POLITECNICO DI TORINO
Repository ISTITUZIONALE

ESPON InTerAlp [Interface territories across the Alpine region] - Final report

Original
ESPON InTerAlp [Interface territories across the Alpine region] - Final report / Chilla, T., Bertram, D., Cotella, G., Berisha, E., Bragaglia, F., Casavola, D., Rivolin, U., Puntillo, E., Shaker, Y., VITALE BROVARONE, E., Dallhammer, E., Gaugitsch, R., Mollay, U., Mansutti, S., Schirpke, U., Marot, N., Strauss-Gallmann, U., Roux, E., Wein, T., Günther, E., et al.. - ELETTRONICO. - (2024), pp. 1-92. [10.13140/RG.2.2.27146.79046]

Availability:
This version is available at: 11583/2997211 since: 2025-02-05T09:35:01Z

Publisher:

Published
DOI:10.13140/RG.2.2.27146.79046

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

25 November 2026

ESPON

Co-funded by the European Union
Interreg

TARGETED ANALYSIS

InTerAlp

Interface Territories across the Alpine region

Final report
November 2024

This targeted analysis is conducted within the framework of the ESPON 2030 Cooperation Programme, partly financed by the European Regional Development Fund.

The ESPON EGTC is the Single Beneficiary of the ESPON 2030 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.

This delivery does not necessarily reflect the opinions of members of the ESPON 2030 Monitoring Committee.

Coordination
Michaela Gensheimer (ESPON EGTC)

Technical Support
Martin Gauk (ESPON EGTC)

Lead authors
Tobias Chilla, Dominik Bertram – Friedrich-Alexander University Erlangen-Nürnberg
Giancarlo Cotella, Erblin Berisha, Francesca Bragaglia, Donato Casavola, Umberto Janin Rivolin, Erika Puntillo, Yahya Shaker, Elisabetta Vitale Brovarone – Politecnico di Torino
Erich Dallhammer, Roland Gaugitsch, Ursula Mollay, Sabrina Mansutti – ÖIR
Uta Schirpke – individual expert
Naja Marot – University of Ljubljana, Biotechnical Faculty
Ueli Strauss-Gallmann – strauss raumentwicklung
Emmanuel Roux – individual expert, University Grenoble Alps

Contributors
Theresa Wein, Elias Günther, Niklas Vogel – Friedrich-Alexander University Erlangen-Nürnberg

Steering Committee
Josiane Meier – Federal Ministry for Housing, Urban Development and Building (DE)
Tomaž Miklavčič – Ministry of Natural Resources and Spatial Planning (SI)
Cristina Pellegrino – Lombardy Region (IT)
Luisa Pedrazzini – Consultant, Istituto Nazionale di Urbanistica (IT)
Silvia Jost, Sébastien Rieben – Federal Office for Spatial Development ARE (CH)
Michael Roth – Federal Ministry for Agriculture, Forestry, Regions and Water Management (AT)
Sylvie Vigneron – Commissariat à l'aménagement, au développement et la protection du massif des Alpes (FR)

Information on ESPON and its projects can be found at www.espon.eu.
The website provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

© ESPON 2030

ISBN: 978-2-919816-91-0

Layout and graphic design by BGRAPHIC, Denmark

Printing, reproduction or quotation is authorised provided the source is acknowledged and a copy is forwarded to the ESPON EGTC in Luxembourg.

Contact: info@espon.eu

ESPON

Co-funded by the European Union
Interreg

TARGETED ANALYSIS //

InTerAlp

Interface Territories across the Alpine region

Final report

November 2024

Disclaimer

This document is a final report.

The information contained herein is subject to change and does not commit the ESPON EGTC and the countries participating in the ESPON 2030 Cooperation Programme.

The final version of the report will be published as soon as approved.

Table of contents

1 Introduction 8

2 Mapping interface territories across the Alpine region 10
2.1 Definition approach 10
2.2 Spatial typologies 14

3 Alpine interface territories as a specific geographic category 17
3.1 A new geography 17
3.1.1 The European Alps beyond Functional Urban Areas 17
3.1.2 The geographic specificity of mountain-lowland areas 18
3.1.3 The challenge of double-demand with half of space 20
3.2 Territories with sharp contrasts 24
3.2.1 Territories of environmental contrasts 24
3.2.2 Territories of socio-economic contrasts 28
3.3 Territories with a geographic funnel effect 34
3.3.1 Transalpine gateways and mobility funnels 34
3.3.2 Energy transit zones 39
3.4 Territories with common challenges and specific roles 43
3.4.1 Addressing cross-cutting issues of climate change 43
3.4.2 Hazard prevention areas 44
3.4.3 Tourist and recreation areas 47
3.4.4 Areas of water infrastructure 50
3.4.5 Agglomeration areas of hospitals and universities 53
3.4.6 Energy production patterns 55
3.5 Territories with no specific governance 59
3.5.1 Interface territories and Alpine multi-level governance 59
3.5.2 Spatial and sectoral governance and planning 60
3.5.3 Challenges and opportunities for Alpine interface territories from a governance perspective 65

4 Positioning the spatial category of interface territories 81

5 Summary: The geographical specificities of interface territories 84

6 Policy implications 86

7 List of annexes 88

8 References 89

Lists of maps, figures, tables and boxes

List of maps

Map 1 Interface territories across the Alpine region 13
Map 2 Spatial typologies of Alpine interface areas 15
Map 3 The Alpine region beyond Functional Urban Areas....17
Map 4 Degree of inclination in Alpine interface areas....20
Map 5 Degree of urbanisation....21
Map 6 Population development....22
Map 7 Naturalness....24
Map 8 Ecological connectivity....26
Map 9 Protected areas in municipal areas....27
Map 10 Landscape diversity....28
Map 11 Population density....29
Map 12 Water abstraction....30
Map 13 Average internet speed....32
Map 14 Total number of foreign direct investment projects (2003-2015)....33
Map 15 Rail and road transport infrastructure....34
Map 16 Intermodal transport....35
Map 17 Airport infrastructure....38
Map 18 Population within visual range of energy infrastructure....39
Map 19 Population in direct proximity to energy infrastructure....40
Map 20 Projected changes in surface temperature between 2021-2050 (in Celsius)....43
Map 21 Infrastructure in hazard zones....45
Map 22 Site-protecting forest....46
Map 23 Object-protecting forest....47
Map 24 Tourism hotspots....48
Map 25 Opportunities for nature-based recreation....49
Map 26 Accessibility of water-based recreation....50
Map 27 Water availability....51
Map 28 Location of hospitals....53
Map 29 University locations....54
Map 30 Plant capacities (MW), plant types and locations by NUTS 3 region....55
Map 31 Hydropower – plant types and capacities....57
Map 32 Wind energy potential (in MWh/km2) and wind park locations....58
Map 33 Interface territories, mountain and lowland areas....81

List of figures

Figure 1 The 'mountain-lowland' perspective: Turin and Grenoble/Rhône-Alpes as two examples for Alpine interface territories....8
Figure 2 Schematic of the definition of interface territories (A) and illustrative panorama from above Garmisch-Partenkirchen towards Munich (B)....11
Figure 3 Boxplot on visitation rates in mountain, interface and lowland areas across the Alpine region....23
Figure 4 Boxplot on naturalness in mountain, interface and lowland areas across the Alpine region....25
Figure 5 Boxplot on electricity demand in industry per capita for interface, mountain and lowland areas across the Alpine region....31
Figure 6 Multilevel institutional mapping of spatial governance and planning in the Alpine region....59
Figure 7 Summary assessment of spatial and sectoral governance in the Alpine region....62
Figure 8 Positioning of interface territories across the Alpine region....82

List of tables

Table 1 Spatial arguments for typology definition....14
Table 2 Spatial typologies of Alpine interface areas....16
Table 3 Degree of Alpine integratedness – Scoring system....61

List of boxes

Box 1 Mapshots of exemplary InTerAlp case regions....19
Box 2 Sectoral mapshots on 'mobility and transport' for exemplary InTerAlp case regions....37
Box 3 Sectoral mapshots on 'energy' for exemplary InTerAlp case regions....42
Box 4 Sectoral mapshot on 'water for an exemplary InTerAlp case region....52
Box 5 Territorial integrated plan (PITER) Alcotra Interreg....66
Box 6 Pan-Alpine potentials for spatial development in Alpine interface territories....67
Box 7 Federal Agglomeration Policy, Switzerland....68
Box 8 Future Mountains Programme, France....69
Box 9 Turin's Strategic Metropolitan Plan, Italy....71
Box 10 Verein Agglomeration Werdenberg-Liechtenstein....73
Box 11 Mayors' meetings, Germany....74
Box 12 Local Mobility Concepts, Austria....76
Box 13 Local Energy Concept, Slovenia....78
Box 14 River/Lake/Wetlands Contracts, Italy....80

1 Introduction

The Alpine region extends from the Mediterranean Sea in the southwest to the Danube plains in the northeast and is one of Europe's most complex and diverse territories with a series of geographic specificities.

The ESPON InTerAlp project aims at a better understanding of interface territories between the *peri-Alpine lowlands* and the *inner-Alpine highlands* (see Figure 1). By mapping patterns, flows and spatial development trends, this project wants to support the development of appropriate spatial governance and policy approaches.

Figure 1
The 'mountain-lowland' perspective: Turin and Grenoble/Rhône-Alpes as two examples for Alpine interface territories[1]





1 Photo above: View of the metropolitan area of Turin, with the mountain valleys in the background (Photo: Andrea Mucelli, CC BY-NC-SA 2.0, https://www.flickr.com/photos/bluestardrop/8296928890; Photo below: Air photo of the Presqu'île, Grenoble Metropolitan Area, North-West Territory (Photo: Agence d'urbanisme de la région grenobloise).

Alpine interface territories are a spatial category that has so far hardly been an object to any analytical reflections. While extensive knowledge exists for many spatial categories, including mountain, urban, rural and lake areas (e.g. ESPON Alps2050, ESPON LAKES, ESPON METRO, ESPON PROFECY), the spatial dynamics of the transition areas between inner and outer Alpine zones have yet to be subjected to systematic analysis. These regions are often perceived either as peripheral from a mountain perspective or as suburban from a core city perspective. Putting them at the focus of regional development and policy analyses is a novel approach.

Alpine interface territories link mountainous and inner-Alpine areas with pre-Alpine lowlands and, thus, are a very specific territorial type: Highly dynamic flows and interdependencies as well as controversial stakeholder interests meet in a rather limited spatial framework. Organizing sustainable spatial development in this geographical context is a challenge (Chilla & Streifeneder 2018). These challenges extend beyond administrative boundaries and require pan-Alpine strategies and cross-border instruments in spatial planning and development (e.g. in relation to ecological fragmentation, sharp socio-economic disparities and multi-level governance obstacles).

The ESPON InTerAlp project provides a systematic exploration of the specific spatial dynamics, challenges and opportunities associated with Alpine interface territories. The analysis addresses a number of key questions, including the definition and delineation of Alpine interface territories, the identification of common challenges and opportunities, and the review of governance frameworks and instruments for Alpine spatial planning and development.

The InTerAlp project contributes to a comprehensive understanding of the *functional* territorial development dynamics and flows that characterise the Alpine interface territories. In addition, the project analysed the types and quality of the spatial and sectoral *governance* and policy mechanisms that are currently in place. The project provides evidence-based *guidance* towards a more integrated, sustainable and inclusive development of the Alpine region, with particular reference to Alpine interface territories, for the benefit of both urban and rural areas in the Alpine context.

This final report contributes to the emerging Alpine Spatial Development Perspective (ASDP), initiated by the Alpine Convention Working Group on Spatial Planning and Sustainable Development (AC WGSPSD).[2] The ***ESPON InTerAlp Policy brief*** supports regional and national stakeholders across the Alpine region with new territorial evidence to address the specific challenges and opportunities of Alpine interface territories to facilitate integrated and sustainable spatial development.

[2] https://www.alpconv.org/fileadmin/user_upload/Organisation/TWB/SPSD/SPSD_WG_Mandate2023-2024_fin_en.pdf

2 Mapping interface territories across the Alpine region

2.1 Definition approach

Figure 2 shows a schematic of the general understanding of interface territories **(A)** and panorama from above Garmisch-Partenkirchen towards Munich **(B)** to illustrate the approach. Interface areas are a very specific type of territory, linking lowland areas with mountainous Alpine highlands. The definition and delineation has to go beyond existing administrative boundaries and capture the complex functional dynamics that transcend these boundaries.

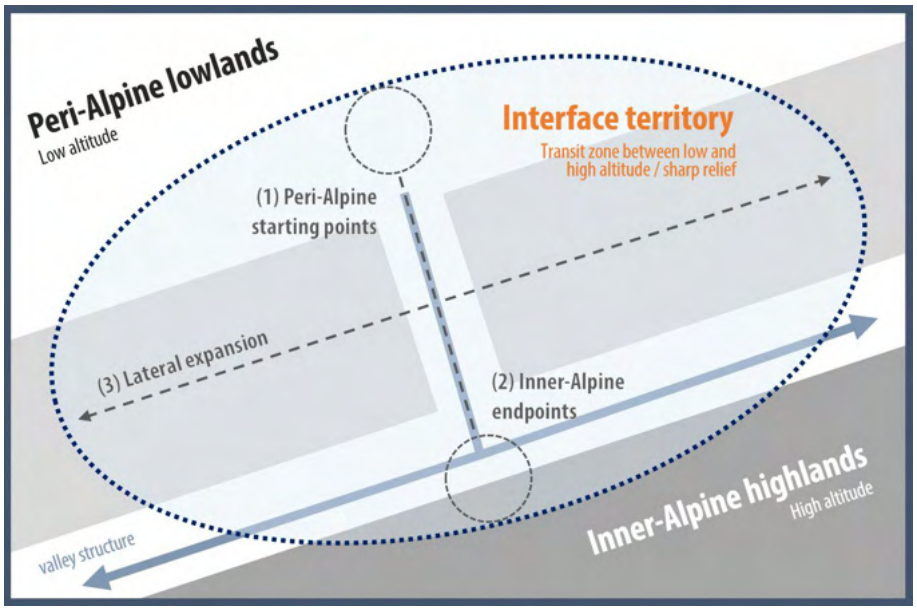
General criteria for the spatial concretisation include the following aspects:

- Interface territories link the peri-Alpine lowlands (low altitude) with the inner-Alpine highlands (high altitude). They involve several kinds of flows and relations, such as transport flows, demographic interlinkages and ecosystem-services.
- Interface territories represent the transition zone between low and high altitude, encompassing areas with sharp relief.
- The definition of interface territories is based on arguments of the Alpine settlement system, the transport infrastructure and morphological arguments such as topographical elevation and the river system. Spatial patterns in demographic organisation, environmental regionalisation and transport infrastructure provide the data framework (e.g. accessibility to central places, functional urban areas, water catchment areas, transport infrastructure, geomorphological arguments like altitude and slope).

The concrete methodological definition is based on (1) peri-Alpine 'starting points', (2) inner-Alpine 'endpoints' and (3) the lateral expansion of interface areas. The schematic illustrates the peri-Alpine starting points and inner-Alpine endpoints that have to be defined somewhere within or around the circles as well as the lateral expansion being delineated somewhere alongside the arrow extensions. The photo (B) demonstrates this logic as it is taken from the 'inner-Alpine endpoint' showing the 'peri-Alpine starting points' in the background and illustrating the lateral expansion on the left and right side of the picture. The photo shows the settlement system with the interface territory as well as the transport infrastructure, protecting forest alongside the steep mountain ranges and different aspects of land use within the valley structure (e.g. agriculture, industry, housing, etc.).

Figure 2
Schematic of the definition of interface territories (A) and illustrative panorama from above Garmisch-Partenkirchen towards Munich (B)

A)



B)



Accordingly, a technical definition to delineate comparable, methodologically standardised and fully reproducible interface areas throughout the Alps has been developed. This definition formulates precise and comprehensible variables that must be fulfilled in binary form (yes or no). The criteria describe whether a Local Administrative Unit (LAU) geometry can be assigned to an interface area within the perimeter of the EU strategy for the Alpine region (EUSALP). This written definition also includes the option to combine the arguments (and, or, if).

The elaboration of the definition was tested in several steps within the Geographical Information System and adapted several times after discussions in the project team. It is relevant to note, that from a methodological point of view, interface areas do not overlap. The resulting definition is the following:

(1) Peri-Alpine starting points

For the definition of *peri-Alpine starting points* of interface areas, functional urban areas, i.e. the large cities with a wide commuter catchment area, are the relevant starting elements. A mountain-lowland distance threshold as well as the infrastructure network leading towards the mountains result in operators defining the respective LAU geometries as peri-Alpine starting points:

- LAU geometries of FUA incl. commuter area (by OECD) with at least 25% overlap of a 15 kilometer distance buffer to topography with 1,000 meters above normal sea level, and/or
- LAU geometries that fully overlap with a highway/primary road/secondary road or main railway line in 15-minute isochrones of Alpine centers (see Chilla et al 2022) within a maximum distance buffer of 15 kilometers distance buffer to topography with 1,000 meters above sea level, and/or
- LAU geometries within 15 kilometers of topography at 1,000 meters above sea level between a metropolitan FUA (> 1 million inhabitants; according to OECD) and topography at 1,000 meters above sea level.

(2) Inner-Alpine endpoints

For the definition of the *inner-Alpine endpoints*, the argumentation is based on two elements. Firstly, the delineation is based on the concept of central valleys with high accessibility (based on the results of 9th Report on the State of the Alps, cf. Chilla et al. 2022). Secondly, the interface areas end where the relevant road network leading into the mountainous area is crossed by another road network already running through the mountains. This argument is of particular relevance for the delineation of interface areas and the functional analyses within the InTerAlp project. Without this argument, all transalpine transport corridors would be completely defined as interface areas and together with the lateral expansion arguments more than 70% of the high Alpine area (above 1000 meters altitude) would be defined as interface areas:

- Crossing of the main entering peri-Alpine first rank road by another inner-Alpine first rank road, and/or
- LAU geometries overlap with endpoints of accessibility corridors of Alpine centers with at least 5,000 inhabitants.

(3) Lateral expansion

For determining the *lateral expansion* of the interface areas, in particular water and energy supply arguments are considered. In order to cover relevant river systems, hydroelectric power plants as well as nature conservation and recreation areas, a lateral distance buffer is applied to the resulting interface corridor between the peri-Alpine starting and the inner-Alpine endpoints:

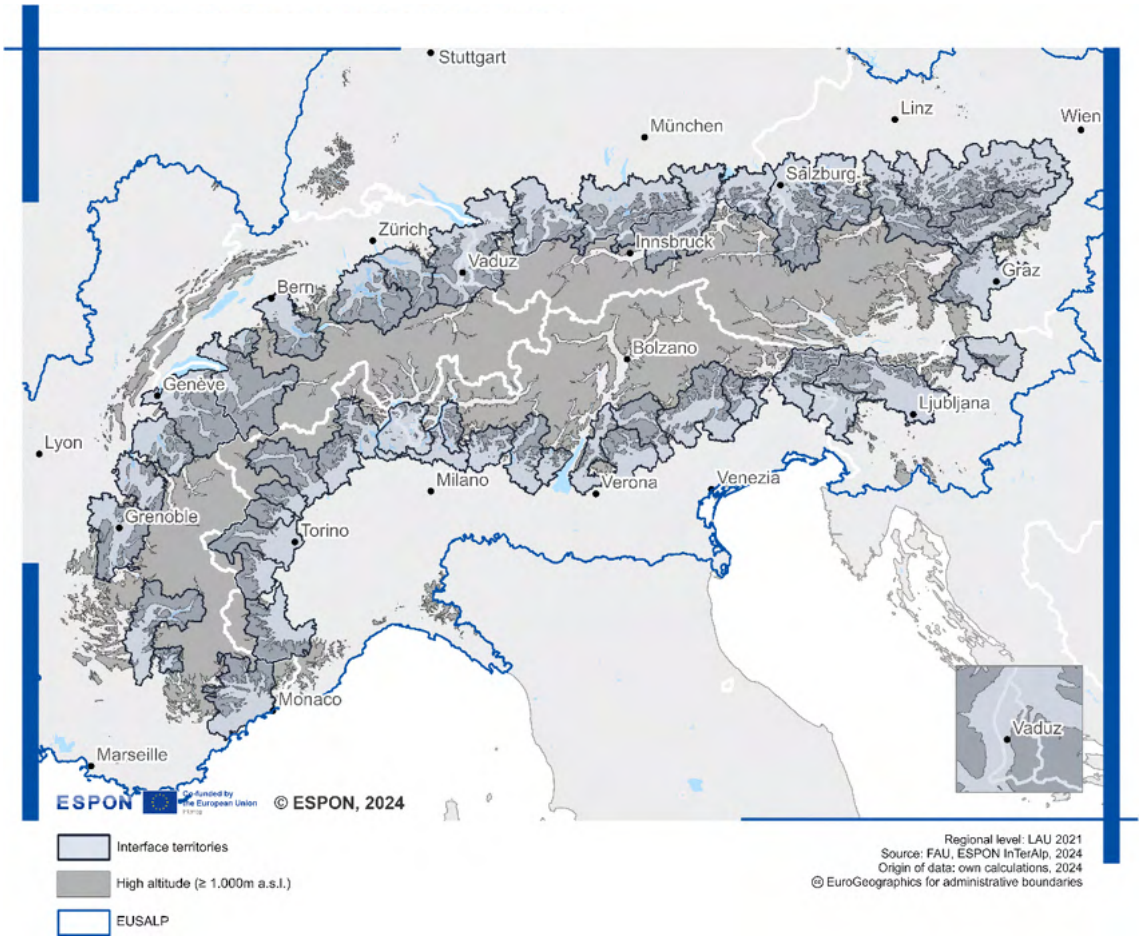
- LAU geometries with
  - at least 50% overlap of a 10 kilometer distance buffer to the corresponding interface accessibility corridor (result of defining start and end points), and
  - at least 50% overlap of topography with 1,000 meters above sea level, and/or
- LAU geometries overlapping the transport system (rail and road) and at least 25% overlap of 15 kilometer distance buffer to topography at 1,000 meters above normal sea level, if the peri-Alpine starting point is located in between of a metropolitan functional urban area (> 1 million inhabitants; according to OECD) and topography at 1,000 meters above normal sea level.

