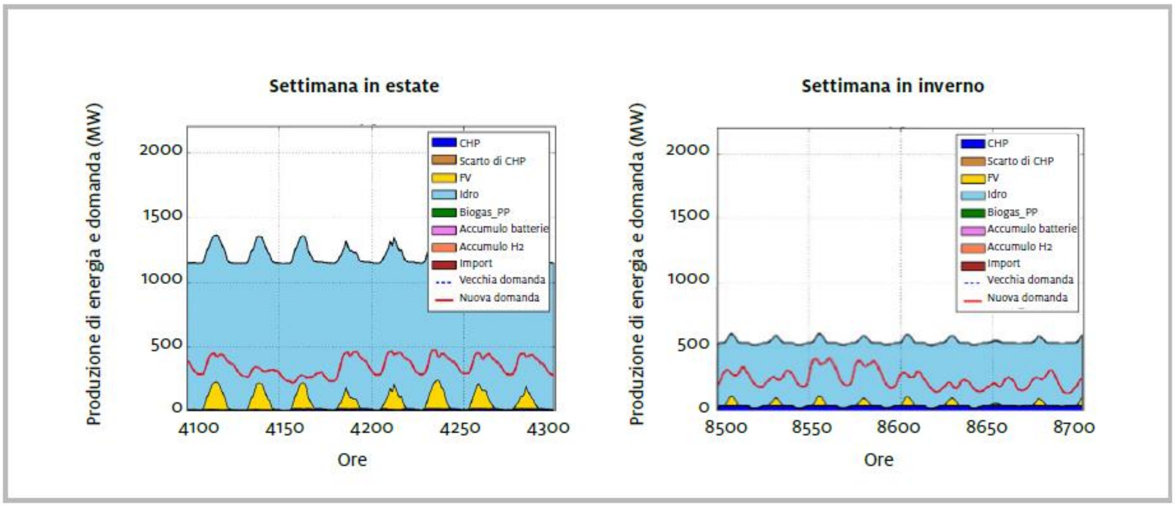


Source: Klimaplan Südtirol 2040

Current hydrogen initiatives are mostly focused on the production of green hydrogen from additional sources for utilization in the SASA fleet of public transport buses, in a closed loop. For the purpose of the AMETHySТ pilot, we are looking at stationary use of hydrogen for power and heating/cooling, where production and consumption of green hydrogen takes place on site. Hence, there is not a direct connection to any other hydrogen initiative in the territory. However, potential synergies might emerge in the future, for example regarding tourist transport using fuel cell buses.

As a general rule in the territory, electricity production from hydropower and also from PV is considerably lower in the dry winter months. This is the time when there is a higher import of electricity from neighbouring regions and other energy sources. <u>It is here that hydrogen as an energy vector for stationary use can unfold its full potential for seasonal energy storage</u>.

Fig. 6: One summer and one winter week of production in South Tyrol (2015 as baseline)