For more information on the concrete definition approach to define and delineate interface territories, please see ***Scientific annex I (Definition and delineation of Alpine interface territories)***. This annex provides a definition of peri-Alpine starting points, inner-Alpine endpoints and the lateral expansion that is replicable for other mountain areas. For more information on the metadata behind this research, please see ***Scientific annex II (Metadata overview)***.

Map 1 illustrates the delineation of Alpine interface territories. These interface areas are part of several overlapping governance frameworks (e.g. Alpine Convention, EUSALP). They are often addressed by different spatial planning systems and are characterised by flows and interdependencies that go beyond their perimeters.

The map shows that interface areas almost form a 'ring' around the morphological Alps even if this ring is not ‘closed’. Some areas do not have any interface areas like those south of Grenoble, north-east of Ljubljana or near Bern. These ‘interruptions’ can be explained by the spatial structure: The interface areas are based on characteristics of the Alpine settlement system, transport infrastructure and morphological aspects such as topographic relief and the river system. The natural barriers (steep topography and altitudes above 1,000 m) interrupt settlement and infrastructure links.

Map 1
Interface territories across the Alpine region



2.2 Spatial typologies

The definition and delineation of interface areas allows to a categorization based on overlapping of georeferenced open data and spatial arguments. This spatial classification includes the key elements of population density, links to Functional Urban Areas (FUAs), existing transport infrastructure, links to metropolitan cities and transnational relevance (see Table 1).[3]

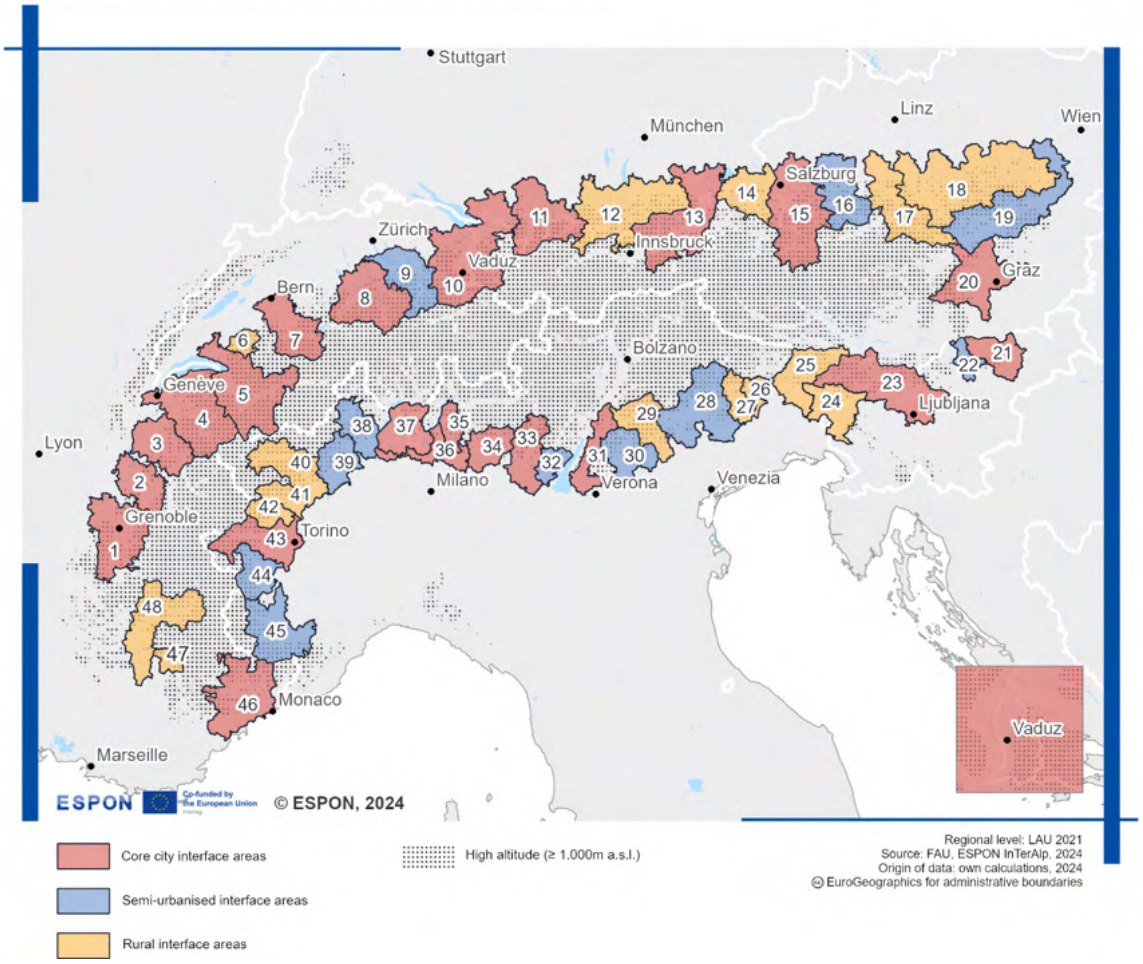
Table 1
Spatial arguments for typology definition

Spatial argument	Operationalisation	Data sources
Population	Degree of urbanisation: The degree of urbanisation is determined through a geostatistical analysis, which identifies whether interface areas are predominantly densely, intermediately, or thinly populated.	Eurostat, 2024
Links to Functional Urban Areas	Investigation of the interconnections between the transport infrastructure of the interface are and the adjacent Functional Urban Areas (overlaps with peri-Alpine core cities or the commuting area)	OECD, 2024
Existing transport infrastructure	Investigation of roads and railway transport infrastructure of interface areas (national motorways, primary routes, railroads)	INSPIRE Geoportal, 2024

The Alpine interface territories combine a high degree of spatial diversity, encompassing natural and vulnerable mountain areas and economically robust lowland regions with large urban centres. Map 2 illustrates the Alpine interface territories categorized in three Alpine specific spatial typologies. The numbered interface territories are assigned to specific designations. Table 2 shows the 48 Alpine interface territories classified in their spatial typologies and assigned to designations. We identify 22 core-city interface areas, 11 semi-urbanised interface areas and 15 rural interface areas across the Alpine region. It is striking that eleven interfaces are cross-border areas.

3 For more methodological information on the spatial typology approach and metadata, please see Scientific annex I (Definition and delineation of Alpine interface territories) and Scientific annex II (Metadata overview).

Map 2
Spatial typologies of Alpine interface areas



The red signature shows **core city interface areas**. Those territories have a densely populated core city within their perimeter (e.g. Turin, Ljubljana/Julian Alps, Grenoble/Rhône-Alpes region, Bern/Thun, Salzburg). They show a high gradient from densely populated to sparsely populated natural areas. They are predominantly densely populated (based on the Degree of Urbanisation (DEGURBA) classification at LAU level), have a comprehensive transport infrastructure (railway and primary roads) and are linked to at least one Functional Urban Area (mostly in the peri-Alpine lowlands).

The blue signature illustrates **semi-urbanised interface areas**. They bring together intermediately populated areas (e.g. Vienna/Mürz Valley, Zürich/Schwyz/Glarus, Vicenza/Schio). The semi-urbanized interface territories have a medium population density in more than half of their area. These areas mostly comprise a comprehensive transport infrastructure (railway and primary roads) and are linked by transport infrastructure to at least one Functional Urban Area (mostly in the peri-Alpine lowlands).

The yellow signature demonstrates **rural interface areas**. Those are rather sparsely populated (e.g. Sisteron/Gap, Aosta Valley, Liezen, Bulle, Bad Reichenhall/Berchtesgaden Alps, Gorizia/Nova Gorica). The rural interface territories are thinly populated and have a transport system based at least on primary roads (but not motorways). Whereas the core city and semi-urbanized interface territories are linked to large transport corridors, this is different for the rural interface territories.

Table 2
Spatial typologies of Alpine interface areas

Spatial typology	Interface areas
Core city interface areas	**(01)** Grenoble/Rhône-Alpes region (FR), **(02)** Chambéry (FR), **(03)** Annecy (FR), **(04)** Geneva/Annemasse/Thonon-les-Bains (CH/FR), **(05)** Rhone Valley (CH/FR), **(07)** Bern/Thun (CH), **(08)** Zug/Luzern (CH), **(10)** Alpine Rhine Valley (DE/CH/AT/LI), **(11)** Allgovia (DE/AT), **(13)** Rosenheim (DE/AT), **(15)** Salzburg (AT/DE), **(20)** Graz (AT), **(21)** Maribor (SI), **(23)** Ljubljana/Julian Alps (SI/AT), **(31)** Trento (IT), **(33)** Brescia (IT), **(34)** Bergamo (IT), **(35)** Lecco (IT), **(36)** Milano fringe (IT), **(37)** Lugano (CH/IT), **(43)** Turin (IT), **(46)** Nice (FR)
Semi-urbanised interface areas	**(09)** Zürich/Schwyz/Glarus (CH), **(16)** Gmunden (AT), **(19)** Vienna/Mürz Valley (AT), **(22)** Velenje (SI), **(28)** Belluno/Piave Valley (IT), **(30)** Vicenza/Schio (IT), **(32)** Gavardo/Salò (IT), **(38)** Domodossola (IT), **(39)** Biella/Borgomanero (IT), **(44)** Pinerolo (IT), **(45)** Cuneo/Cottian Alps (IT)
Rural interface areas	**(06)** Bulle (CH), **(12)** Munich fringe (DE/AT), **(14)** Bad Reichenhall/Berchtesgaden Alps (DE/AT), **(17)** Liezen (AT), **(18)** Vienna/Lower Austria fringe (AT), **(24)** Gorizia/Nova Gorica (IT/SI), **(25)** Udine (IT), **(26)** Maniago (IT), **(27)** Pordenone (IT), **(29)** Bassano del Grappa (IT), **(40)** Aosta Valley (IT), **(41)** Cuorgnè (IT), **(42)** Ciriè (IT), **(47)** Digne-les- Bains (FR), **(48)** Sisteron/Gap (FR)

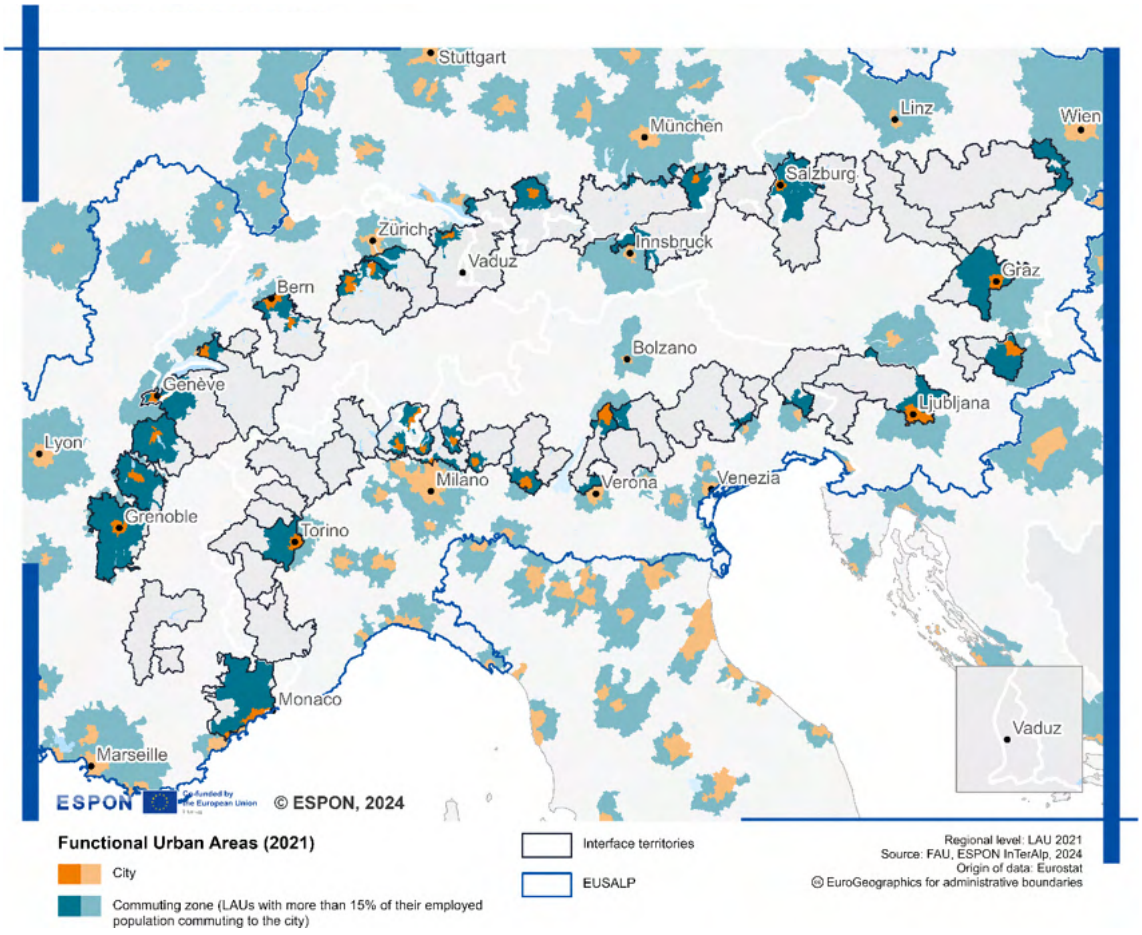
3 Alpine interface territories as a specific geographic category

3.1 A new geography

3.1.1 The European Alps beyond Functional Urban Areas

Interface territories can be described as a new form of geography illustrating the functional links between the Alpine high- and lowlands: Map 3 pictures both, the delineation of Alpine interface territories, as well as Functional Urban Areas across Europe. The map shows very little overlap between Alpine interface territories and existing Functional Urban Areas – which is striking, as the settlement system is the backbone of the interface definition.

Map 3
The Alpine region beyond Functional Urban Areas



From an Alpine perspective, this shows how important it is to capture 'roles of settlements beyond pure size' (Bertram & Chilla 2023a). To understand territorial dynamics in mountain contexts, it is necessary to consider also rather small places and fine scale dynamics. From a conceptual level, this argument shows the potential of linking urban and rural debates for the spaces *in between*. In doing so, the InTerAlp project builds on a series of projects that address territorial sub-categories (see, for example, ESPON Alps2050, ESPON LAKES, ESPON METRO, ESPON PROFECY).

Recognizing interface territories as a specific geography means to understand those areas as a relevant spatial category across the Alpine region alongside Functional Urban Areas (FUAs), high mountain areas, metropolitan regions and transnational corridors. This is a precondition for the development of effective policies. Focusing on the relevant flows, structures as well as potentials and challenges means to aim at a tailor-made strategy of territorial development.

3.1.2 The geographic specificity of mountain-lowland areas

The InTerAlp project zooms into a series of relevant case studies to examine specific interface areas in more detail. These cases provide an in-depth exploration of different regional settings. The case studies include the interface areas of the Alpine Rhine Valley, Turin, Munich-Tyrol, Ljubljana / Julian Alps, Grenoble/Rône-Alpes and Vienna / Lower Austrian Alps (for more information see the ***ESPON InTerAlp Case study portfolio***).

Box 1 shows two exemplary mapshots illustrating the spatial configuration of the interface areas of Turin and Grenoble/Rhône-Alpes. These conceptual and abstract representations highlight geographic specificities of interface areas:

- **'Role beyond size':** Most interface territories host towns and cities with a low population size carrying more prominent functions than their size suggests (Bertram & Chilla 2023b). This concerns economic decision making capacity, political institutions, and education facility. These centers close existing gaps in accessibility within their settlement system (e.g. Sargans, Kranjska Gora, Leoben, Crolle, Villard de Lans, Susa in the InTerAlp case regions).
- **'Mobility magnets'**: Most of the larger cities are located at the foot of mountains (e.g. Munich, Turin, Ljubljana) and generate high levels of individual mobility towards the mountains, mostly for recreational and tourism reasons. Vice versa, the metropolitan nodes attract daily commuting towards the larger employment centers. In addition, the core cities are logistics hubs and generate high freight traffic intensities, partly as transit transport across the Alps.
- **Valley-based structure**: The valley-based structure is an important element for spatial development. Supporting the functions of cities of different sizes along the axes enables an efficient organization in terms of transport modes, energy consumption and economic flows.
- **Funnel effects**: Across the Alpine region, interface territories are those areas where space is getting 'narrower'. Only a limited number of road and rail axes carry flows, often in rather small corridors. In this situation, interface territories function as 'entry points' and tend to be 'hot spots' of transport and mobility policy. This is particularly true when interface territories function as 'gateways' for transalpine traffic.
- **Polycentric strengths**: Some interface territories are central valleys organised in a polycentric way and jointly have the economic power of a large city (e.g. Alpine Rhine Valley, Inn valley, Susa valley, Grésivaudan valley). Central valleys have a well-developed road or/and rail transport infrastructure leading to peri-Alpine lowlands. Moreover, they have a strong impact on the hinterland, as a large number of employees lives in the side valleys and travels to work into the main valleys.

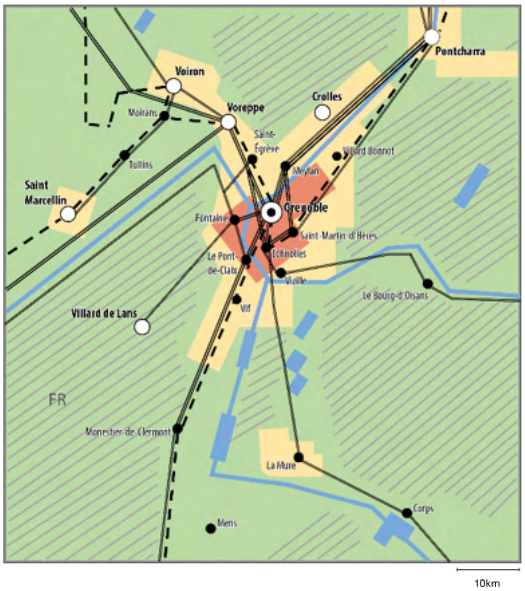
Box 1
Mapshots of exemplary InTerAlp case regions

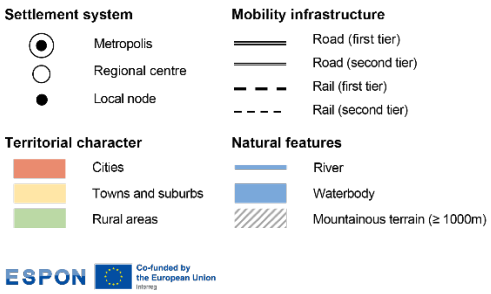
Spatial organisation in the interface territories of Turin (top) and Grenoble/Rhône-Alpes (bottom)

The **Turin interface area** is characterised by Turin's status as the primary urban centre. Other relevant urban settlements are located in the vicinity of Turin, including Collegno, Orbassano, and Moncalieri, as well as along the primary infrastructure networks that originate from it. These include the route from Turin to the Lanzo Valley via Ciriè to the northwest, the route from Turin to the Pinerolo area in the southwest, the route from Turin to the Carmagnola area in the southeast, and the route from Turin to Chivasso in the northeast. The principal orientation is an east-west axis, which connects the city of Turin with Susa and the border with France, traversing a relatively narrow valley. The valley is distinguished by the prevalence of extensive infrastructure and the presence of multiple smaller side valleys to the north and south. The area is characterised by sparsely populated mountain ranges and settlements concentrated along the main infrastructure network.



The **Grenoble/Rhône-Alpes interface territory** is characterised by the urban area of Grenoble, with a number of smaller settlements that have assumed functions typically associated with larger settlements. The urban area of Grenoble shows a high population density, and smaller towns that function as 'city entrances'. In the wider region, smaller settlements are distributed across the rural and mountainous areas. Villard Bonnot and Crolles are local centres situated on either side of the Grésivaudan valley, to the east. Villard de Lans represents the principal focal point of the Vercors region to the west. Vizille and Bourg d'Oisans constitute the eastern entrance to the Oisans valleys. The towns of Voiron, Moirans, Voreppe and the surrounding areas constitute a structuring agglomeration community to the north of the Grenoble metropolis. Saint-Marcellin, situated in the lower Grésivaudan valley, serves as a local hub that plays a role in organising the space between Grenoble and the Rhône valley.





ESPON Co-funded by the European Union

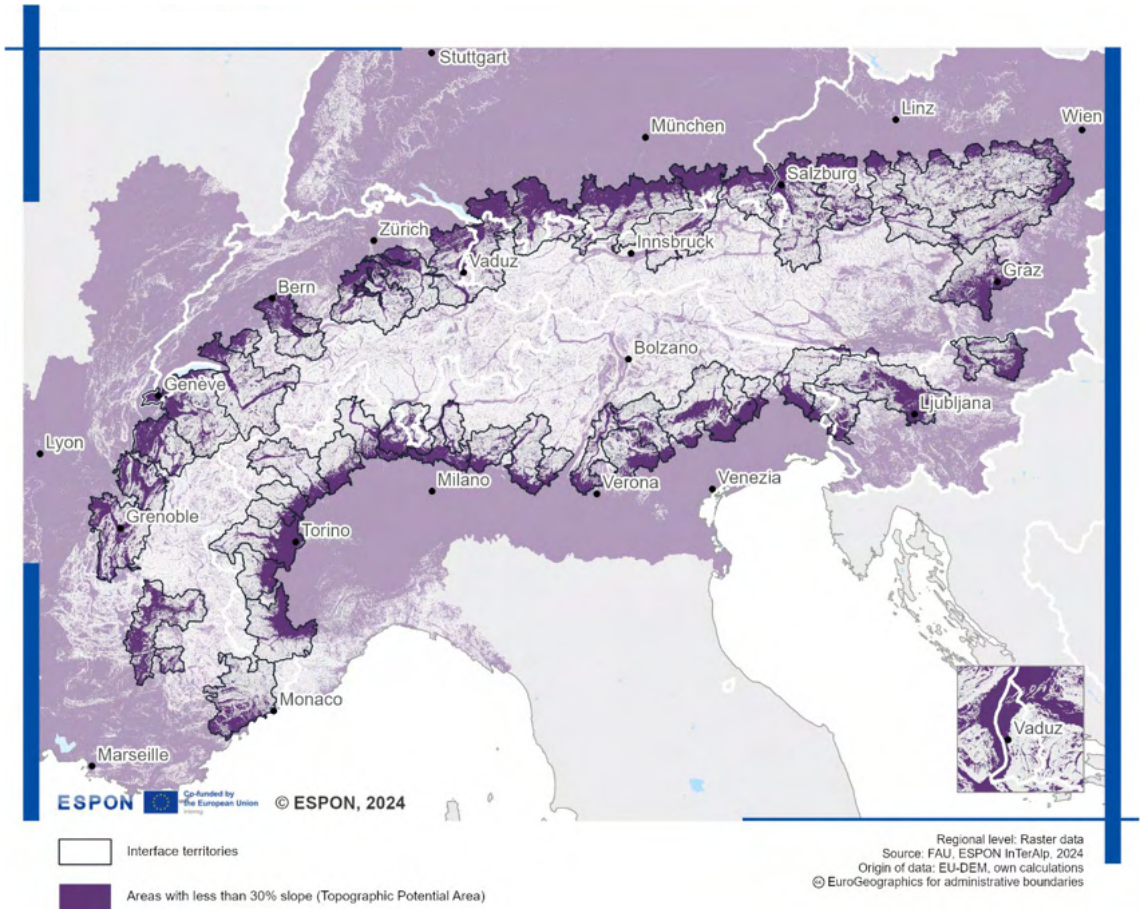
For more information on case studies, see the ***ESPON InTerAlp Case study portfolio***

3.1.3 The challenge of double-demand with half of space

3.1.3.1 Scarcity of land and competing interests

Interface territories across the Alpine region face a high level of competing interests for land use. At the same time, the share of useable land is limited. This is true because of ecological concerns, but also the pure steepness of the relief limits the scope. Map 4 shows the degree of inclination within Alpine interface areas. The purple signature demonstrates those areas with less than 30% slope steepness in a raster resolution of 25 meters, indicating theoretical availability for agriculture, infrastructure and other human activities (Lambracht 2024).[4]

Map 4
Degree of inclination in Alpine interface areas



4 Spatial planning and development are closely linked to infrastructure and safety measures. The feasibility of constructing in steep topography is contingent upon a number of factors, including local building regulations, engineering considerations, soil integrity, and the specific context (Sanap and Sapate, 2020). Thus, it is inaccurate to suggest a universal threshold for a degree of inclination making land unsuitable for land use dynamics. The literature reflects on different arguments in this context:

- The risk of avalanches and landslides is a significant concern at slopes above 30 degrees (Van Gelder et al., 2010).
- It is recommended that construction on terrain should be seamless up to a slope of 15 per cent. Beyond this threshold, significant cost escalation can be expected (e.g. Gorsevski et al. 2003; FLF 2017).
- The British land capability classification limits the use of heavy harvesting machinery on slopes of 15 degrees or more (e.g. Jarasiunas 2016).

The spatial pattern in this map shows limited flat or gently sloping land within the interface areas in close proximity to peri-Alpine lowlands. At the same time, competition of land use interests is high, including for housing, energy and tourism (see e.g. Map 18, Map 24).

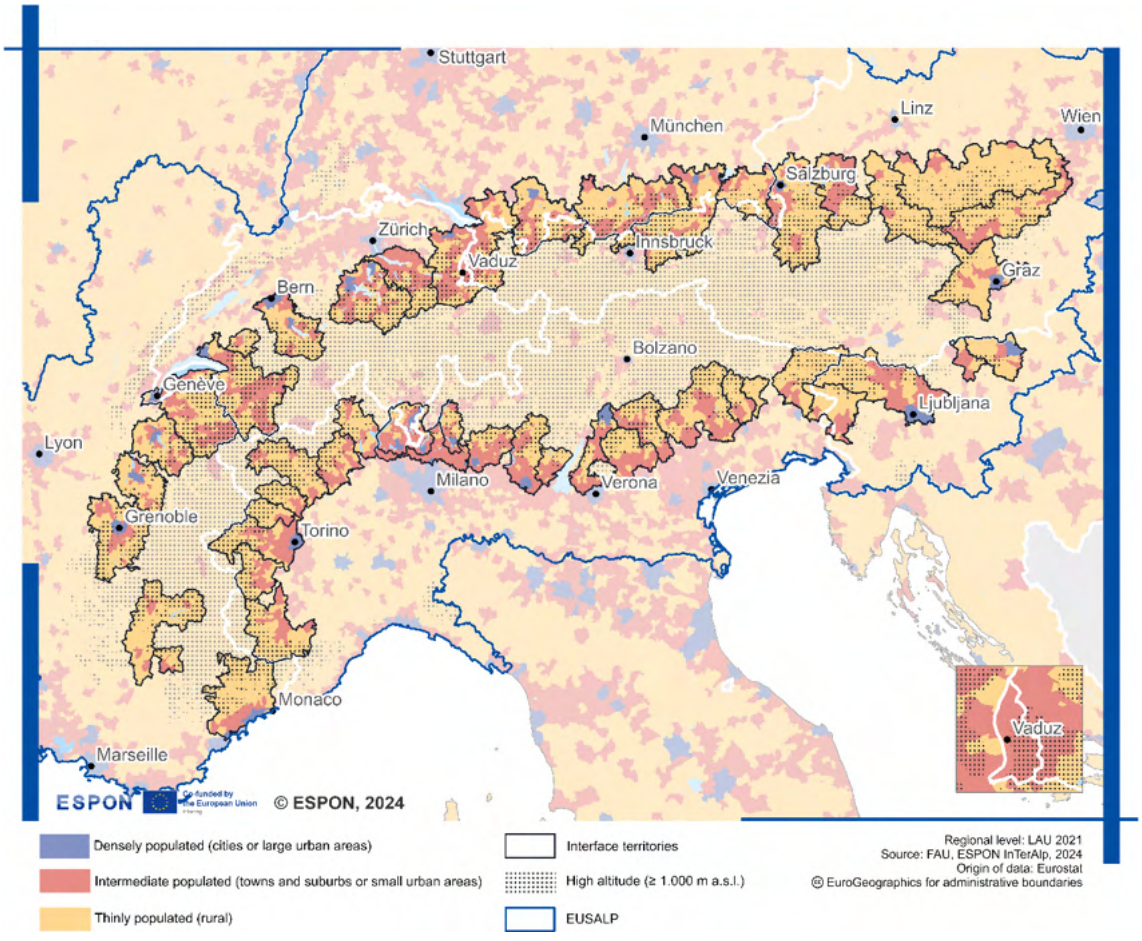
This poses challenges also for nature conservation and open space protection. The fact of limited land availability combined with already sealed soils in valley locations leads to particular 'pressure' in interface areas. This combination of limited topographic suitability, competing demands and the need for environmental protection creates a complex set of priorities for land management in interface areas. This setting means that interface areas are particular 'test-cases' at the forefront of sustainable spatial development.

3.1.3.2 Urban and rural areas

Map 5 illustrates the degree of urbanisation (DEGURBA) and the areas situated above 1,000 metres above sea level within the EUSALP perimeter. The DEGURBA is founded upon a population distribution grid comprising raster cells of 1 km². The indicator is based on a combination of population size and population density thresholds, which are used to create three mutually exclusive classes.

- **Cities** (alternate name: densely populated areas): At least 50% of the population lives in urban centres (with a high population density).
- **Towns and suburbs** (alternate name: intermediate density areas): At least 50% of the population lives in urban clusters and less than 50% of the population lives in urban centres.
- **Rural areas** (alternate name: thinly populated areas): At least 50% of the population lives in rural grid cells.

Map 5
Degree of urbanisation



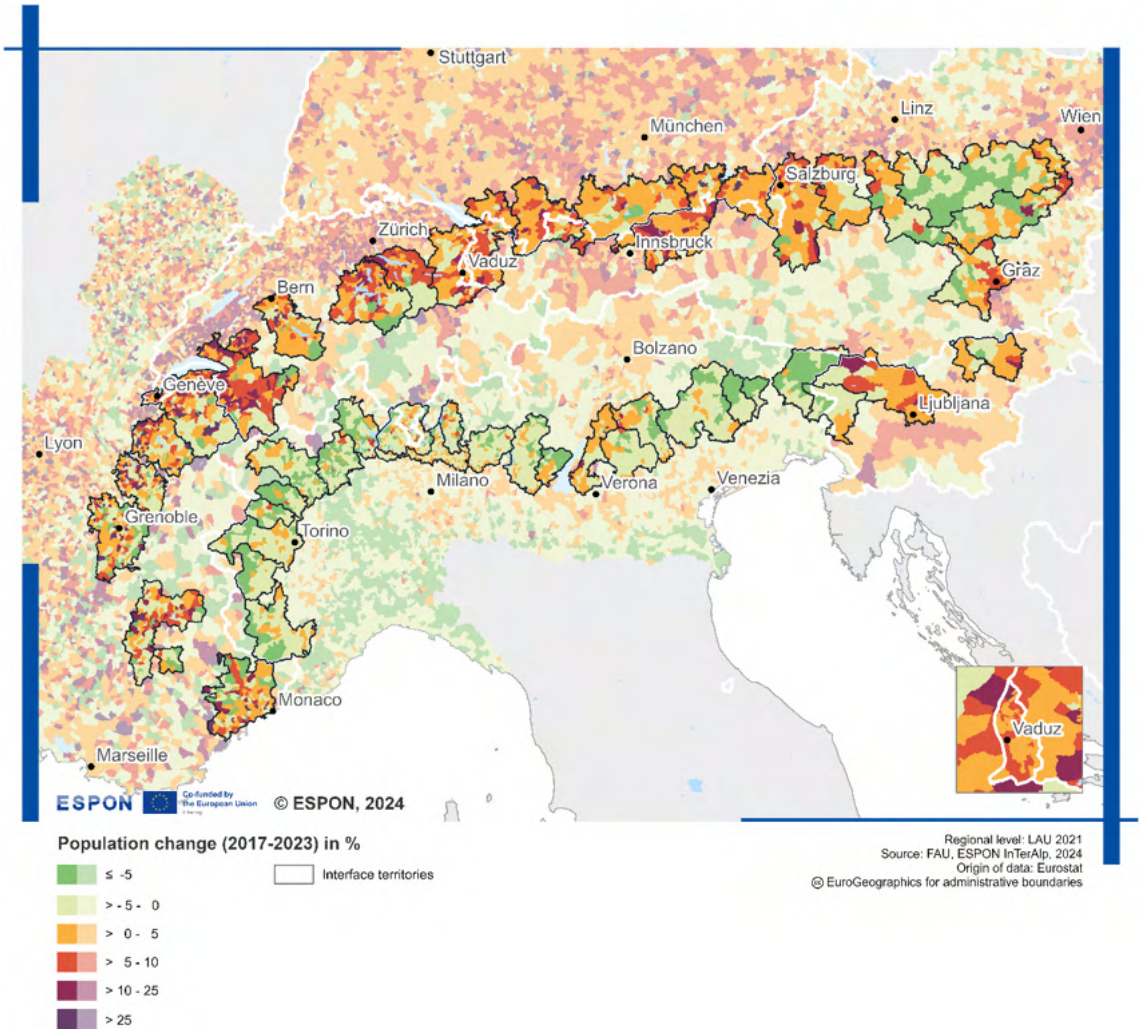
The map illustrates the predominantly rural character of the inner Alpine regions. While the cities of Innsbruck, Bolzano and Klagenfurt are characterised by high population density within the inner Alps, the majority of other urban centres or large urban areas are situated in interface areas (e.g. Turin, Grenoble, Geneva, Berne, Salzburg, Graz or Ljubljana) or in the peri-Alpine lowlands (e.g. Munich, Linz, Vienna, Verona, Milan, Lyon, Zurich).

In interface territories, areas of varying degrees of urbanisation exist in proximity to one another. It is evident that in interface areas, the valley structures (e.g. Inn Valley, Rhone Valley, Sava Valley) show a considerable degree of urbanisation. This, in the context of the already mentioned high degree of inclination in these areas, demonstrates the significant pressure on available land and the high relevance of efficient spatial development to organise the various competing sectoral interests.

3.1.3.3 Population development

Sustainable spatial development strategies have to consider demographic information on a fine scale. Map 6 illustrates the demographic trend between 2017 and 2023 at the municipal level. The overall demographic trend can be classified as either positive or negative based on the demographic components of in-/outmigration over municipality borders, as well as childbirths and deaths. The intensity of the red signature indicates the strength of the overall positive trend, whereas the intensity of the green signature indicates a negative demographic development.

Map 6
Population development



The overall picture demonstrates a significant correlation between the degree of urbanisation and the observed demographic trends. Over the course of the analysed period, metropolises and larger cities have consistently been the main drivers of population growth, whereas rural areas have shown a much more diverse range of population development patterns. In general, there are considerable differences between the Alpine countries.

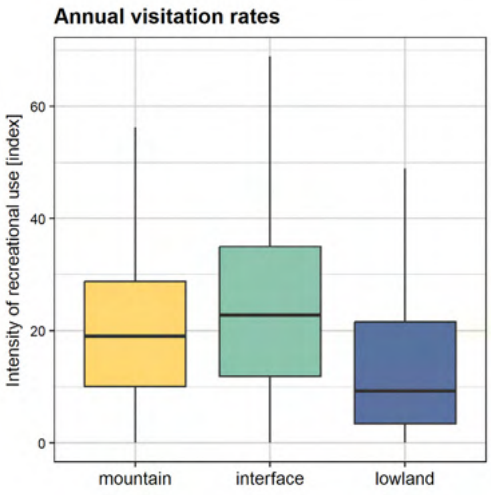
The population trends along the European transport corridor gateways are zones of more positive demographic trends, particularly in the interface areas of the Alpine Rhine Valley, the Rhône Valley, the Slovenian motorway junction and the Brenner corridor. These interface areas are territories where the main transalpine corridors originate and terminate across the Alpine region. In this map, it is mainly the core city interface territories and those that are part of a transalpine corridor that show the most positive population development.

3.1.3.4 Visitation rates

Figure 3 shows mean annual visitation rates based on georeferenced photo data for mountain, lowland and interface areas of the European Alps The boxplots show the median and range of the data for mountain, interface and lowland areas, as well as the dispersion within each spatial category. The interquartile range, i.e. the size of the box, represents 50% of the data values. Whiskers (lines at the top and bottom of the boxes) provide information on the range of the data - in this case the boxplots have been cleaned of outliers in order not to distort the pattern of the data by extreme values (for more methodological information on the positioning approach, please see ***Scientific annex I: Definition and delineation of Alpine interface territories***).

This positioning indicates that popular tourist areas are often located in interface territories. The median of visitation rates per year is highest in the interface areas and lowest in the peri-Alpine lowlands. This implies that interface areas have attractive destinations for touristic use, but are also under high pressure from high visitation rates. This poses serious challenges to mobility infrastructure and ecosystem corridors as well as potential disturbance to wildlife and vegetation. The positioning refers to visitation numbers estimated from the density of geo-referenced photos in relation to user days. Photographs appearing in social media can be considered as a reliable proxy for visitation frequency, which correlates well with official visitation statistics. Based on the metadata of the online photo-sharing website Flickr, photo user days (PUDs) are calculated, i.e. the number of users who took at least one photo per day at a specific location. The density of PUDs is obtained using a moving window with a radius of 1.5 km, which shows the average visitation rates for each municipality. The indicator provides important information on the actual use of the green infrastructure outside urban areas.

Figure 3
Boxplot on visitation rates in mountain, interface and lowland areas across the Alpine region



3.2 Territories with sharp contrasts

3.2.1 Territories of environmental contrasts

3.2.1.1 Naturalness

Map 7 shows the degree of human impact on the natural environment. Natural and semi-natural ecosystems are essential for the conservation of biodiversity, as they provide suitable habitats for plant and animal species. Such ecosystems are also more resilient towards natural hazards and vital to support human-wellbeing. However, human activities lead to direct and indirect changes in the biophysical environment and ecosystems. Sustainable management practices in agriculture and forestry have less impact on ecosystems than intensive agricultural practices, intensive forestry and urbanisation.

The naturalness index is calculated from the hemeroby values of each land cover type, based on an ordinal scale ranging from 'ahemerob - no human impact' to 'metahemerob - sealed soil', weighted according to the proportion of the urban area they occupy. This index is an integrative measure of the impact of all human interventions on ecosystems. High index values indicate less human impact and more natural ecosystems, while low index values represent highly modified ecosystems. Inner-Alpine areas generally contain more natural ecosystems than peri-Alpine lowland areas. This contrast is reflected in the interface areas, which cover the whole gradient from highly natural to highly modified ecosystems. This is particularly evident in the Italian interface areas.