Source: EURAC - Scenari per l'Alto Adige verso la neutralità climatica

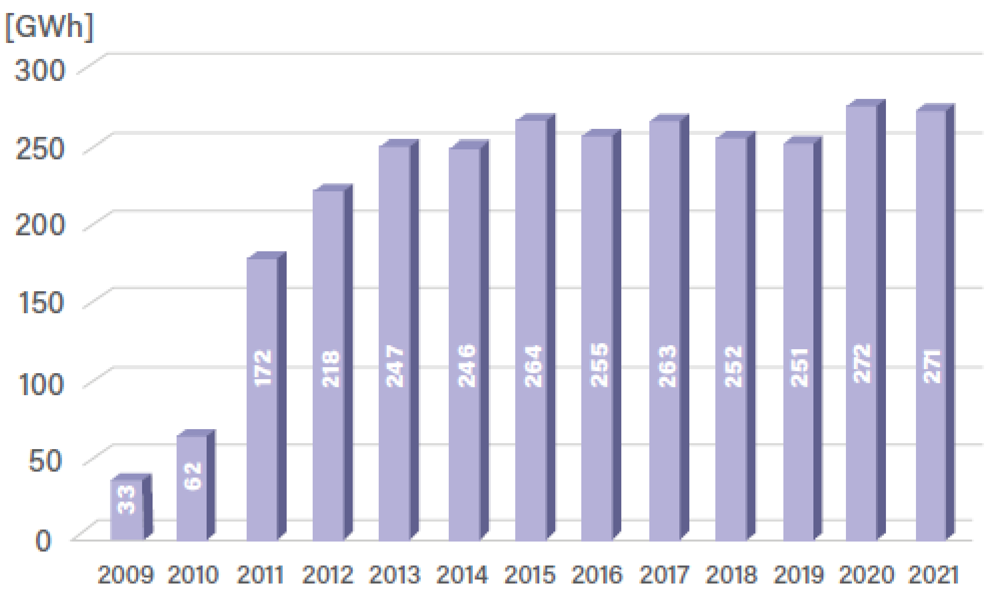
RES PRODUCTION POTENTIAL

The potential for hydrogen production has not been quantified yet. If adverse impacts on the national energy mix are to be avoided, hydrogen can only come from additional green electricity.

The potential for additional PV plants is calculated to be in the range of 1,500 – 1,800 GWh per year, across the province of Bolzano, taking into account installation on facades, roofs, transport infrastructure. Different scenarios forecast an additional installation between 7 and 65 MW of photovoltaic capacity up until 2050 (Source: EURAC - Il potenziale fotovoltaico dell'Alto Adige).

There are, as of 2022, 54 energy cooperatives in the province. They all could, in principle, utilize surplus electricity for hydrogen production.

Fig. 7: Electricity production from PV in the territory



Source: Klimaplan Südtirol 2040

DECARBONIZATION AND LOCAL IMPACT

The decarbonisation potential and local impact, as well as the economic implications of the transformation, are going to be the object of the pilot analysis and cannot be quantified at this time. The final objective shall be to assess the potential role of hydrogen, and related costs, in reaching maximum energy autonomy in stationary use.

4.HYDROGEN PRODUCTION AND USE POTENTIAL

Auvergne-Rhône-Alpes

Mountain regions have a special role to play in the energy transition:

- Their sensitivity to climate change
- Their resources
- The geographical configuration of isolated territories: a key role in the development of disconnected, autonomous energy solutions and efficient storage devices.

A number of potential applications for hydrogen have been identified:

a mountain ecosystem	what hydrogen can bring
ski areas (snowgroomers, tourist mobility, etc)	Zero emission mobility
Living territories (home to work, logistics, isolated homes, etc)	Storage, conversion, resistance to cold and uneven
Valley (international traffic flows, industries, etc)	Decarbonize industry
RES production (hydroelectricity, DHC, etc)	different production types
climate change impacts	eco-friendly

The primary end-user could be the ski resorts, particularly Tignes, Courchevel, Miribel and Val Thorens, especially for transporting tourists and snow groomers. The main consumption of fossil fuels is linked to the operation of the resorts, particularly the snow groomers, but to a lesser extent, and other snow vehicles. But above all, the carbon impact is caused by the flow of tourists, mainly during the winter season.

Vehicle use seems to represent an interesting potential for valley-station transport, regular public transport with daily buses and construction and public works vehicles, as well as for the transport of goods to and from stations.

As far as industry is concerned, according to the analysis of greenhouse gas emissions, industry has a major impact. A valley-wide approach therefore seems highly relevant, and would enable us to work on a stable and controllable need for hydrogen and to build shared infrastructures.

The pilot area identified therefore appears to be a relevant perimeter. It represents a potential for multiple uses and different links in the chain, enabling a global ecosystemic approach.

Friuli Venezia Giulia

Regarding the potential implementations of hydrogen use, several possibilities have been identified. In the following table they have been ranked by complexity, cost, environmental and social impact.

- **Last mile touristic transport**: it could be foreseen, during weekends and holidays, buses leaving from Tolmezzo (the main town of the area) or even just departing from Sutrio to cover the last kilometres and limit the access of private cars to the mountain.

- **Regular public transport**: TPL runs the regular public transport service of the region. Starting from the local valley transport (from Paluzza to Tolmezzo), the use of hydrogen buses could be expanded to the entire Carnia area.

- **Snow groomers**: hydrogen snow groomers have already been launched on the market. Turning these vehicles into hydrogen fuelled ones could make the Zoncolan ski resort the first carbon neutral ski resort in the Alps.

- **Forestry & mining vehicles**: companies operating in forestry and mining have available data on fuel consumption and working hours. Thanks to this information it could be easier to implement hydrogen from a technical point of view.

- **Private cars/trucks**: a refuelling station located in a strategic point of the valley could help the diffusion of hydrogen mobility.