Map 7
Naturalness

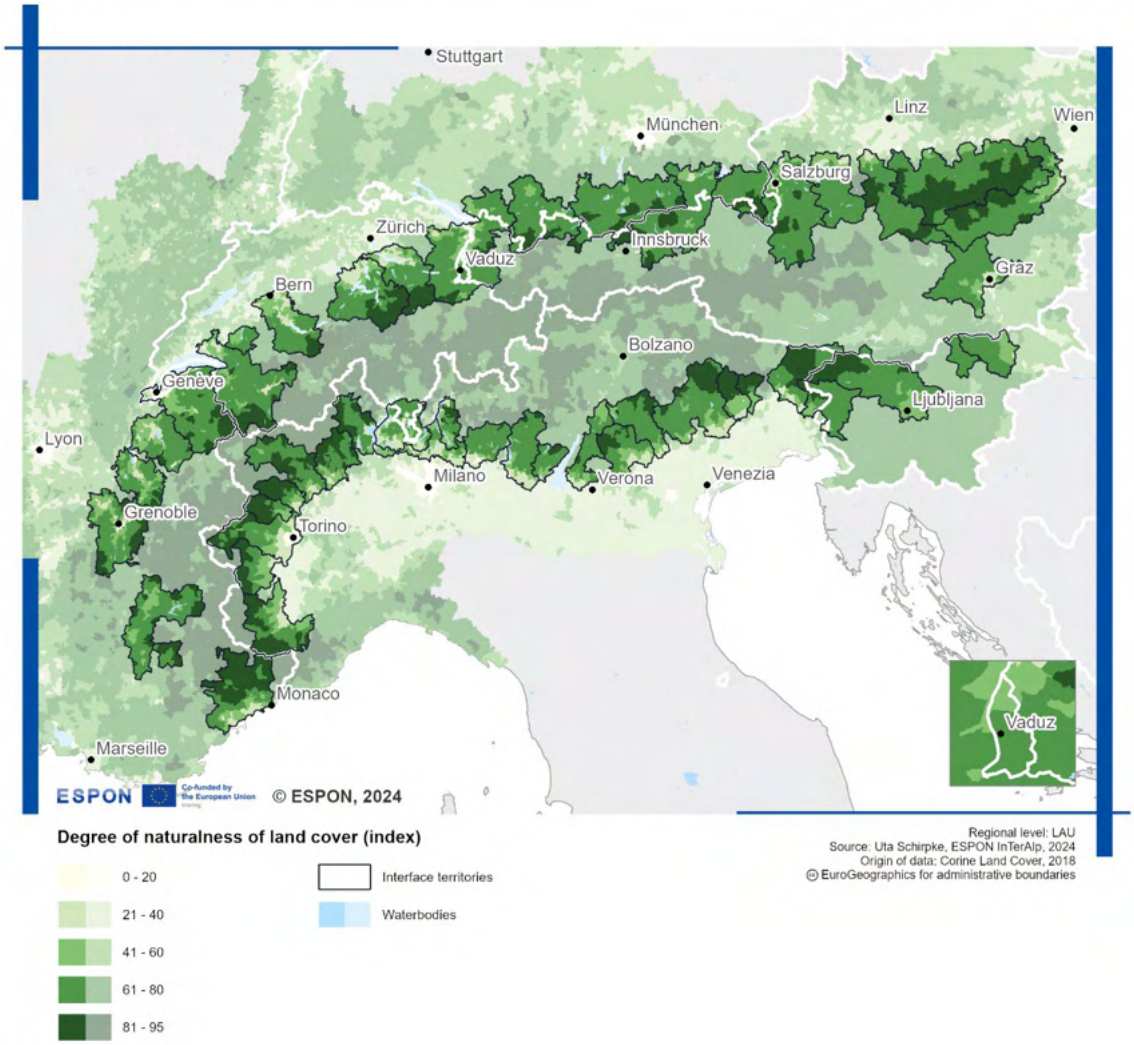
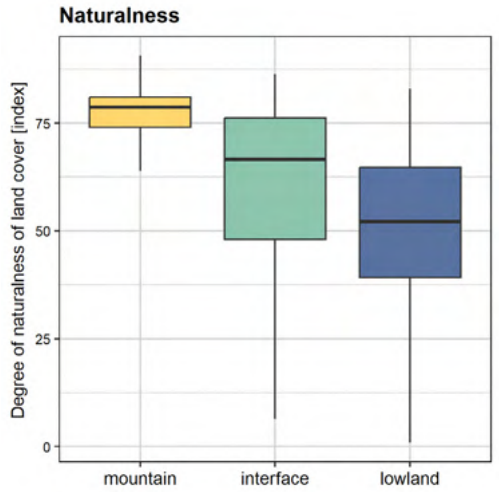


Figure 4 shows the differences in naturalness, expressed as the level of human impact on ecosystems, between inner-Alpine mountain areas, interface areas and peri-Alpine lowland areas. While the mountain areas are characterised by the highest level of naturalness, the lowland areas have the lowest level of naturalness. The interface areas show the greatest variation, as they include the high contrasts between inner-Alpine areas and peri-Alpine lowland areas.

Figure 4
Boxplot on naturalness in mountain, interface and lowland areas across the Alpine region

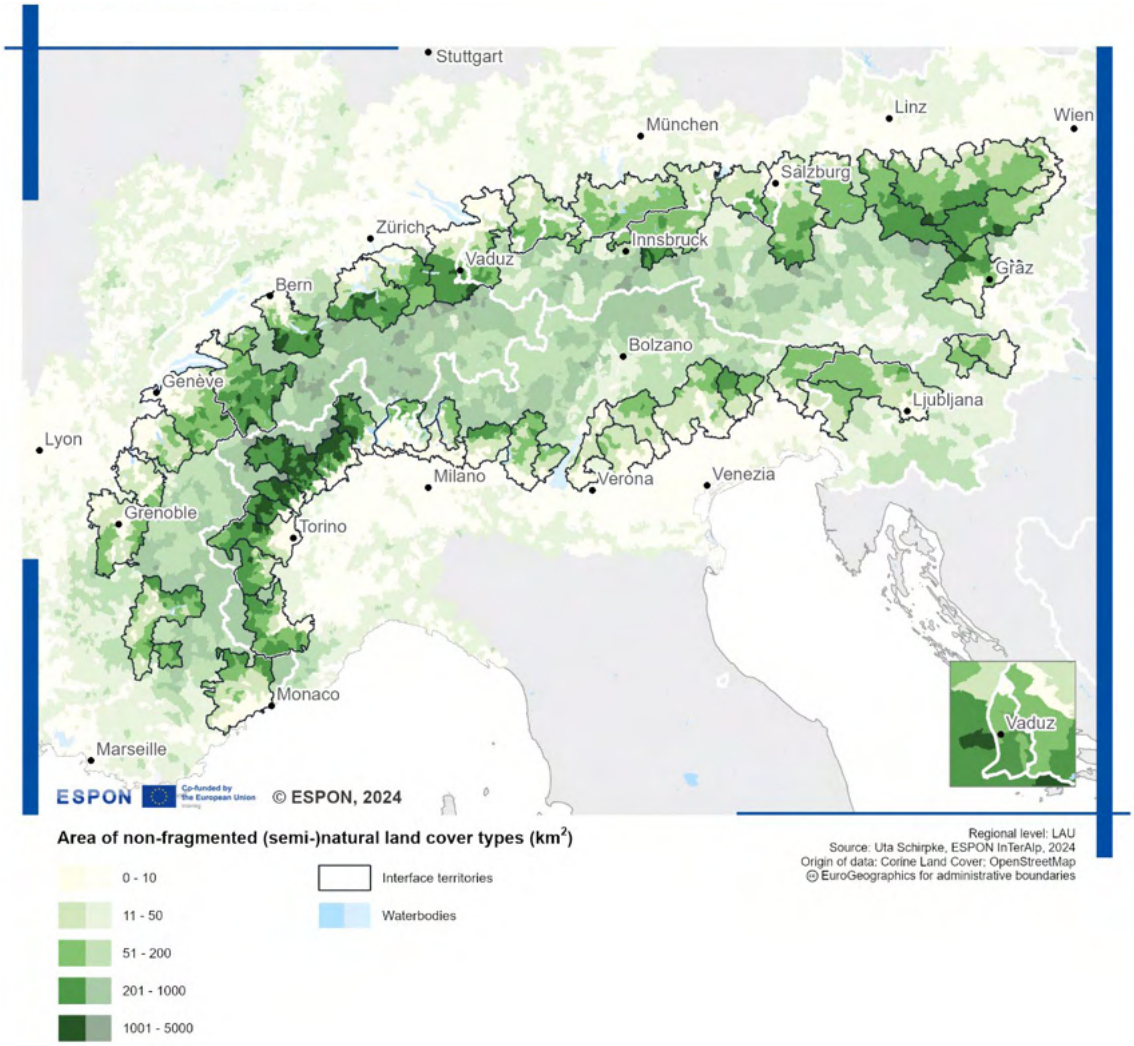


3.2.1.2 Ecological connectivity

Recognising the importance of green infrastructure in the Alpine region is crucial for ensuring ecological balance, preserving corridors of ecological connectivity and biodiversity, as well as ensuring the overall resilience of the ecosystem (see Interreg Alpine Space AlpGOV, Marot et al. 2019). Land use dynamics, urban sprawl and human activities lead to habitat fragmentation, which is the physical disintegration of continuous habitats into smaller patches, decreasing the resilience of ecosystems and threatening biodiversity. Landscape connectivity is therefore key for maintaining species dispersal and sustaining ecological processes and functioning. In short, connectivity is highly influenced by spatial landscape patterns and human-made infrastructures.

Map 8 shows an index that represents the average size of (semi-)natural land cover types, excluding built-up areas, glaciers, bare rock and lakes, not cut through by transport infrastructure, that intersect each municipality. The indicator shows differences in ecological connectivity between inner-Alpine areas, interface areas and peri-Alpine lowland areas. Ecological connectivity is highest in inner-Alpine areas and lowest in peri-Alpine lowland areas, which are highly fragmented.

Map 8
Ecological connectivity



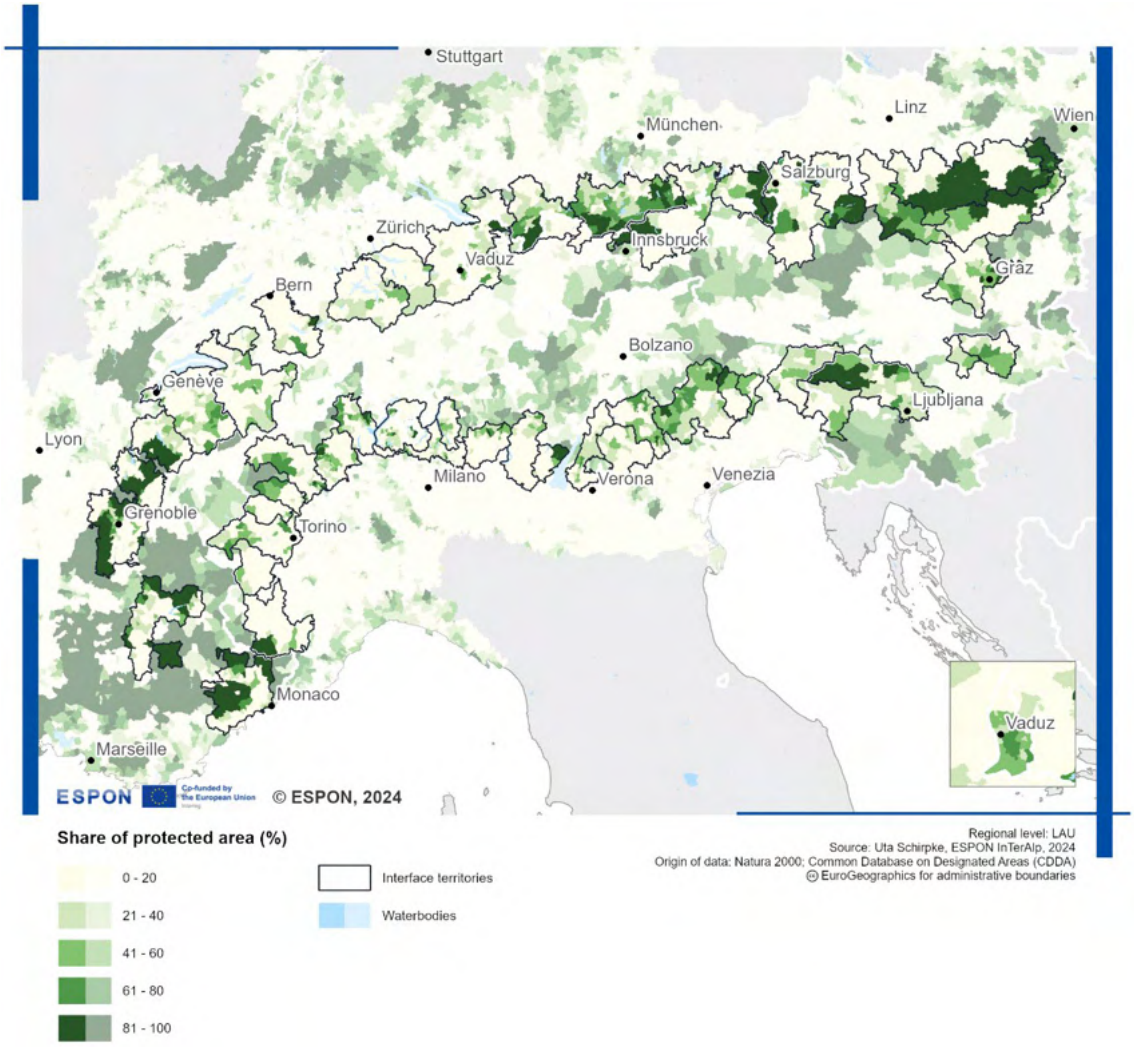
The map shows a high territorial diversity, with high values mainly in the inner-Alpine areas and low values mainly in the peri-Alpine areas. In this respect, the interface areas represent a meeting point of fragmented areas with still connected ecological systems. There is also a high diversity across the Alpine interface areas (e.g. Tessino/Lugano with mainly low values and the Bavarian Alps with mainly high values).

3.2.1.3 Protected areas in municipal areas

Map 9 shows the share of the municipal area covered by protected areas. The indicator is computed by calculating the percentage of the municipal area covered by protected areas of different International Union for Conservation of Nature (IUCN) categories. Municipalities in the western and eastern parts are generally characterised by a higher presence of protected areas, but there are no clear differences between inner-Alpine areas, interface areas and peri-Alpine lowlands.

The presence of protected areas indicates natural environments and high biodiversity, as protected areas focus on the conservation of plant and animal species by providing and protecting suitable habitats. Human activities and exploitation of natural resources are usually limited, depending on the type of protected area.

Map 9
Protected areas in municipal areas

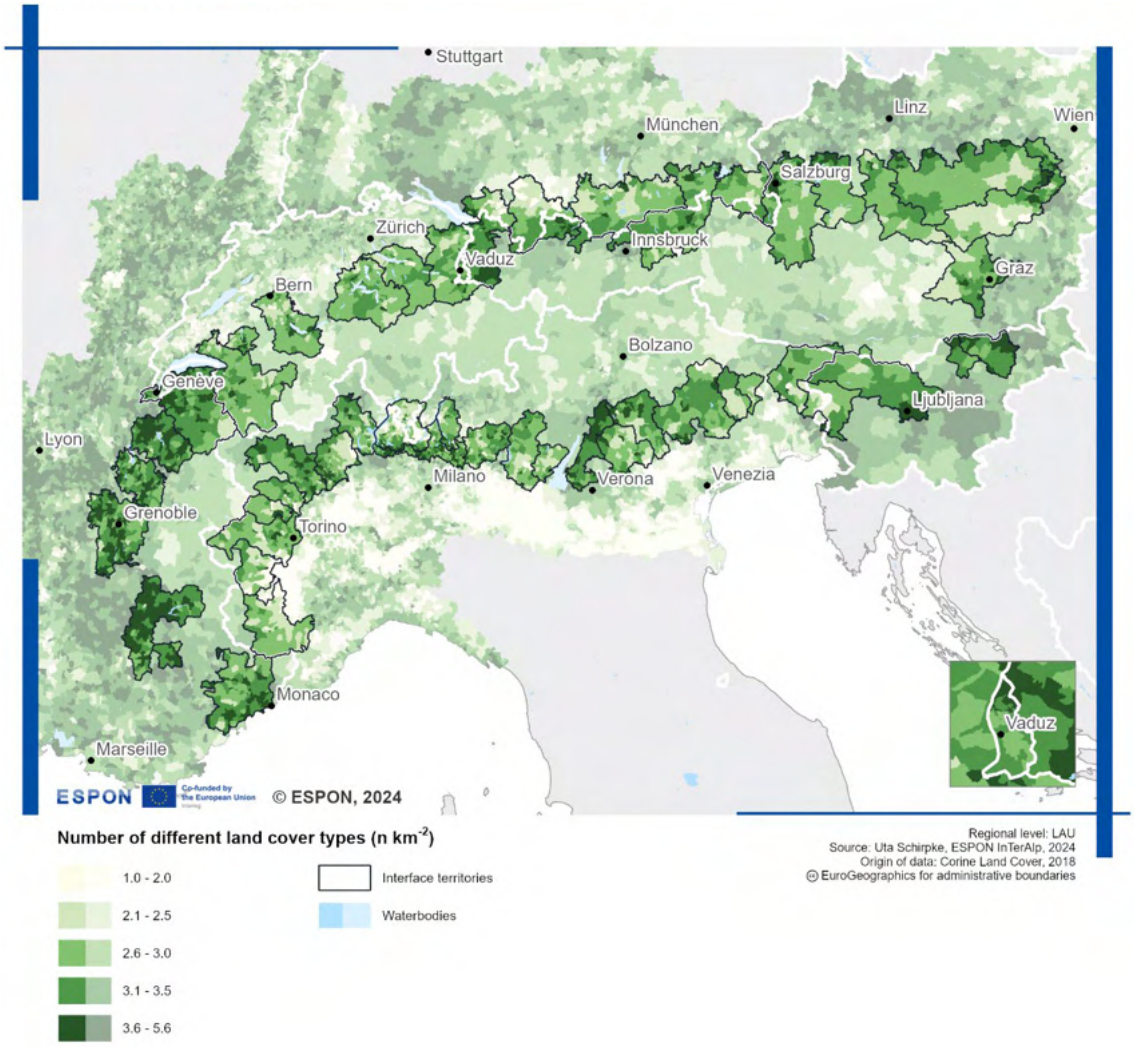


3.2.1.4 Landscape diversity

Map 10 shows the average number of different land cover types per square kilometre within each municipality. The indicator shows spatial differences between inner-Alpine areas, interface areas and peri-Alpine areas. The interface territories are generally characterised by a higher landscape diversity compared to the mountain and lowland areas. This can be explained by high altitude gradients and a high variety of different land uses within a limited area.

Landscape diversity is a measure of biodiversity at the landscape scale. High landscape diversity also has a positive effect on biodiversity, as many different land uses are found within a small area, providing habitats for different plants and animals. High landscape diversity also enhances ecosystem resilience by influencing ecological processes and functions, reducing vulnerability to natural hazards and environmental change, and supporting human health and well-being through the provision of ecosystem services. Land-use changes that result in reduced landscape diversity therefore reduce the benefits of biodiversity and well-being.