- **Remote generation**: it could be foreseen for mountain huts or alpine pastures to install small hydrogen generation/cogeneration units and refill their low-pressure tanks, which reduces risks and costs.

	COMPLEXITY	COSTS	ENVIRONMENTAL IMPACT	SOCIAL IMPACT
LAST MILE TOURISTIC TRANSPORT	2	3	2	3
SNOWGROOMERS	2	5	3	4
YEAR-ROUND REGULAR PUBLIC TRANSPORT	2	4	3	4
FORESTRY & MINING	2	5	3	1
PRIVATE TRANSPORT	2	2	4	4
REMOTE AREAS APPLICATIONS	2	2	1	1

The AMETHyST pilot concept, that will ideally kickstart the hydrogen activities in the mountain areas of Friuli, consists of utilizing the excess energy produced by SECAB from spring to autumn to produce green hydrogen locally. SECAB's hydropower plants in fact have a variable production throughout the year, depending on precipitations and on the amount of accumulated snow in the mountains that melts during spring. During winter the water flow decreases, sometimes reaching no flow conditions because of freezing temperatures, and SECAB needs to buy electricity from the national grid to supply its clients. During the rest of the year, SECAB production exceeds the demand and SECAB sells it to the national grid. By producing green hydrogen locally, besides increasing the value of this excess green energy for SECAB, the opportunity of developing a local supply chain (with connected economic development) and decarbonizing the local economy arise.

The first final user of this local supply chain could be the local ski resort on mount Zoncolan. The ski resort is already supplied by 100% renewable energy from SECAB for what it concerns the lift and snow farming consumption. The main consumption of fossil fuels is therefore related to snowgroomers and other snow vehicles. By decarbonizing the snowgroomers fleet the resort could become the first carbon-free ski resort in the Alps, gaining great visibility and marketing opportunities.

Second, since the energy excess is relevant and snowgroomers only operate for four months, another more-stable end uses should be selected. The most logic expansion of the project is public transport, either for last-mile touristic transport (but this is still concentrated during winter) or regular public transport with daily buses that could, at a first stage, refill in the area. Further looking in the future the refill station could be expanded for private light and heavy vehicles.

Trentino Alto Adige – Fondazione Bruno Kessler

For the Madonna di Campiglio ski resort, the following potential end-uses for hydrogen were considered:

- Fuel cell or H2 combustion engine systems:
  - Stationary fuel cells for electricity production for snow production and ski lifts operation and other electricity consumption centers.
  - Replacing the diesel-powered snow groomers with hydrogen fuel cell or hydrogen internal combustion engine (ICE) counterparts.
  - Hydrogen fuel cell electric vehicles for private mobility or snow mobiles.
  - Small scale cogeneration fuel cell systems for heat and power generation (replacing, in particular, the oil fuel demand for heating).
- H2 boilers for space heating in the district facilities (e.g., offices).

To exploit the seasonality of the energy consumption of the resort, a large-scale storage facility should also be considered.

Table 11 reports the results of a qualitative approach to the ranking of the abovementioned hydrogen end-use applications. Complexity and costs represent the technical and economic effort, respectively, that is necessary to implement the specific H2 solution. Environmental and social impacts represent the benefits obtainable from them. The scale used runs from 0 to 5, and in the case of complexity and costs, they represent a low and high effort, respectively. The opposite is true for the environmental and social impact, so 5 represents a highly beneficial (positive) impact.

In order to assign values to each effort or benefit category, specific features were considered:

- Complexity:
  - Installation and use of specific H2 solution in Alpine area (large volumes/surface area occupied, permitting complexity, safety issues)
  - Maintenance (frequency, duration)
- Costs
  - Capital costs (Capex)
  - Operating costs (Opex)
- Environmental impact
  - Direct emissions and air quality
  - Indirect emissions
- Social impact
  - Promotion of pilot territory as a “green” business
  - Jobs creation

A thorough analysis of the environmental impact should consider not only direct and indirect emissions reduction, but also other factors, such as land use, resources (water, raw materials) use, visual impact, and so on. In order to do this, a detailed analysis of each implemented technology would be needed, but it is out of the scope of this study.

It is to note that both the environmental and social impact rankings used hereby take into account the substitution of the current implemented technology by the single hydrogen solution. For example, a hydrogen refueling station would be taking the place of a conventional refueling station (or alternatively, adding onto an existing one). Therefore, the environmental impact (for example) is neither improved nor worsened and set to zero.