Map 10
Landscape diversity



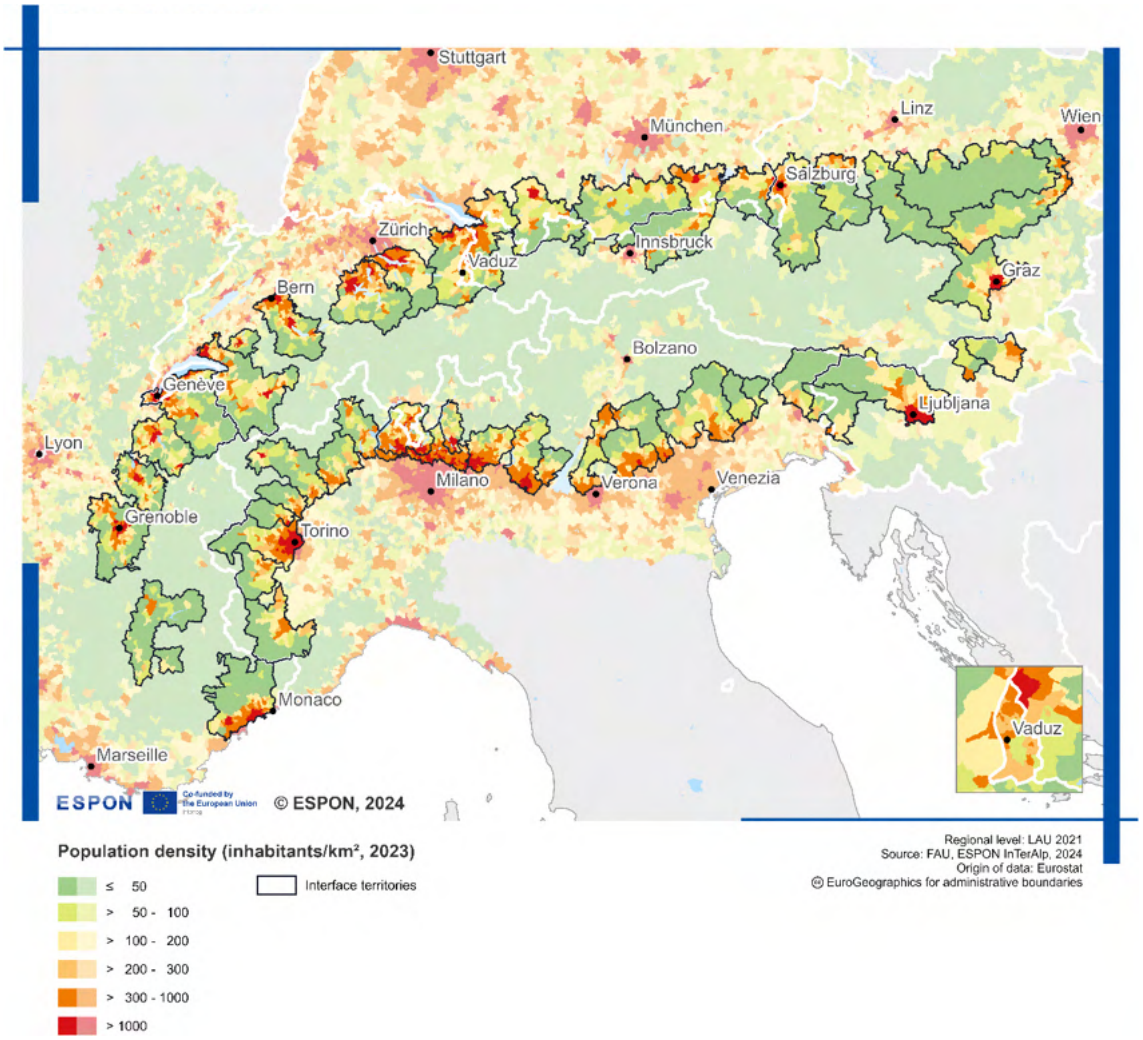
3.2.2 Territories of socio-economic contrasts

3.2.2.1 Population density

Map 11 shows the population density in 2023 at the municipal level. The calculation is based on the annual average population divided by the surface area, expressed in inhabitants per square kilometre. This metric allows a comparative analysis of the intensity of settlements in different geographical areas and reveals distinctive patterns in the Alpine region.

Despite differences in national and regional contexts, the Alpine settlement system shows considerable similarities. Compared to the peri-Alpine lowlands, the inner-Alpine areas show a predominantly lower population density. This reflects the constraints imposed by the mountainous terrain, which limits the extent and intensity of human settlement. Accordingly, the morphological structure of the inner-Alpine region has a strong influence on settlement patterns, whereas the peri-Alpine areas are characterised by a ring of agglomeration around the mountain region.

Map 11
Population density



The interface areas show a strong contrast between densely and sparsely populated areas, highlighting the heterogeneity of settlement patterns in these transition zones between the peri-Alpine lowlands and the inner-Alpine highlands.

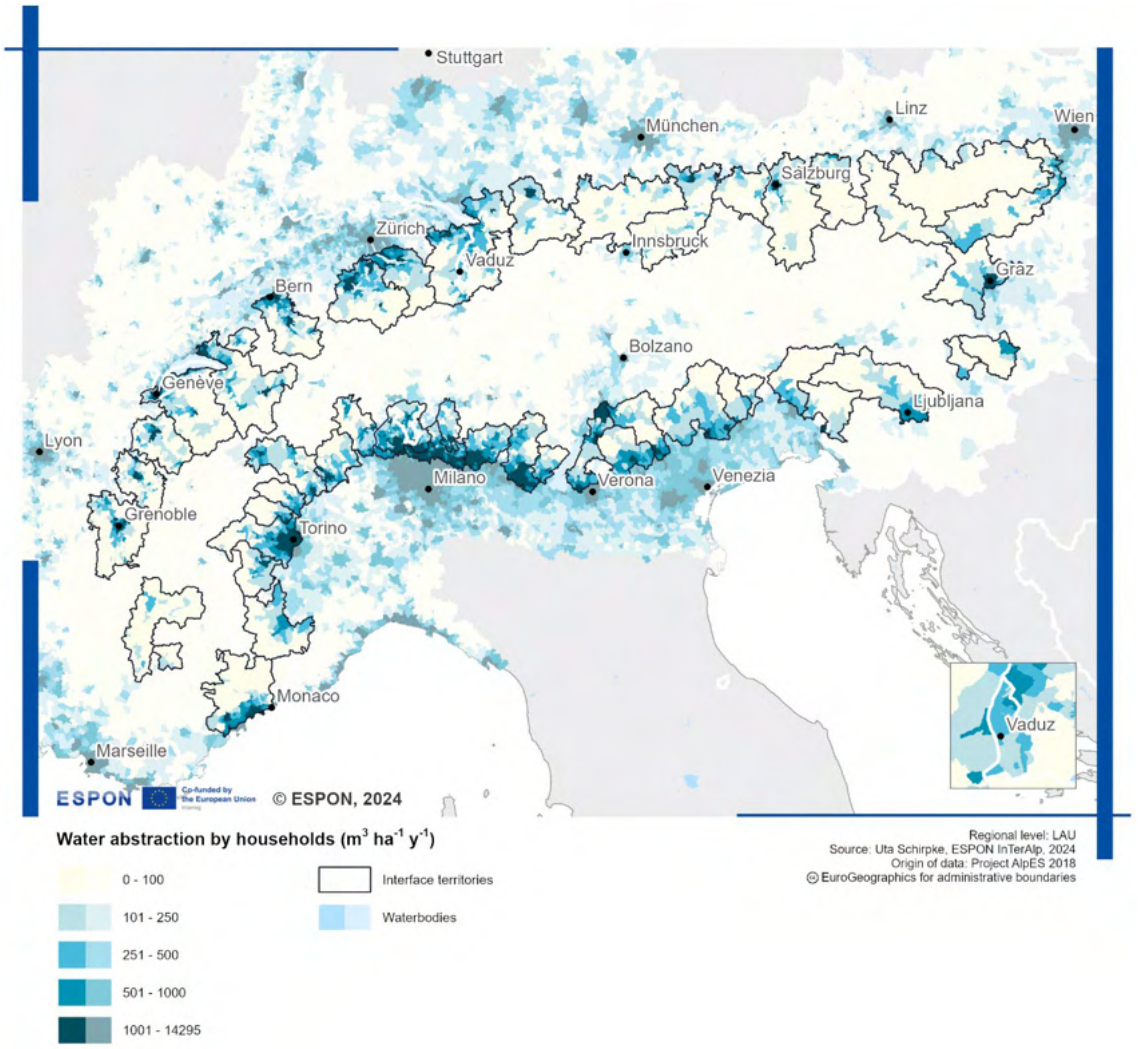
The map also illustrates the fundamental influence of the valleys on the configuration of the settlement structure. Examples include the Inn valley, east of Innsbruck; the Alpine Rhine valley, which extends north and south of Liechtenstein; the Isère valley, between Geneva and Grenoble; and the Sava valley in Slovenia. These valleys act as focal points for population concentration, underlining their importance within the wider Alpine settlement system.

3.2.2.2 Water abstraction

Map 12 shows the sharp contrasts in the interface areas, illustrated by water abstraction. The range of values within the interface areas connects lowland areas, which have the highest abstraction rates, with mountain areas, which are generally characterised by low abstraction rates due to low population density. This spatial pattern is particularly evident, for example, in the interface areas of the Lombardy region or in Turin, Grenoble/Rhône-Alpes and Graz.

Water abstractions indicate the demand for drinking water by households and reveal differences in water demand between inner- and peri-Alpine areas. Household demand for drinking water is based on regional data downscaled to municipality level using tourism and demographic data.

Map 12
Water abstraction

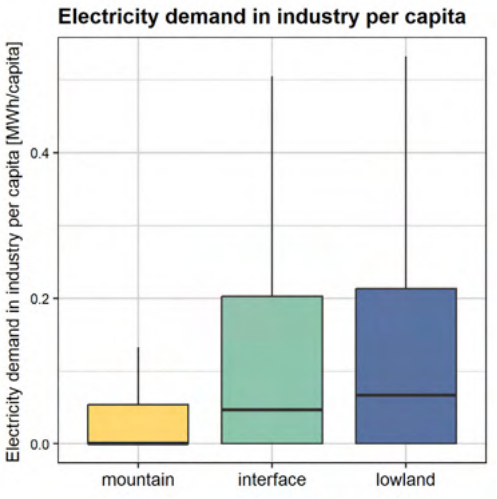


3.2.2.3 Electricity demand in industry

Figure 5 shows the industrial electricity demand per capita for mountain, interface and lowland areas in the Alpine region at the municipal level. The industrial energy demand indicator is provided as 1x1 km grid data for the EU, modelled by the JRC. Energy demand totals per LAU have been aggregated by intersection of LAU areas and the grid, with values proportionally assigned to LAUs based on geographic overlap. To ensure comprehensive coverage of the project area, corresponding data for Swiss municipalities at NUTS3 level have been approximated based on information provided by employment data and energy data.

Figure 5

Boxplot on electricity demand in industry per capita for interface, mountain and lowland areas across the Alpine region



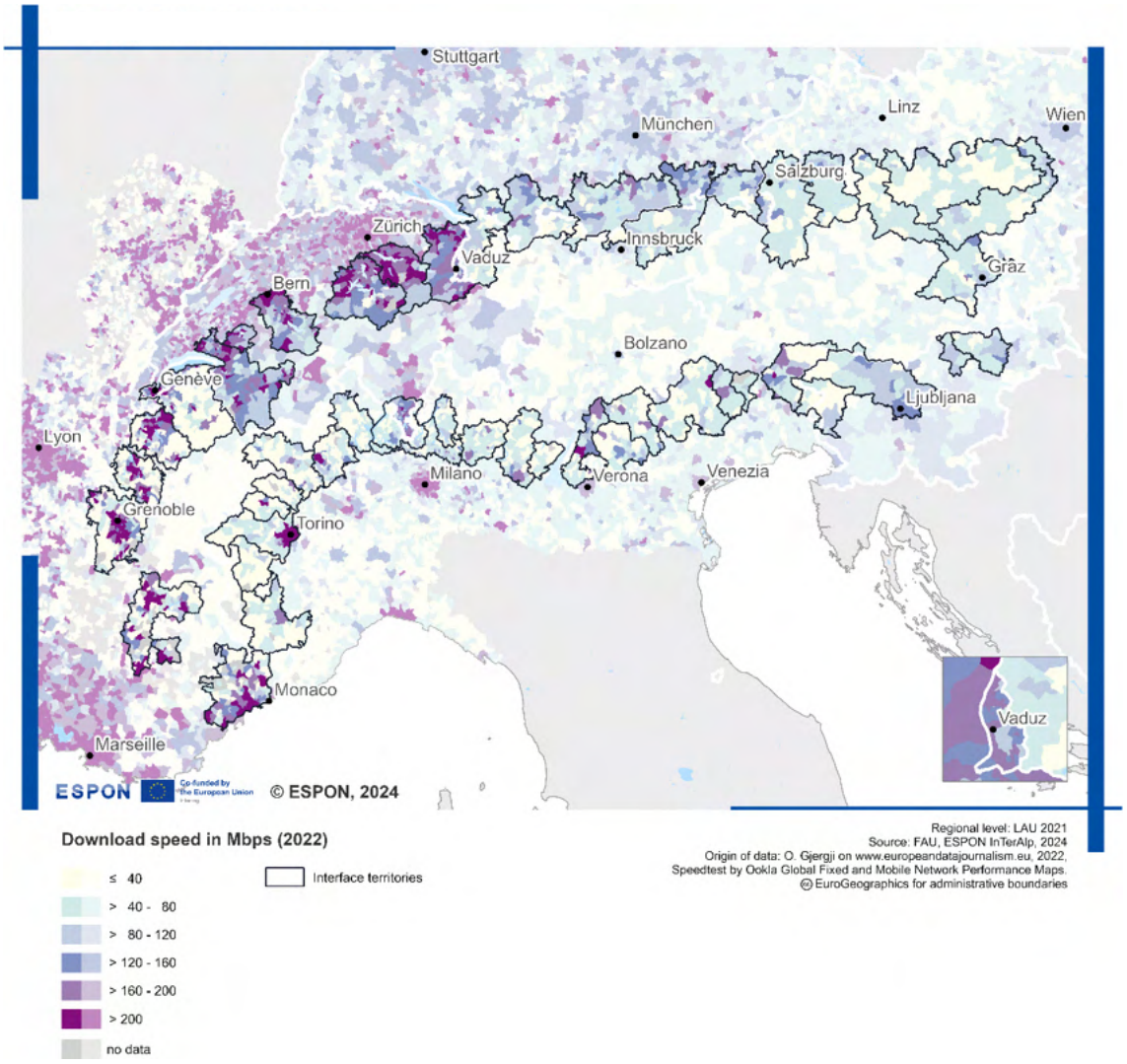
The boxplot highlights the different distribution patterns, where mountain areas generally show the lowest average energy demand, while lowlands and interface territories are quite similar in terms of average and median values. Interface territories show both a higher number and more extreme outliers than lowland municipalities. Municipalities with no industrial energy demand represent 29% of the lowland areas, 34% of interface territories and 56% of the mountain regions.

The analysis of energy demand in the industrial sector shows structural similarities between lowland and interface areas, both of which differ significantly from mountain regions. However, although energy demand is a proxy for industrial activity, it can be significantly distorted by the different types of industry and their respective energy consumption. Nevertheless, energy demand is particularly relevant in conjunction with other energy-related indicators. Energy production is particularly concentrated in mountain regions (hydropower) and in lowland areas (fossil and nuclear energy sources, wind energy). There is a significant funnel effect in energy transport, with interface areas being on average the most affected by transport infrastructure. However, energy demand in industry highlights their strong position in productive industries and the corresponding dependence on externally produced energy and the corresponding transport infrastructure.

3.2.2.4 Internet speed

Map 13 shows the download speed at the municipal level. As digitalization is one of the key prerequisites for successful regional development, this indicator is of high relevance, especially from an economic perspective. The challenge is to avoid 'digital divides', i.e. extreme differences in economic, social and spatial terms.

Map 13
Average internet speed



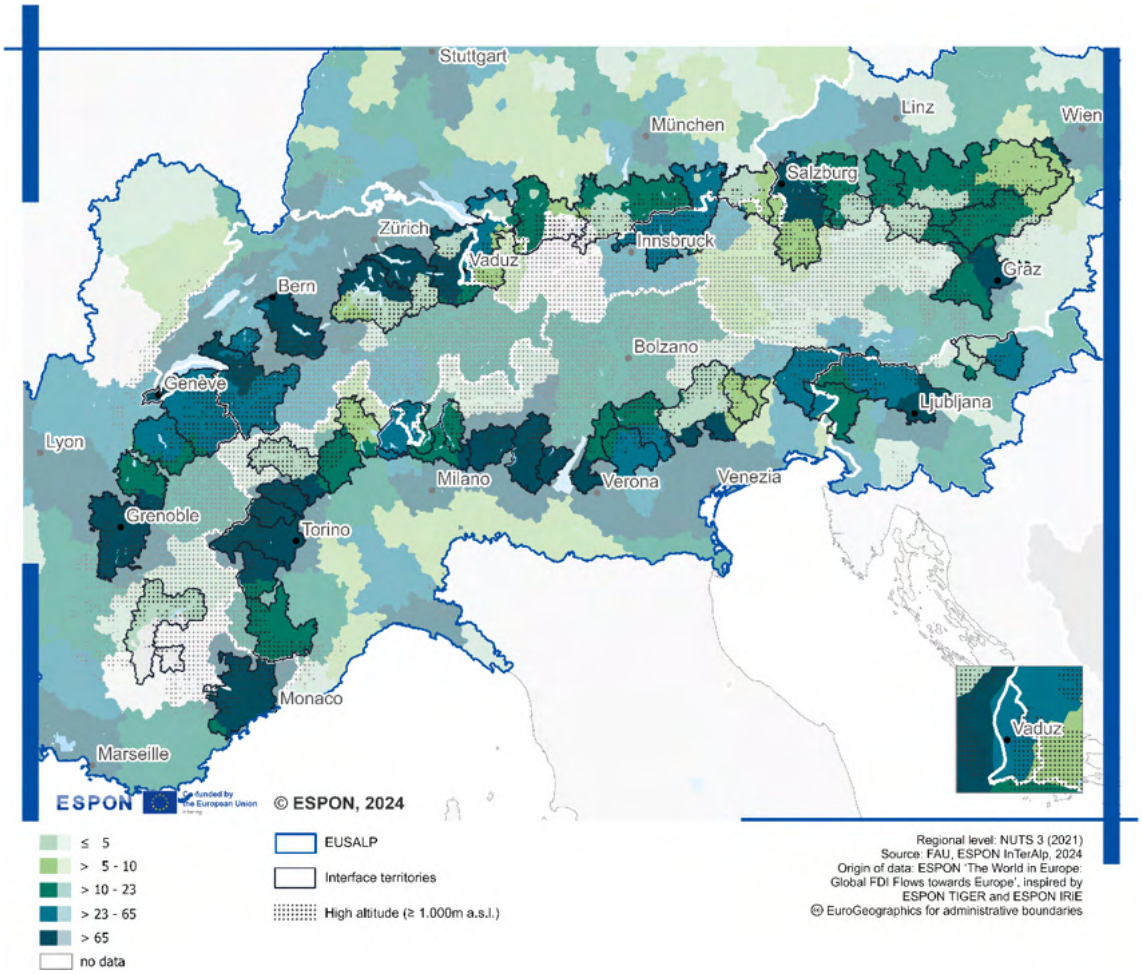
Obviously, download speed varies considerably across the Alps. The range is from less than 40 megabits per second to more than 200. The national affiliation affects the interface areas. The interface areas with Swiss and French participation have the highest average download speeds. In particular, the interface areas Zürich/Schwyz/Glarus (CH), Bern/Thun (CH), Zug/Luzern (CH), Rhône Valley (CH/FR) show particularly high download rates. In the other interface areas mainly the urban centres show high download speed rates, namely in the cases of Geneva/Annemasse/Thonon-les-Bains (CH/FR), Annecy (FR), Chambéry (FR), Grenoble/Rhône-Alpes region (FR), Digne-les-Bains (FR), Sisteron/Gap (FR), Nizza (FR) and Turin (IT).

Even though this is only one indicator among others, it illustrates the importance of spatial balance in digitisation processes. Morphology does not play a dominant role in the average internet download speed. The obvious relevance of national affiliation hints at the role of political frameworks. Even if infrastructure investment is predominantly organised at national level, a number of pan-Alpine challenges need to be addressed, including issues of vocational training, exploiting the potential of remote working and learning from best practice. This map shows some sharp urban-rural differences within the interface areas. Infrastructure investment is much more likely to pay off in urban areas than in rural contexts. Policy instruments such as procurement rules and financial support can make a major difference in this context.

3.2.2.5 Foreign direct investment projects

The analysis of economic flows is essential for understanding cross-border and international economic interdependencies, employment opportunities and the potential of different economic sectors. Map 14 shows the total number of foreign direct investment (FDI) projects between 2003 and 2015 at district level (both greenfield projects and merger and acquisition (M&A) deals and from both intra-European and extra-European sources). A greenfield project is a cross-border investment in a new physical project or the extension of an existing investment that creates new jobs and capital investment. M&A deals include mergers, acquisitions, initial public offerings, private equity and venture capital deals. This indicator is based on the results of ESPON TIGER and data from the ESPON project 'The World in Europe: Global FDI Flows towards Europe'.

Map 14
Total number of foreign direct investment projects (2003-2015)



The spatial pattern shows a high number of FDI projects in particular in interface areas in close proximity to major urban centres such as Turin, Milan, Verona, Ljubljana, Graz, Vienna, Salzburg, Munich, Innsbruck, Vaduz, Zurich, Bern, Geneva, Grenoble and Monaco. Even though this spatial resolution (district level) is not compatible with the delineation of interface areas (municipality level), this spatial pattern is of high interest as it reflects the high level of economic linkages across national borders in the European Alpine region. In particular, the core city and semi-urbanised interface areas show a high relevance for tailor-made governance solutions in cross-border economic activities.

3.3 Territories with a geographic funnel effect

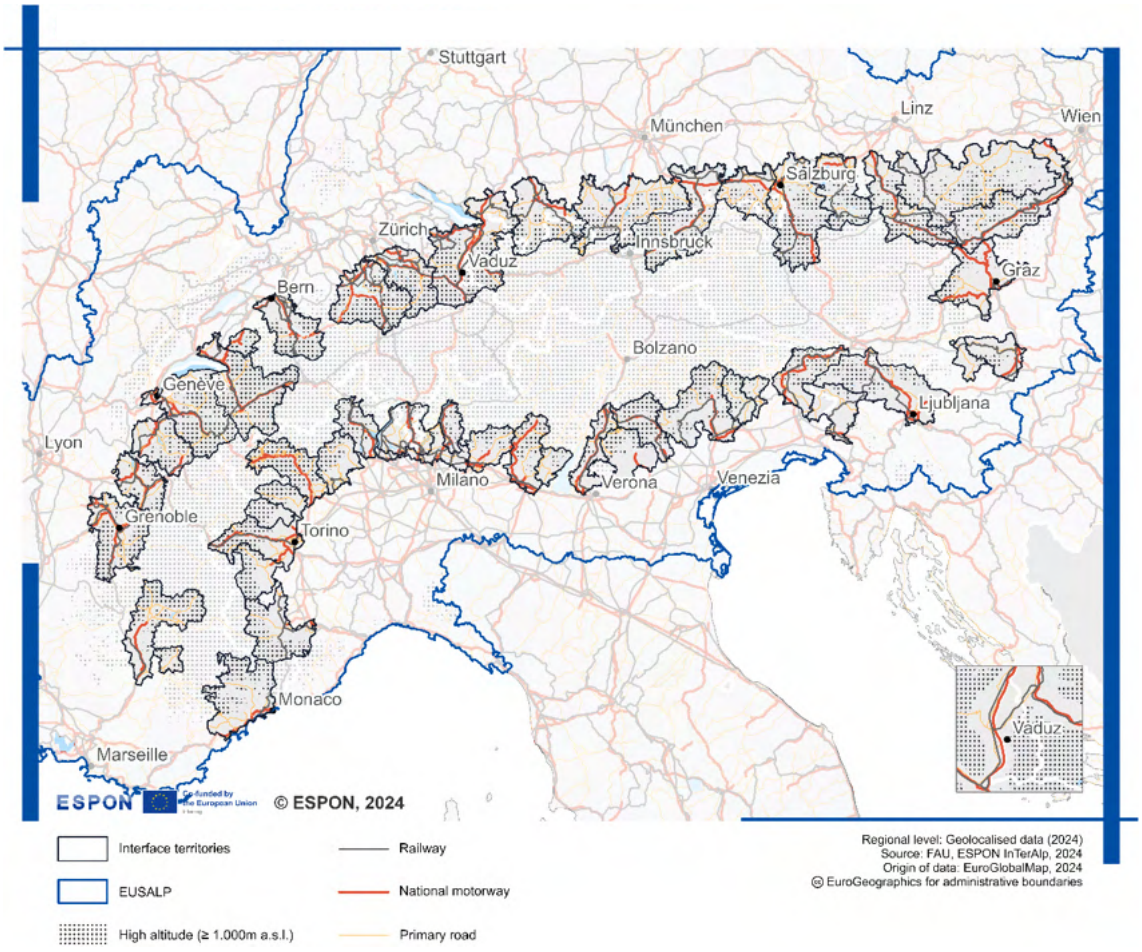
3.3.1 Transalpine gateways and mobility funnels

3.3.1.1 Rail and road infrastructure

The exploration of transport infrastructure and mobility flows in the Alpine region is important to ensure efficient connectivity, reduce urban-rural disparities and facilitate sustainable transport options. Understanding and optimising transport networks is essential to improve accessibility, reduce congestion and promote environmentally friendly mobility solutions in the diverse and morphologically challenging Alpine territories.

Map 15 shows the main transport infrastructure across the Alpine region. The map illustrates railways, national motorways as well as primary roads. The map illustrates several specificities of interface areas: Several interface territories serve as gateway areas. They are territories where the main European transport infrastructure enters the Alpine highlands. Most highly frequented transalpine corridors originate and terminate within Alpine interface territories (e.g. Brenner, Gotthard, Fréjus). Many areas have an important cross-road function, as connections entering the Alpine area and those going in parallel to the relief (e.g. Geneva, Grenoble, Alpine Rhine).

Map 15
Rail and road transport infrastructure



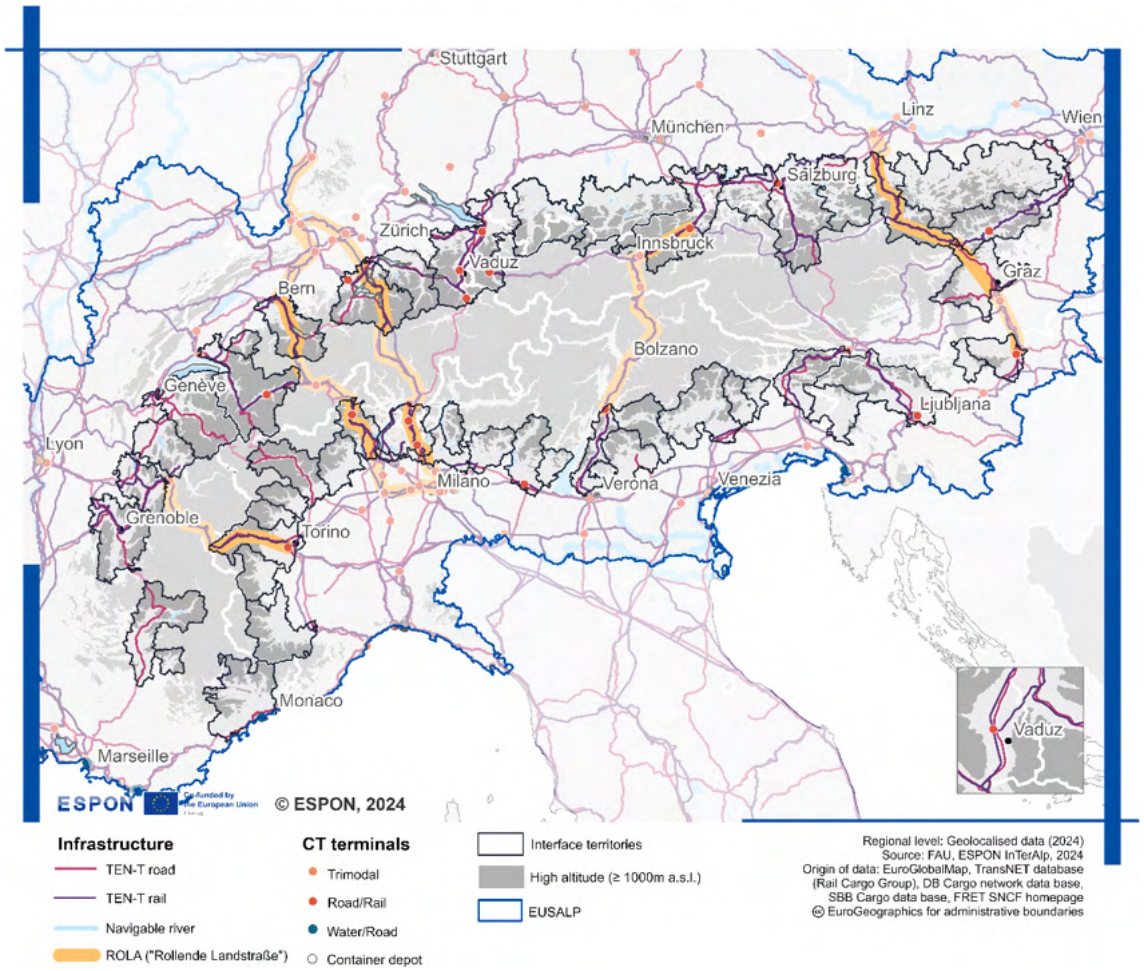
Interface territories are areas in which space for transport is narrowed towards a rather small number of road and railway axes. This comes along with transport and mobility issues that are very prominent

between the lowlands and the Alpine highlands. They are 'burning glasses' for transport and mobility challenges. From a transport and mobility perspective, the mountainous areas are primarily transit spaces or magnets for flows from lowlands (e.g. tourism, recreation, commuting). This results in significant potential for modal split and multi-modal hubs. Effective spatial planning is essential for the transport and mobility sector, particularly in interface territories. The funneling of flows from pre-Alpine areas into narrow transport axes in mountainous areas requires high territorial knowledge for spatial development.

3.3.1.2 Intermodal transport

One of the key concerns in Alpine transport debates is multimodality and modal shift from road to rail. The intermodal freight network is of high relevance in this respect. Map 16 shows Trans-European Transport Network (TEN-T) axes for rail and road as well as combined transport terminals and 'Rollende Landstraße' axes (rolling road is a transport system for intermodal transport on rail, i.e. a train that transports trucks on rail).

Map 16
Intermodal transport



The data on relevant waypoints and connecting axes of the Alpine transport network are based on an extensive desktop research and geolocalisation process (compilation and validation of transfer connections, intermodal nodes/terminals, warehouses, ports, etc.).[5]

Across the Alpine region, combined transport terminals (CT terminals) are mainly located in interface areas, where space is getting 'narrower'. Only a limited number of road and railway axes carry the flows, often in rather small corridors. In this situation, especially core city and semi-urbanized interface areas tend to be 'hot spots' of transport and mobility policies. The argument of *'double demand within half the space'* captures this situation in a condensed way. It reflects that in interface areas the demand for transport infrastructure is often much higher than in most other spatial categories. In addition, several interface areas are part of the wider TEN-T network and are 'gateways' for lowland-mountain transit mobility and transport across the Alpine region.

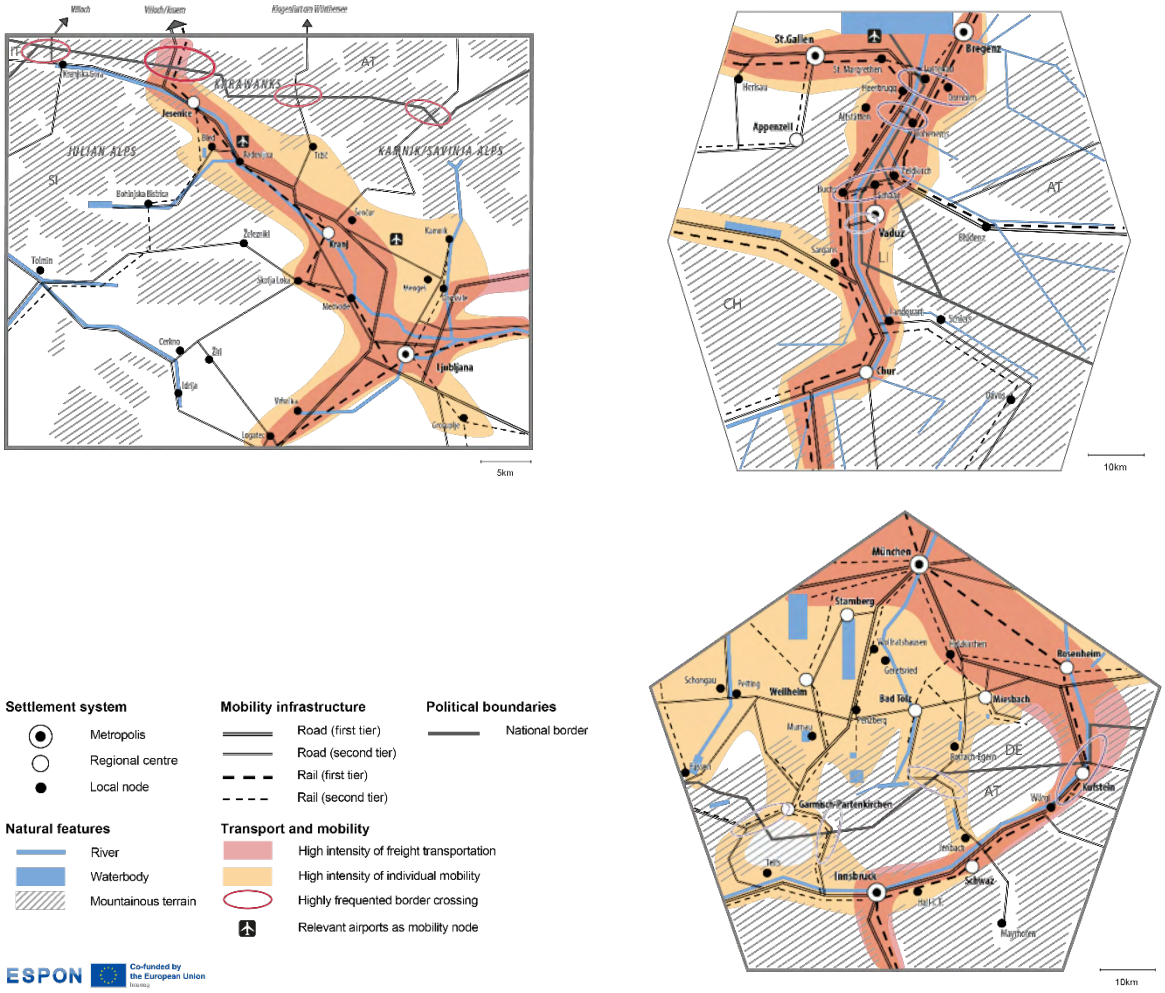
Box 2 shows mapshots on mobility and transport in the interface areas of Ljubljana/Julian Alps, Alpine Rhine Valley and Munich-Tyrol. Overall, the InTerAlp case regions show similarities in their spatial composition and sectoral debates. The spatial development debate on mobility and transport plays an important role in almost all the core city interface areas. Most core cities are logistic hubs and generate high freight traffic intensities, especially in transit corridors across the Alps. These interface territories are to be understood as 'gateways' for transalpine traffic and thus generate discussions on spatial development, including environmental, socio-economic and financial concerns.

In addition, most of the metropolises are located at the foot of mountains (e.g. Munich, Turin, Ljubljana) and generate a high level of individual mobility towards the mountains, mostly for recreational and tourism reasons. Vice versa, the metropolitan nodes attract daily commuting towards the business areas.

5 The cargo/freight groups (e.g. Rail Cargo Group, DG Cargo Group, SBB Cargo Group, FRET SNFC) present relevant data on their homepages as comprehensive databases. This data is compiled, harmonised and visualised for the Alpine region, addressing all interface territories. The EuroGlobalMap and OpenStreetMap function as additional databases to complement existing data. The same approach is applied to implement the rolling road network for the entire Alpine region.

Box 2
Sectoral mapshots on 'mobility and transport' for exemplary InTerAlp case regions

Interface territories of Ljubljana/Julian Alps (upper left), Alpine Rhine Valley (upper right) and Munich-Tyrol (lower right)



Interface territories as geographic funnels

In the Alpine region, interface areas are those regions where available space is becoming increasingly limited. Only a modest number of road and rail axes serve to facilitate the movement of people and goods, frequently operating within relatively narrow corridors. In such circumstances, interface areas frequently emerge as focal points for transport and mobility policy. In the majority of the InTerAlp case regions, the debate surrounding the relationship between transport and mobility in spatial development is a prominent feature of the regional policy landscape. This is evidenced by the high levels of freight transportation and individual mobility observed for example in the case regions of Ljubljana/Julian Alps, Alpine Rhine Valley and Munich-Tyrol. These interface areas are part of the wider TEN-T network and act as 'gateways' for lowland-mountain transit mobility and transport across the Alpine region. Furthermore, these interface areas exhibit a high level of recreation demand and opportunity in close proximity to each other.

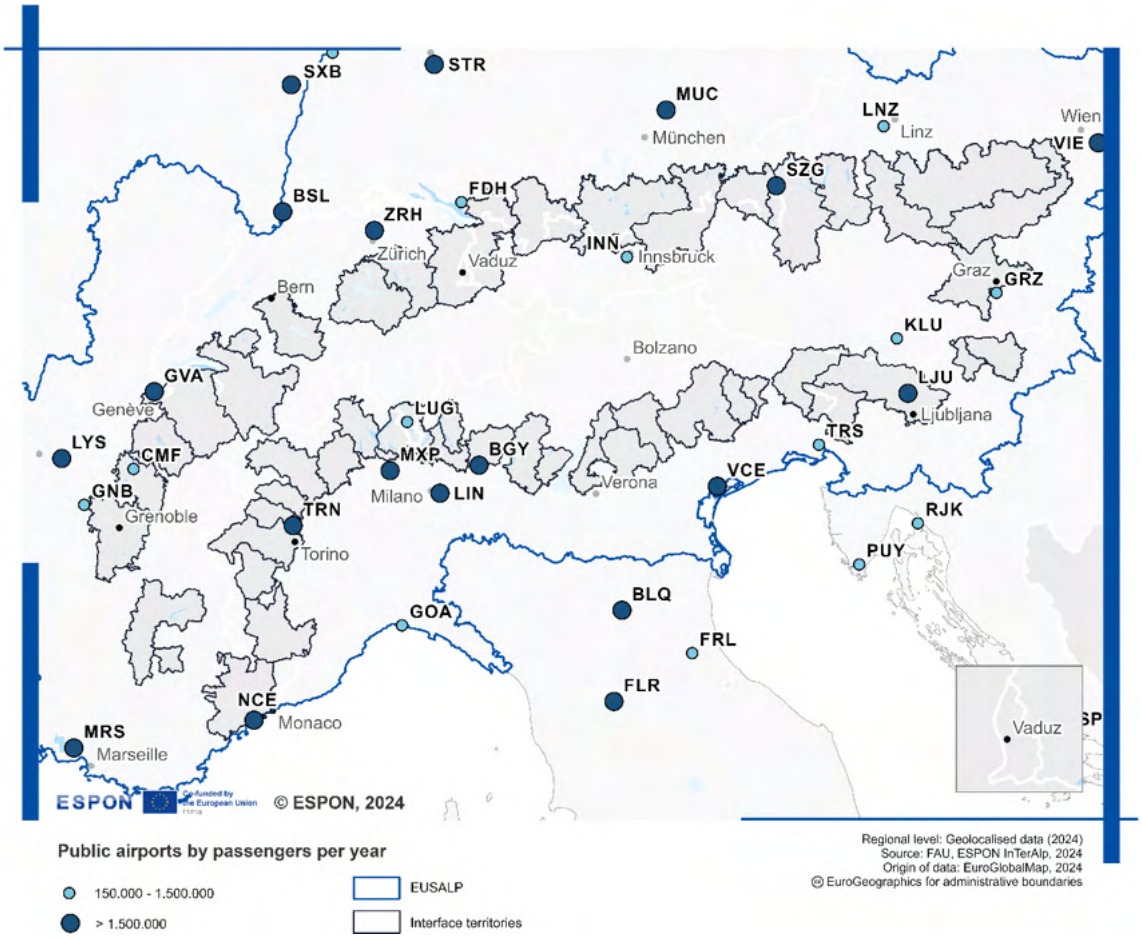
For more information on case studies, see the ***ESPON InTerAlp Case study portfolio***

3.3.1.3 Airport locations

The airports in the Alpine region serve as transport hubs for freight logistics and business flights, thereby integrating the region into the global economy. They play a role in tourism, providing access to the region's tourist destinations and supporting local economies that are dependent on visitors. In addition, airports provide mobility infrastructure for the Alpine population, connecting them to national and international networks.