Additionally, it is important to note that the emissions reductions from individual hydrogen solutions are measured against the emissions from a single unit of the conventional energy they replace. Take the stationary fuel cell (SFC) as an example: it generates carbon-free electricity which substitutes electricity from the grid. This grid electricity is derived from a mix of energy sources, including both renewable and traditional sources. Therefore, the emission reduction credited to the SFC might be less than that of, say, a fuel cell electric vehicle (FCEV) that substitutes a fossil fuel vehicle - whether it's a snow groomer or a passenger car. This is because the FCEV replaces entirely non-renewable diesel fuel. However, the overall decarbonization potential of SFC is larger than that of FCEVs if the whole ski resort is considered (see *Table 9*), due to the much higher electricity demand (*Table 3*) compared to the fossil fuels consumption (*Table 5*).

Table 11 – Potential positive and negative impact of hydrogen for various end-uses in the pilot territory. Complexity and costs are intended as effort to implement H2 solutions, while environmental and social impact are intended as potential benefits.

End-use	Technology	Efforts		Benefits	
		Complexity	Costs	Environmental impact	Social impact
Electricity generator for ski-lifts, snow production, other (e.g., electric heating)	Fuel cell	3	4	3	3
Snow-groomers	Fuel cell/ICE	3	3	4	3
Private mobility (light-duty vehicles)	Fuel cell/ICE	2	3	4	3
Residential heating	H2 boiler	1	3	3	2
Seasonal storage*	H2 liquid/gaseous storage	4	5	0	2
Hydrogen refueling station (HRS)	-	4	4	0	3

* Seasonal storage is not truly an end-use application, but it is needed if PV is used (surplus electricity in summer season, peak consumptions in winter season).

Trentino Alto Adige – Autonomous Province of Trento

As mentioned in the previous chapters, one of the solutions to implement hydrogen use in the territory may be blending it into the natural gas network. Other sectors for implementing hydrogen can be mobility and use at industrial production sites. In the latter case, it is worth mentioning the launch of a project involving the production of hydrogen through electrolysis powered by a new photovoltaic field, later used at neighbouring companies for their own production processes. This intervention was also possible thanks to public financing of the capital cost of the photovoltaic plant and electrolyser. There is in fact a low propensity to invest on the part of companies in the area, mainly due to high capex and opex.

The indication coming from the world of research and development (universities, research foundations and specialised companies) is that the technology supporting the realisation of hydrogen is for the most part mature and ready from an industrial point of view to support end-user investments, while neither the demand nor the opportunity for local production of green hydrogen is lacking and not easily identifiable.

The impact (in the sense of a negative impact) that may result from the implementation of hydrogen in the different sectors envisaged in the 2021-2030 PEAP and in the proposed pilot, which will have the characteristics of replicability and scalability across the territory, is estimated below.

	COMPLEXITY	COSTS	ENVIRONMENTAL IMPACT	SOCIAL IMPACT
BLENDING NATURAL GAS NETWORK	3	3	2	2
MOBILITA'	4	4	2	3
PILOT	4 / 5	3 / 5	2	2 / 4

Different degrees of impact have been included for the pilot, depending on the case study that can be implemented. As will be seen below, in fact, the pilot considers three case studies, two of which have a very high level of complexity (new network or modification/integration of existing network) while the third presents a lower level of complexity.

The pilot project identified by the Autonomous Province of Trento to support the decarbonisation of Alpine territories in the framework of Amethyst will be a feasibility study on the implementation of green or renewable hydrogen as an energy vector in an integrated production and distribution system serving a non-methanised mountain tourist village.

The Trentino territory is characterised by the presence of vast areas not served by the methane transport and distribution network. Approximately one third of Trentino municipalities (66 out of a total of 166) are not connected to the natural gas network; these are mainly the Rendena and Giudicarie Esteriori areas and the upper Val di Non and Val di Sole, as well as other municipalities scattered throughout the territory. Part of these municipalities are instead served by a wood biomass district heating network. Most of these are located in mountainous areas where tourism is very important. At the altitudes where many of these villages are located, moreover, innovative technologies such as heat pumps are not particularly efficient. It was therefore thought to propose the implementation of hydrogen as an energy carrier to respond to the decarbonisation of civil heating.