Map 17 shows public airports ranked by passengers per year. The data refer to the year 2013 and are based on the Eurostat database. Airports, together with railway stations, are transport hubs for international freight and mobility. The map shows that, with the exception of Innsbruck and Klagenfurt, all international Alpine airports with at least 150,000 passengers per year are located in the interface regions or in the peri-Alpine lowlands. With Salzburg, Ljubljana, Bergamo, Turin and Genève, five airports within Alpine interface areas have more than 1.5 million passengers per year. In addition to international freight transport, these airports are mobility hubs for international tourists from outside Europe. Ljubljana airport, for example, is of significant economic relevance for the interface area and beyond as an important logistics and international transport centre. It can be classified as a medium-sized Central European airport, connecting Slovenia with major European destinations and, more recently, with Dubai. Another example is the Grenoble/Rhône-Alpes interface area that also serves as a gateway to the mountains and ski resorts.

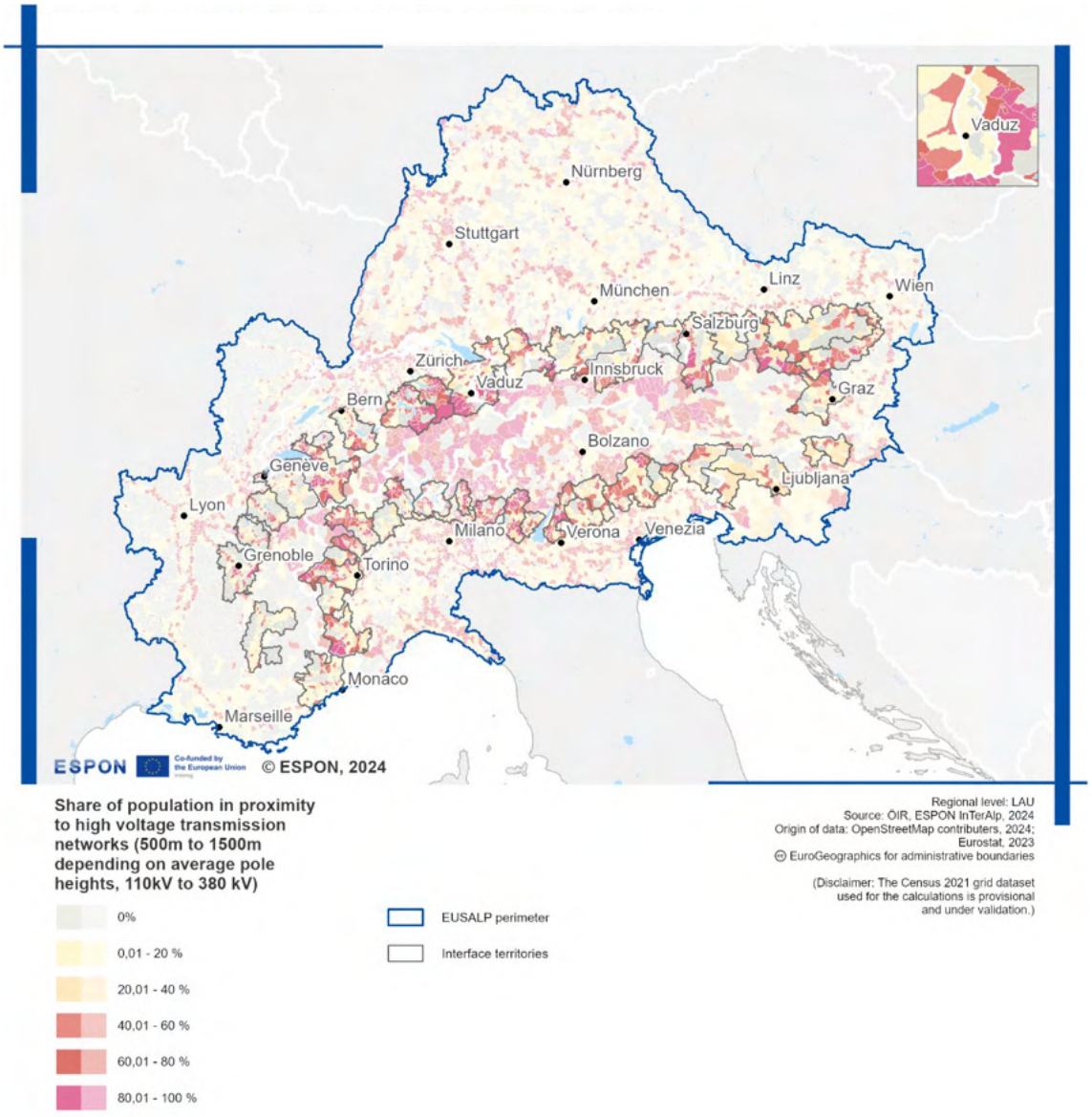
Map 17
Airport infrastructure



3.3.2 Energy transit zones

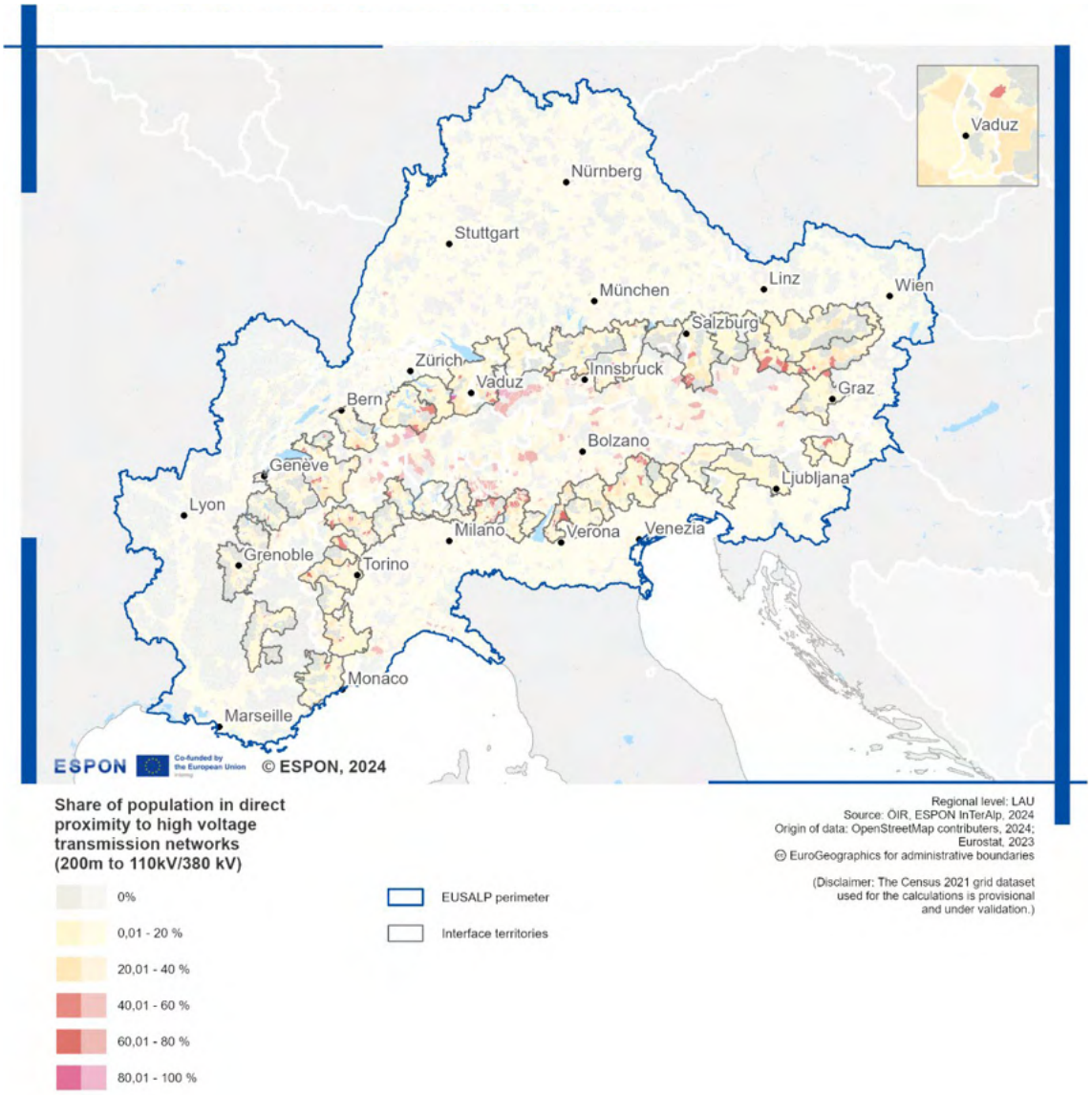
Map 18 and Map 19 visualize the share of population living within visual range (1,500 m) and in direct proximity (200 m) of energy infrastructure, both inside and outside of interface territories. The data is based on Open Infrastructure Map and the Census 2021 population grid and calculated on LAU level. The infrastructure considered is any high-voltage overground energy transport infrastructure. In line with current research, “direct proximity” has been defined as within 200 m of the infrastructure, while “visual range” has been defined based on estimations about pole heights. Thus the range of impact starts at 500 m for 110 kV and reaches up to 1 500 m for 380 kV (and above).

Map 18
Population within visual range of energy infrastructure



The maps highlight that large-scale infrastructure, in particular very high voltage transmission networks (380-400 kV), can be perceived as visually disturbing. Also, they are often seen as a nuisance in terms of noise or (perceived) risk of electromagnetic fields. In confined valleys, the negative effect of such infrastructure on land prices can be challenging for the local population. The potential extent of these aspects is mapped indicating the share of population adjacent to energy infrastructure (within 200 m) and within visual range of energy infrastructure (500-1,500 m dependent on the height of the poles) for interface territories and surrounding regions. Interface territories in this regard show particularly high impacts as compared to lowlands and alpine regions: in Alpine interface areas, about 7,7% of the population live in direct proximity to high-voltage networks (200 m), and 27% are within visual range. A particularly high concentration of regions with higher impacts can be seen in Swiss and northern Italian regions.

Map 19
Population in direct proximity to energy infrastructure



Interface territories are responsible for linking the powerplants from within the wider alpine region with the surrounding lowlands, providing the very different energy sources. This can lead to regional development issues in relation to energy infrastructure, if large parts of a region are affected by the (perceived) negative energy transport infrastructure. As shown by the analysis, alpine interface territories function as 'energy transit zones' linking the power plants from inner-Alpine regions with the surrounding lowlands (see Box 3 as example of the interface area of the Alpine Rhine Valley and Munich/Tyrol). They are however structurally closer to inner-Alpine regions than to lowlands in this regard, as the valley-structure of alpine regions leads to similar spatial development patterns and thus corresponding impacts of energy transport infrastructure.

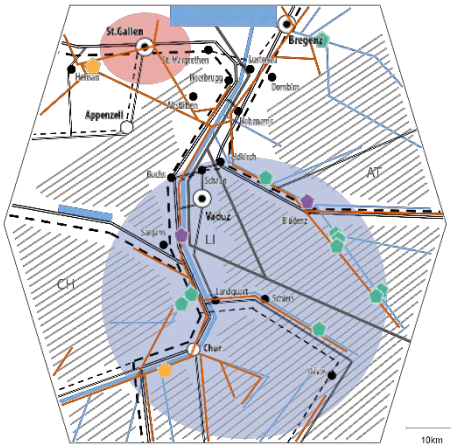
Energy is a highly sensitive issue in the Alps in general, and in interface territories in particular. This involves patterns of production, consumption, storage, transport and of (renewable) energy potentials. Box 3 shows mapshots on energy in the interface areas of the Alpine Rhine Valley and Munich-Tyrol. The energy debate plays an important role for spatial development and is closely linked to the spatial structure of interface territories: Energy is mainly produced in the higher mountain areas, transported through the valleys and mainly consumed in the peri-Alpine lowlands (e.g. Alpine Rhine Valley and Munich-Tyrol case regions). This 'spatial demand' often conflicts with other interests of services of general interest, tourism, transport infrastructure investments and environmental protection and meets on the very limited space. This spatial pattern of production and demand for basic resources is particularly evident in interface territories. These examples illustrate the sensitivity of discussions on spatial development.

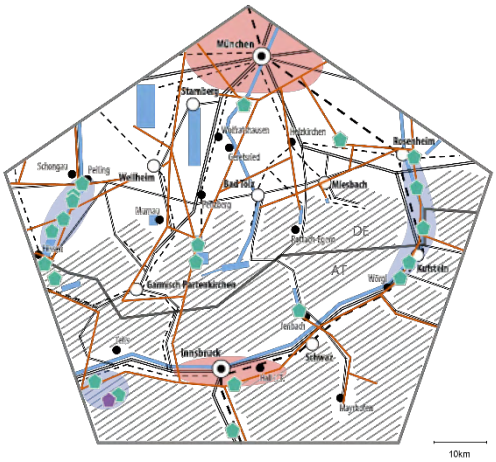
Box 3
Sectoral mapshots on 'energy' for exemplary InTerAlp case regions

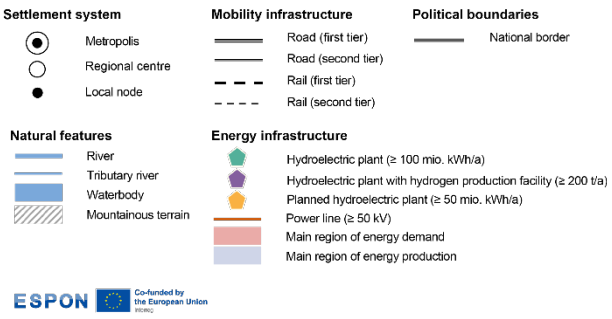
Interface territories of Alpine Rhine Valley (top) and Munich-Tyrol (bottom)

Within the **Alpine Rhine Valley**, hydropower is a central supply of energy. Hydroelectric plants with an output capacity of over 100 million kwh/a are mainly concentrated in the mountainous regions of Vorarlberg (AT). Additional facilities are to be built near Herisau and Chur to ensure energy security throughout the region. These plants pose ecological challenges such as squaring nature conservation with energy production. Moreover, hydrogen is emerging as a significant topic in the interface area, particularly in Switzerland. The canton of St. Gallen has hydrogen filling stations, the St. Gallisch-Appenzellische Kraftwerke AG produces hydrogen, though in relatively modest quantities, and the canton Graubünden is planning to convert a gas pipeline into a hydrogen pipeline.

In the **Munich-Tyrol** interface area, also hydropower is the most important source of renewable energy. The powerplants with a capacity over 10 MW are mostly found alongside major rivers (e.g. Inn and Lech) as well as in the mountainous terrain. While there is no big difference in the number of facilities per country, the installed capacity in Austria is much higher, and capacity expansion is agreed after a long public discussion. The current focus of energy related planning in Germany is on wind power which is far less prominent in Tyrolian planning debates. Power line infrastructure ensures energy transport, comprising two cross-border connections between Germany and Austria. The most important one is the power line via Mittenwald/Scharnitz transmitting high voltage at 220 kV that enables a direct and substantial transport of energy from the biggest powerplants in Austria to Germany. The mapshot shows that energy production capacities are particularly high within the interface territory itself, also because major demand is located in the interface's largest cities of Munich and Innsbruck. This differs from other interface territories that serve rather as energy transit zone.







ESPON Co-funded by the European Union

For more information on case studies, see the ***ESPON InTerAlp Case study portfolio***

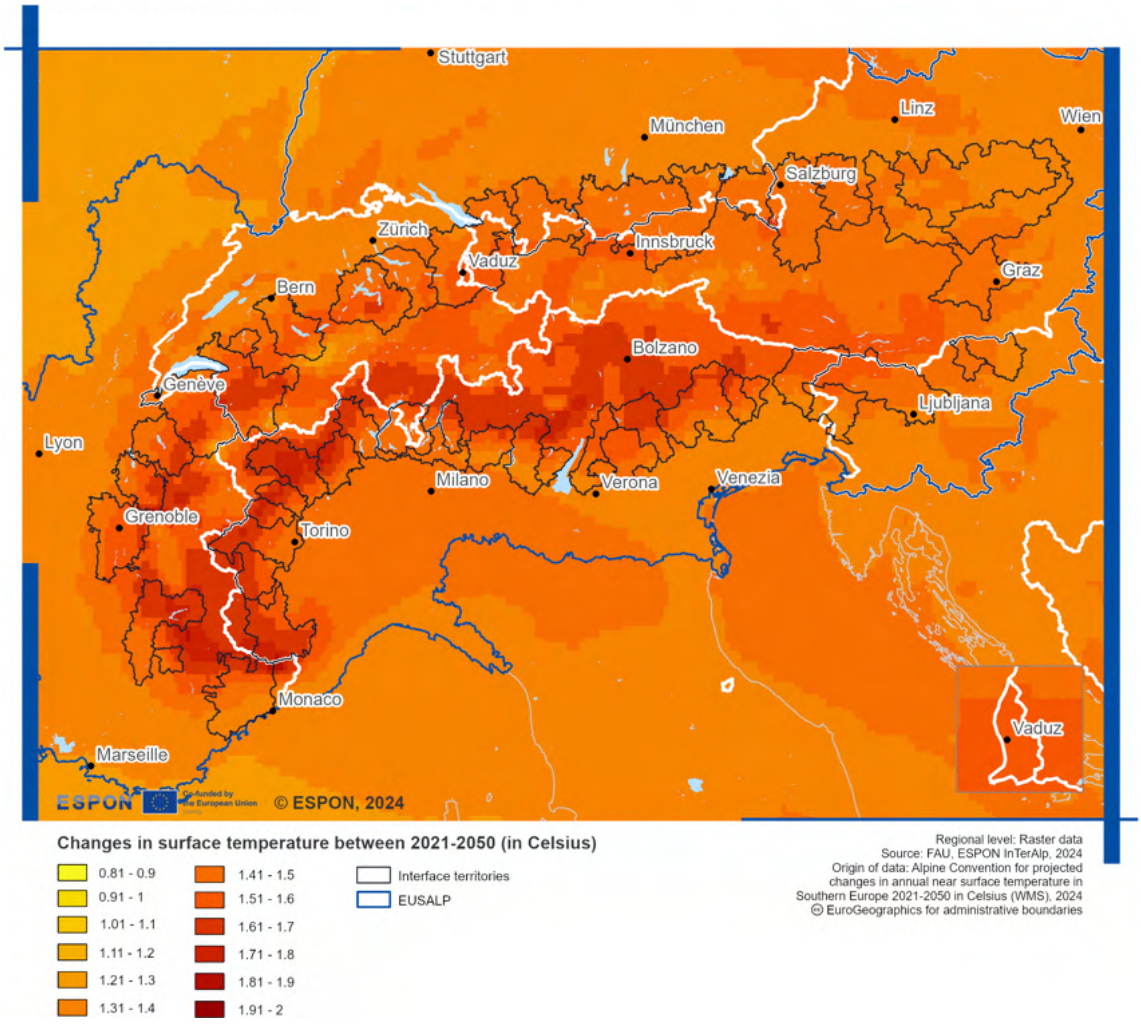
3.4 Territories with common challenges and specific roles

3.4.1 Addressing cross-cutting issues of climate change

Alpine interface areas are sensitive to climate change and related natural hazards. This is due to the high intensity of socio-economic activities, leading to increased vulnerability. It is highly relevant to reflect on the impacts of climate change and natural hazards to develop adaptation strategies that address the increased risks in these areas (e.g. Schirpke & Ebner 2022).

Map 20 shows the projected changes in surface temperature between 2021-2050 (in Celsius). This raster layer shows the projected variation of near surface temperature between the period 2021-2050 and the reference period 1971-2000. Variation of near surface temperature between the period 2021-2050 and the reference period 1971-2000 is obtained as the average of EUROCORDEX rcp45 ensemble scenarios. The layer is accessible through the WMS services at the Alpine Convention Atlas.

Map 20
Projected changes in surface temperature between 2021-2050 (in Celsius)



The spatial pattern shows that the inner-Alpine areas will have a higher surface temperature rise than the surrounding lowlands, or their temperature will change earlier. This is particularly true for the Italian and French interface areas. In these areas, the rural and natural parts are most vulnerable to rising temperatures. This implicates that towns and cities in interface areas have to play a pioneering role in addressing climate change and the economic, social, cultural and environmental impacts of increasing

urbanisation. Early adoption strategies in the face of climate change might create 'first mover advantages' in transformation times.