This is the context for the planning of the extension of the existing network, included in the Provincial Environmental Energy Plan 2021-2030, which also dedicates a special chapter to the provision of blending methane gas with fluids produced from local renewable sources such as green hydrogen and biomethane.

Where it is not possible to envisage the expansion of the gas distribution network, the question arises of how to ensure that the provincial territory has a safe and resilient energy supply system for end users that is in line with the decarbonisation targets dictated by EU regulations. The issue is of particular importance in mountainous areas where the altitude does not favour the implementation of heat pump technology.

The case studies identified for the study are of 3 different types. The first involves the implementation of a new integrated system of production, storage and distribution to users. The second refers to the implementation of hydrogen where an islanded network already exists, fuelled by LPG or LNG. The third case study considers the presence of a biomass district heating system where hydrogen can be integrated instead of the fuel used as a backup for the system (e.g. diesel).

Tirol

Demo4grid – is installed 3,2 MW Alkaline Electrolyze – The main goal is to decarbonize the whole fleet of M-Preis by Hyzon Fuel Cell Trucks. (25 Trucks) – The first is already in use.

Zillertal Fuel cell Train and region, project on hold, financial proof ongoing, Main goal is to decarbonize the Zillertal – Train, a part of the public bus fleet, snow groomers and

Power2X – Jenbach – Project started. Up to 6 MW electrolysis for the Gas-engines of INNIO.

Power2X – Kufstein – Project ongoing, will start soon 2024. 5 MW electrolysis for Mobility, for Hydrogen injection into the natural gas grid and to use the waste heat for heating purposes.

H2Alpin – Project ongoing – Demonstration project for decarbonisation of Public-Busses and trucks for regional delivery.

	COMPLEXITY	COSTS	ENVIRONMENTAL IMPACT	SOCIAL IMPACT
LAST MILE TOURISTIC TRANSPORT	**2**	**3**	**3**	**4**
INDUSTRY LIKE INNIO OR PLANSEE	**2**	**3**	**5**	**4**
YEAR-ROUND REGULAR PUBLIC TRANSPORT	**2**	**4**	**4**	**4**

The **HyWest** project, which was selected for the pilot region Tyrol within the framework of the Amethyst programme, can achieve the following goals if successfully implemented:

Demo4grid => The hydrogen produced can be used in the Therese Mölk bakery and as fuel for the company's own fleet of trucks. Furthermore, MPREIS uses the waste heat from the electrolysis for its own production operations. The overall efficiency of the plant is over 90%. **HyTrain-Zillertal** => The replacement of the existing narrow-gauge Zillertal Railway with a fuel cell variant. Regional production of green hydrogen for the train, buses and container solutions. (Snow groomers)

Power2X-Jenbach => Production of green hydrogen from hydropower. This is used for Innio's combustion engines.

Power2X-Kufstein => Generation of green hydrogen from hydropower. Used for the hydrogen filling station in Kufstein for trucks, buses and cars. Feeding of approx. 10 % hydrogen into the existing natural gas grid.

H2Alpin => Development of procurement models for bus operators and truck operators for the provision of fuel cell vehicles.

Bavarian Oberland

Regarding the potential implementations of hydrogen use, several possibilities have been identified. In the following table they have been ranked by complexity, cost, environmental and social impact.

- **Touristic transport**: A potential use-case for hydrogen in the region could be the implementation of hydrogen trains. In addition, hydrogen buses and taxis / shuttle could potentially serve as touristic transportation.

- **Regular public transport**: The region Oberland is connected to Munich, Rosenheim, Augsburg and Innsbruck via train. Connections from Munich to Schliersee, Tegernsee, Lenggries are not electrified yet and could potentially be run by hydrogen.

- **Snow groomers**: could potentially be used ski resorts in the Region Oberland. However, most of the ski resorts are below 2.500m altitude and therefore are exposed to the risk of decreasing ski tourism due to less predictable winter seasons as an effect of climate change.

- **Private cars/trucks**: a refuelling station located in strategic points of the region Oberland could help the diffusion of hydrogen mobility.

- **Remote generation**: it could be foreseen for mountain huts or alpine pastures to install small hydrogen generation/cogeneration units and refill their low-pressure tanks, which reduces risks and costs.

- **Hydrogen generation in connection with sewage treatment plants**: a potential pilot in the region Oberland demonstrates the possibility to generate hydrogen from sewage.

	COMPLEXITY	COSTS	ENVIRONMENTAL IMPACT	SOCIAL IMPACT
Touristic transport	**5**	**5**	**3**	**3**
Regular public transport	**5**	**5**	**5**	**5**
Snow groomers	**2**	**4**	**1**	**1**
Private cars/trucks	**4**	**5**	**5**	**5**
Remote generation	**2**	**2**	**1**	**1**
Hydrogen generation in connection with sewage treatment plants	**3**	**3**	**4**	**3**

- **Significant reduction in CO2 emissions** using PV electricity and electricity-based heat generation, as well as charging electric vehicles
- **Establishing day/night self-sufficiency** (independence) through local battery storage and thereby reducing the need for grid power
- **Increased security** through e.g. emergency power capability (black start capability)

This project is co-financed by the European Regional Development Fund
through the Interreg Alpine Space programme

- **Fast charging of e-cars** through high charging power at home and relief of the public power grid
- Further increase in self-sufficiency using **hydrogen as long-term/seasonal storage** and reconversion via fuel cells
- **Reduction of the overall energy consumption** (purchased electricity) using an EMS for intelligent and digital data acquisition and control, as well as enabling sector coupling

Executive Summary

Our goal: Technology development and demonstration of a hydrogen-based energy supply for existing buildings

The “Wasserstoffhaus Irschenhausen” shows the change from an analogue energy supply based on fossil fuels to a digital, networked energy supply based on renewable energies and hydrogen.

The energy is generated locally in the house via a photovoltaic system and the excess electricity is used to produce hydrogen by an electrolyser and stored in the seasonal storage tank at the house.

The hydrogen can later be converted back into electricity using a fuel cell, thus supplying the house at night and in winter. Innovative technology for the direct thermal use of hydrogen is used to heat the house.

We test the interaction of different technologies from the electricity, heat and mobility sector (sector coupling) via an intelligent, digital overall control of PV system, storage, electrolyser, fuel cell and heating system including data acquisition and data analysis.

The “Wasserstoffhaus Irschenhausen” offers ideal conditions for a lighthouse project of building-based "sector coupling" on H2 basis. What is special about this project is the use of this forward-looking technology in an old building. The resulting knowledge and results of H2 use can therefore be applied in numerous conventional buildings and transferred to them.

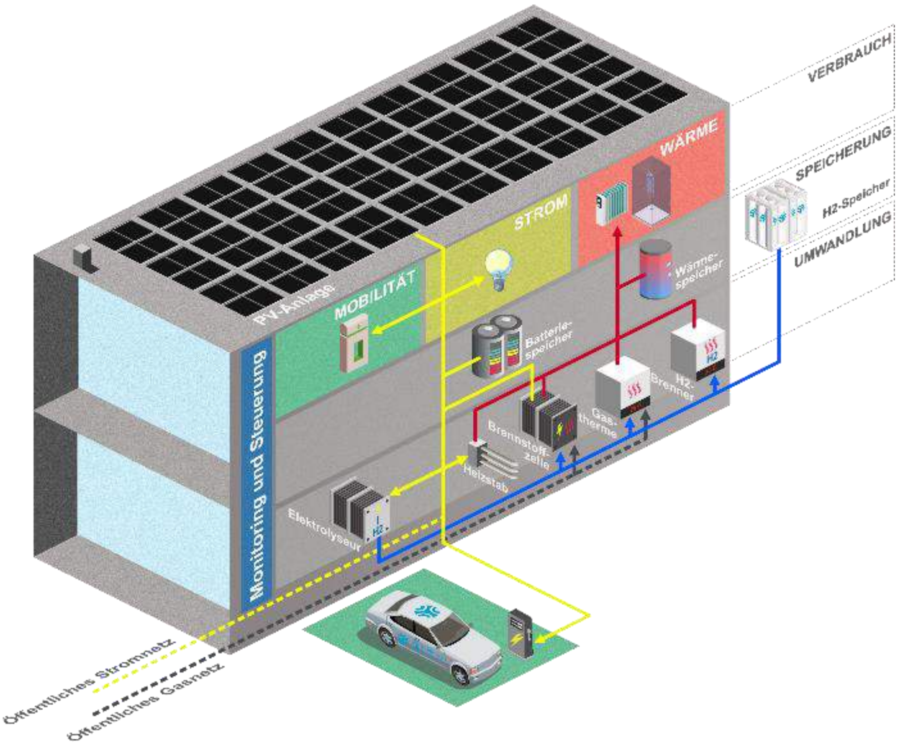


Fig. 1 - Sector coupling and smart networking in the “Hydrogen House Irschenhausen”

During the conversion of the existing building, the following priorities were set:

- Transformation of an existing building from an analog energy supply based on fossil fuels to a digital, networked energy supply based on renewable energies
- Demonstration of the latest H2-ready technologies for sustainable energy supply in the building sector
- Testing the interaction of different technologies from the electricity, heat and mobility sector (sector coupling)
- Use of an intelligent, digital overall data acquisition and control (EMS) of PV system, storage, heat pump, electrolyser and fuel cell Use of an electrolyser to generate H2 with PV power
- Derivation of ESG measures for the renovation of existing buildings (roadmap) for transfer to the housing industry, industrial buildings and energy cooperatives

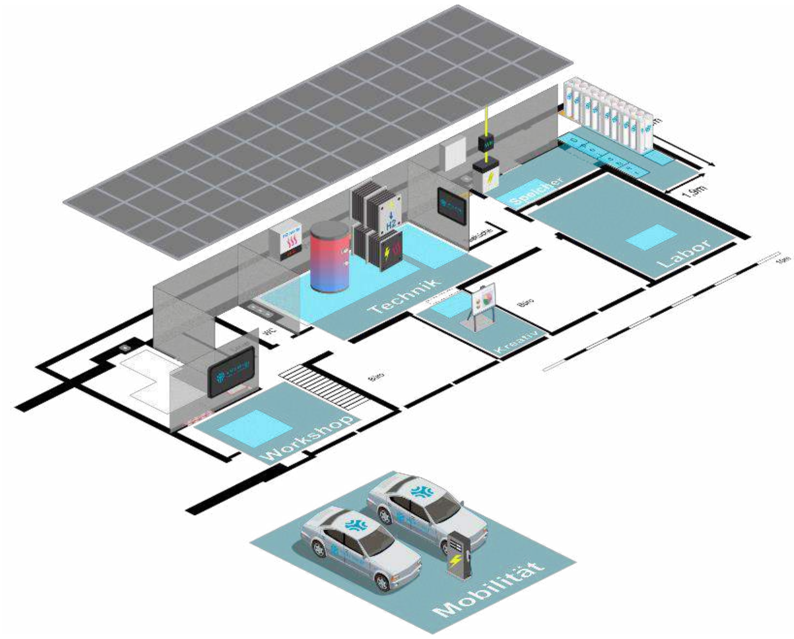


Abb. 2 – concept Wasserstoffhaus Irschenhausen

Wasserstoffhaus – Basic Facts:

Base data

Year of construction:	1962
Living and usable area:	320 qm
Roof area:	230 qm

Energy production

This project is co-financed by the European Regional Development Fund
through the Interreg Alpine Space programme

Photovoltaic system:	30 kWp Leistung
H2 production	
Elektrolyseur:	4,8 kW total approx. 1 kg H2/day (=33,33 kWh)
Energy storage	
Battery storage:	14 kWh
H2 storage:	50 kWh at 35 bars 430 kWh at 300 bars

Canton of Valais

We have identified a wide range of potential hydrogen integration options. In the table below, we have classified these possibilities according to their degree of complexity, cost, and environmental and social impact.

- **Public Transport**: An option could involve introducing hydrogen on the four bus lines in Val de Bagnes, particularly if we are able to produce hydrogen near the bus depot.
- **Snow Groomers**: Hydrogen-powered snow groomer models are already available on the market. Adopting these vehicles could position Verbier ski resort as a pioneer, becoming the first carbon-neutral ski resort in the Alps.
- **Trucks**: The largest road transport company in the valley would also be interested in hydrogen usage, especially if a production zone were optimally situated.
- **Energy Regulation**: The concept of using hydrogen as a storage medium to regulate energy demand in Val de Bagnes has also been considered.
- **Private Vehicles and Tractors**: Establishing a strategically located hydrogen refueling station in the valley could encourage the adoption of hydrogen mobility.
- **Remote Production**: A potential approach could include equipping mountain refuges or alpine pastures with small hydrogen production/cogeneration units, enabling the filling of low-pressure tanks, thus reducing risks and costs.

	COMPLEXITY	COSTS	ENVIRONMENTAL IMPACT	SOCIAL IMPACT
Public Transport	2	4	3	5
SNOWGROOMERS	2	4	4	5
Trucks	2	2	3	3
Energy Regulation	2	5	1	1
Private Vehicles and Tractors	2	2	4	3
Remote Production	2	2	1	1

Our demonstration case aims to validate and test the use of hydrogen as a decarbonization solution specifically for the Verbier ski resort, with a particular focus on its application in the tourism and mobility sector. More precisely, we are focusing on hydrogen applications for snow groomers and buses.

Today, we have confirmed the commitment of the municipality and the ski resort to explore this path. Our next step is to conduct a comprehensive simulation of the potential benefits of hydrogen, precisely assess the required investment costs, analyze expected returns, and examine infrastructure needs and corresponding storage solutions.

Through this in-depth analysis, we will be able to present concrete results to the municipality, which they can anticipate from the use of hydrogen. Our ultimate goal is to secure the necessary budget to establish a dedicated test zone for hydrogen production experimentation, with the aim of supplying it to snow groomers. To ensure the efficiency of our progress in this project, access to accurate data is imperative, and we rely on the project Amethyst to provide us with this crucial information.

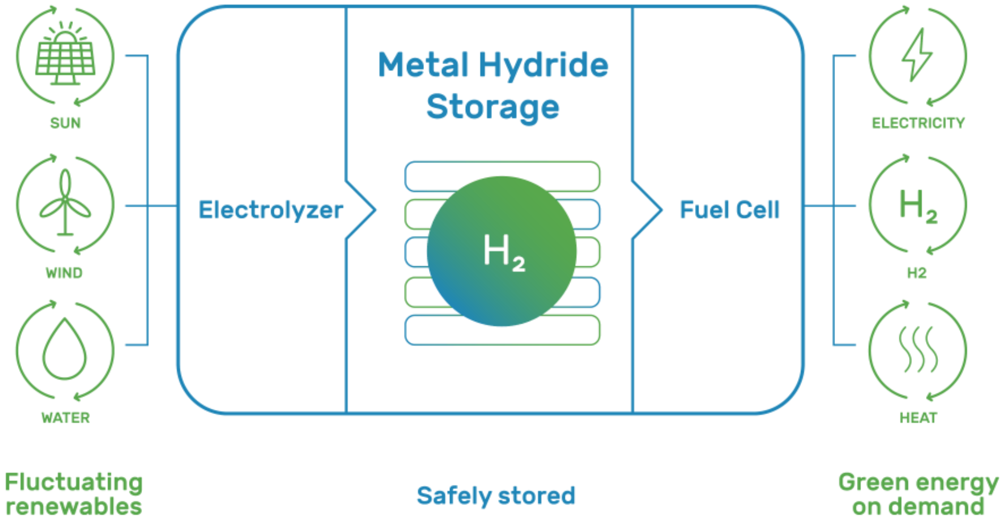
Trentino Alto Adige – Agenzia per l'Energia Alto Adige - CasaClima

The hydrogen implementation in the pilot territory will be the Arieshof tourist accommodation.

Source: arieshof.com

The Arieshof is a tourist accommodation with a strong focus on sustainability, in ST. Lorenzen, a mountain area near Brunico, in the Province of Bolzano. In order to achieve maximum possible energy autonomy and reduce its carbon footprint, it uses a combination of photovoltaic electricity generation, a wood chips cogeneration plant, and an electrolyzer and fuel cell to store and utilize hydrogen according to the energy demand. Hydrogen can be stored in innovative metal-hydride batteries. The Arieshof is therefore a case study for the stationary utilization of hydrogen as one element of a smart, interconnected energy system.

Fig. 8: Role of hydrogen in the pilot



Source: GKN Hydrogen

The evaluation of this pilot case will provide insights into how touristic accommodation services, with their strong seasonal energy fluctuations and wide range of guest services, can benefit from the integration of hydrogen into their energy supply systems. Recommendations for the integration of Hydrogen-Powered Vehicles into the energy concept will be given.

It's important to note that the adoption of green hydrogen in similar structures will depend on factors such as the availability of renewable energy sources, local regulations, and the initial investment required for hydrogen infrastructure. Nevertheless, as the hydrogen industry continues to grow and become more cost-effective, hotels have the potential to play a role in promoting sustainability and reducing their environmental impact through the use of green hydrogen.