The Alps in the morphological sense are home to some 14 million people, 30,000 animal species and 13,000 plant species. Climate change is progressing faster in the Alps than elsewhere: Since the end of the 19th century, temperatures have risen by almost 2°C, a rate about twice as high as the average for the northern hemisphere (Alpine Convention 2017). This poses common challenges for the Alpine region in general and for the interface areas in particular. Interface territories show strong environmental and socio-economic contrasts: high population density in close proximity to areas with a high naturalness index, areas with water resources next to areas with high water abstraction, infrastructure in hazard zones and protected areas next to tourism and recreation hotspots. The challenge of temperature change is a cross-cutting issue with significant impacts on several Alpine spatial development topics.

As Europe's main source of freshwater, the Alps are currently experiencing a reduction in snow cover, an acceleration in glacier melt and a shift in precipitation patterns. These changes are leading to a reduction in water availability during the summer months and an increase in the frequency of droughts. It is essential to implement sustainable water management practices in order to maintain a balance between the various demands on this resource, including those from agriculture, households, hydropower, tourism and ecosystem health. The biodiversity of the Alpine region is under pressure as species adapted to cold environments migrate to higher altitudes due to warming temperatures. In this context it is relevant to establish ecological networks to support migration in order to ensure the conservation of biodiversity. This is particularly relevant in Alpine interface areas, where competing interest for scarce available land put high pressure on environmental issues of spatial development, such as ecological networks.

At the same time, natural hazards such as avalanches, landslides and floods are increasing as a result of climate change, with extreme events becoming more frequent and unpredictable. It is essential that spatial planning integrates hazard mitigation strategies using both natural and artificial measures, while avoiding infrastructure development in high-risk areas. Despite the expansion of Alpine forests due to the abandonment of agricultural land and rising temperatures, these ecosystems are becoming increasingly vulnerable to drought, extreme weather events and pests. It is crucial to implement sustainable forest management practices, as forests play a key role in carbon sequestration, the provision of renewable resources and the mitigation of natural disasters.

The following sections address several common challenges and specific roles of interface areas in Alpine spatial development in more detail.

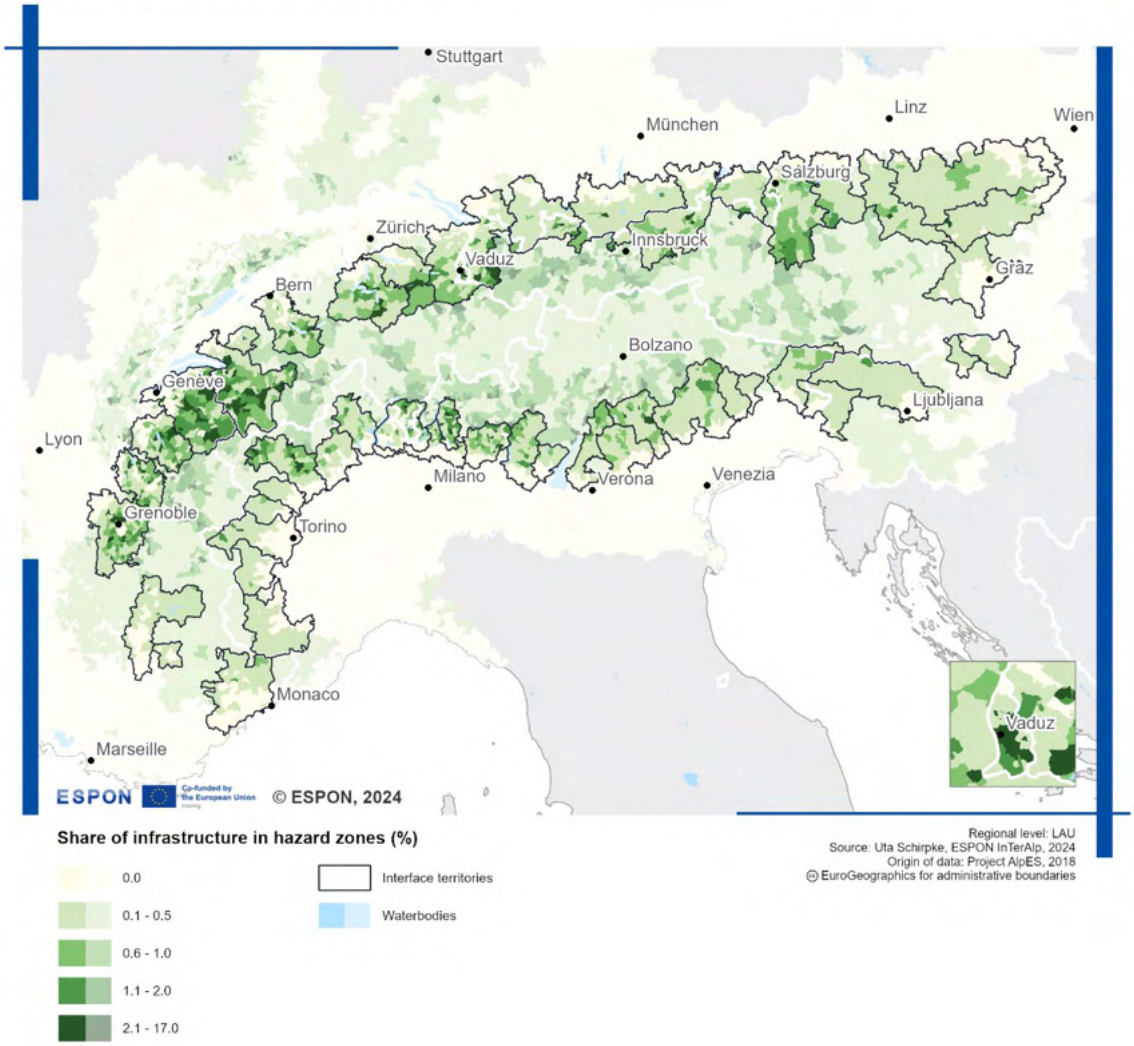
3.4.2 Hazard prevention areas

3.4.2.1 Infrastructure in hazard zones

Map 21 shows the share of human infrastructure located in avalanche and rock-fall hazard zones, representing the demand for protection forest. The indicator quantifies the share of human infrastructure within each municipality located in avalanche and rock-fall hazard zones. The map clearly depicts differences between inner-Alpine and peri-Alpine areas. Due to the high elevation contrasts in the interface territories, these areas also mostly have an elevated demand for protection forest.

Mountain hazards such as avalanches and rockfall can threaten human infrastructures and lives. By quantifying the share of human infrastructure located in avalanche and rock-fall hazard zones, the need for protection measures, such as protection forests, becomes apparent.

Map 21
Infrastructure in hazard zones

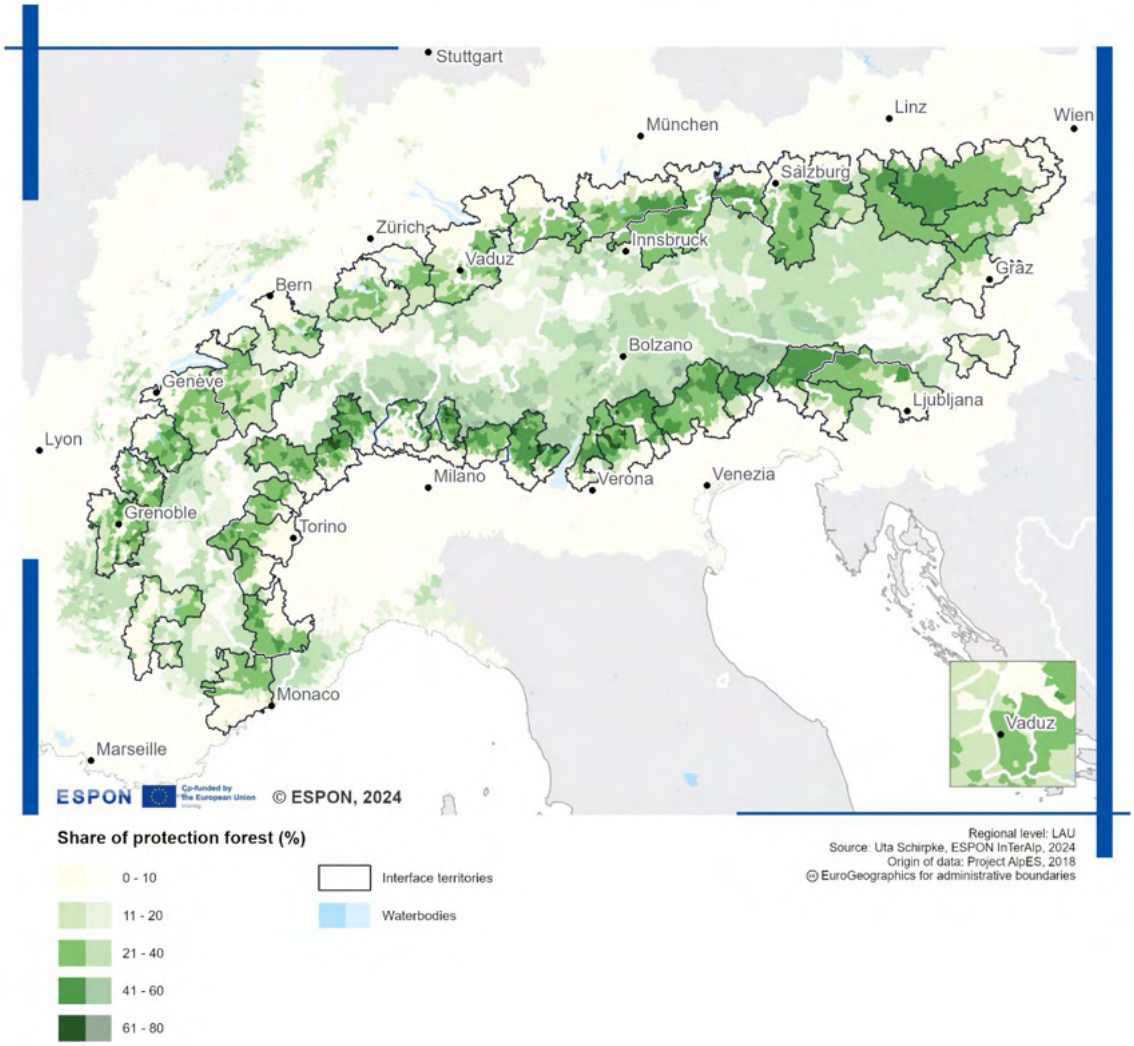


3.4.2.2 Site-protecting forests

Map 22 shows the share of protection forest within each municipality. Protection forests play a crucial role in protecting infrastructure and settlements from natural hazards such as avalanches and rock falls. The indicator site-protecting forest measures the share of forest area within each municipality in general with a protective effect against potential avalanches, rock falls and channel processes regardless whether human infrastructure or settlements are benefitting from the protection forest. Due to differences in topography, the indicator shows differences in the role of protection forest between inner-Alpine and peri-Alpine areas.

Forests contribute to the mitigation of natural hazards and the protection of human infrastructure from hazardous natural processes. The protective function of a forest can vary depending on the hazard. In the case of snow avalanches, the protection of forests lies mostly in the stabilizing effect on the snow cover in the potential avalanche release areas, while the protective effect of a forest against rockfall is strongly dependent on the tree stem density and the diameter to build an actual barrier that shortens the transition zone and runout area.

Map 22
Site-protecting forest

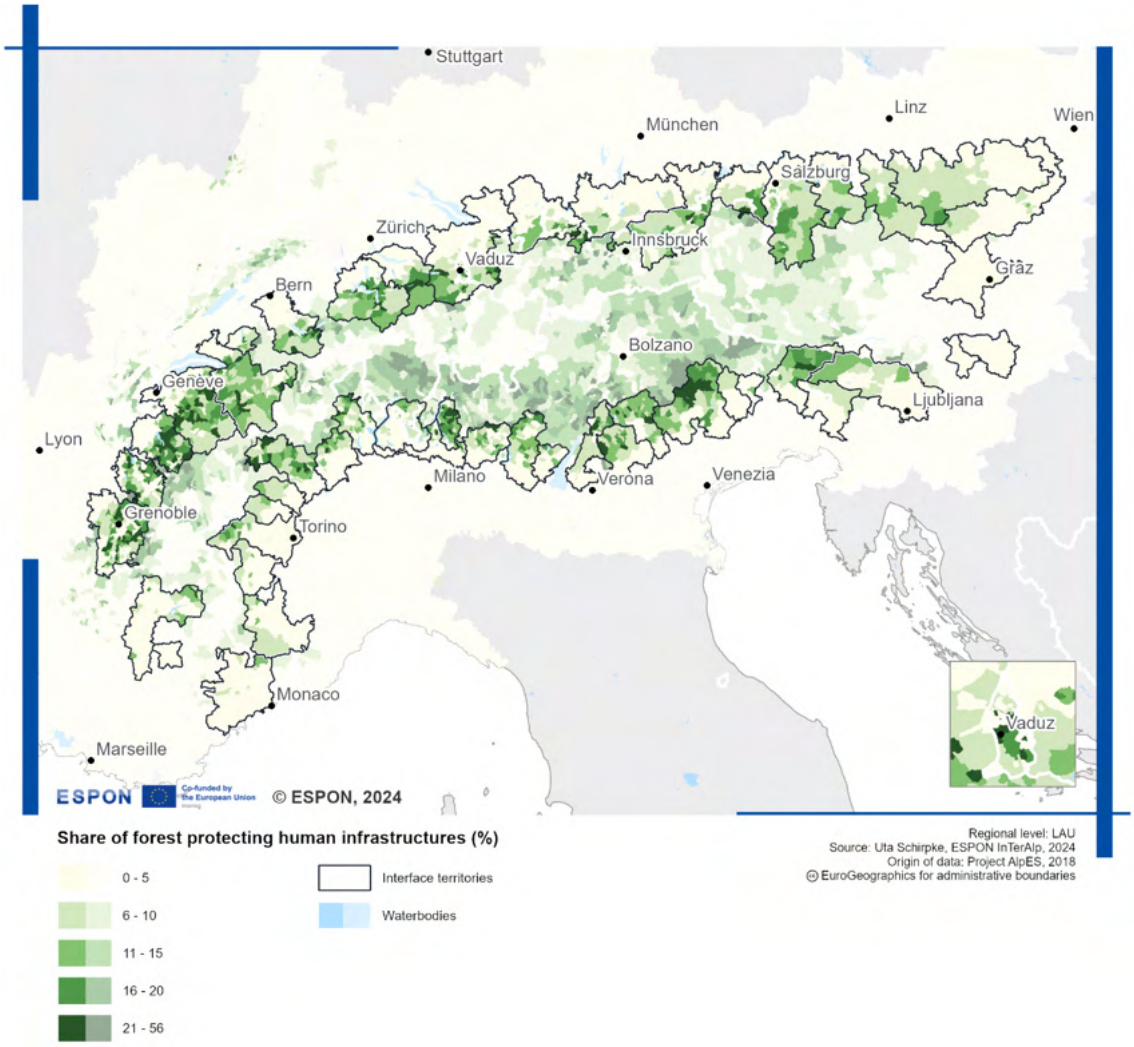


3.4.2.3 Object-protecting forests

Map 23 shows the share of forest area within each municipality with a protective effect for human infrastructure against potential avalanches and rock falls. Due to differences in topography, the indicator shows differences in the role of protection forest between inner-Alpine and peri-Alpine areas.

Forests contribute to the mitigation of natural hazards and the protection of human infrastructure from hazardous natural processes such as avalanches and rockfall. A high share of object-protecting forest can effectively protect human infrastructure and people's lives, while low shares indicate the need to increase the areas of protecting forests or to implement other protection measures.

Map 23
Object-protecting forest



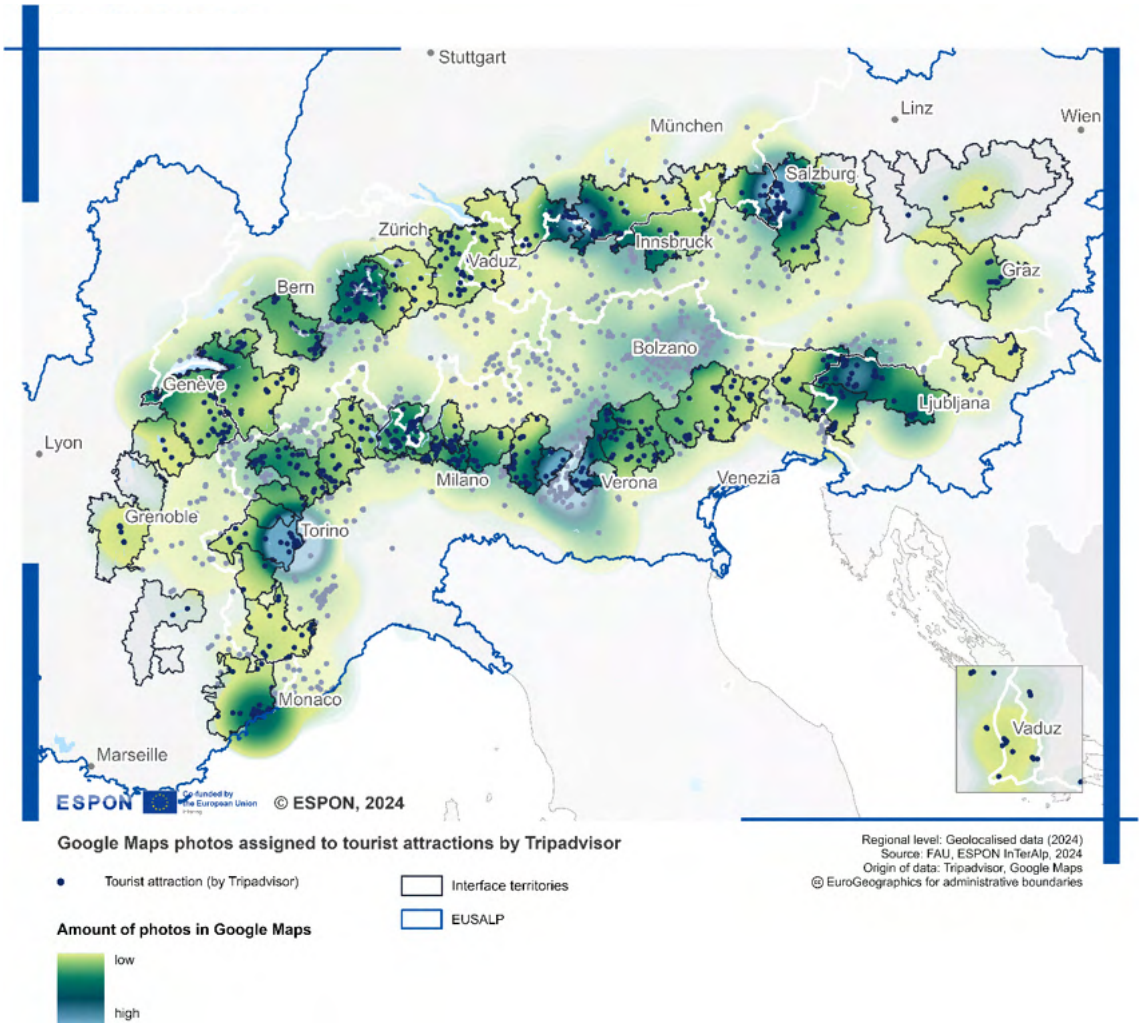
3.4.3 Tourist and recreation areas

3.4.3.1 Tourism hotspots

Interface areas host attractive tourism destinations resulting in significant mobility flows. Map 24 shows tourism hotspots from a pan-Alpine perspective based on Tripadvisor and Google Maps data. The tourism hot spots indicator is an innovative and new indicator focussing on the analysis of social media data. Focusing on tourism as a key economic sector across the Alpine region, our analysis identifies areas with high tourism capacity. By extracting data from Tripadvisor (tripadvisor.com) and Google Maps (google.de/maps) we create heat maps of geo-located touristic points of interest. With data scraping we gather huge amounts of data of popular sightseeing attractions across the Alpine region and reflect on the amounts of reviews and photos uploaded for these points of interest. This reveals tourist 'magnets', enriching our understanding of tourism dynamics.

The visualization demonstrates particularly high numbers of photos uploaded on Google Maps at tourist attractions within interface areas. This magnet function results in challenges for sustainable transport – both in terms of modal shift and accessibility measures.

Map 24
Tourism hotspots

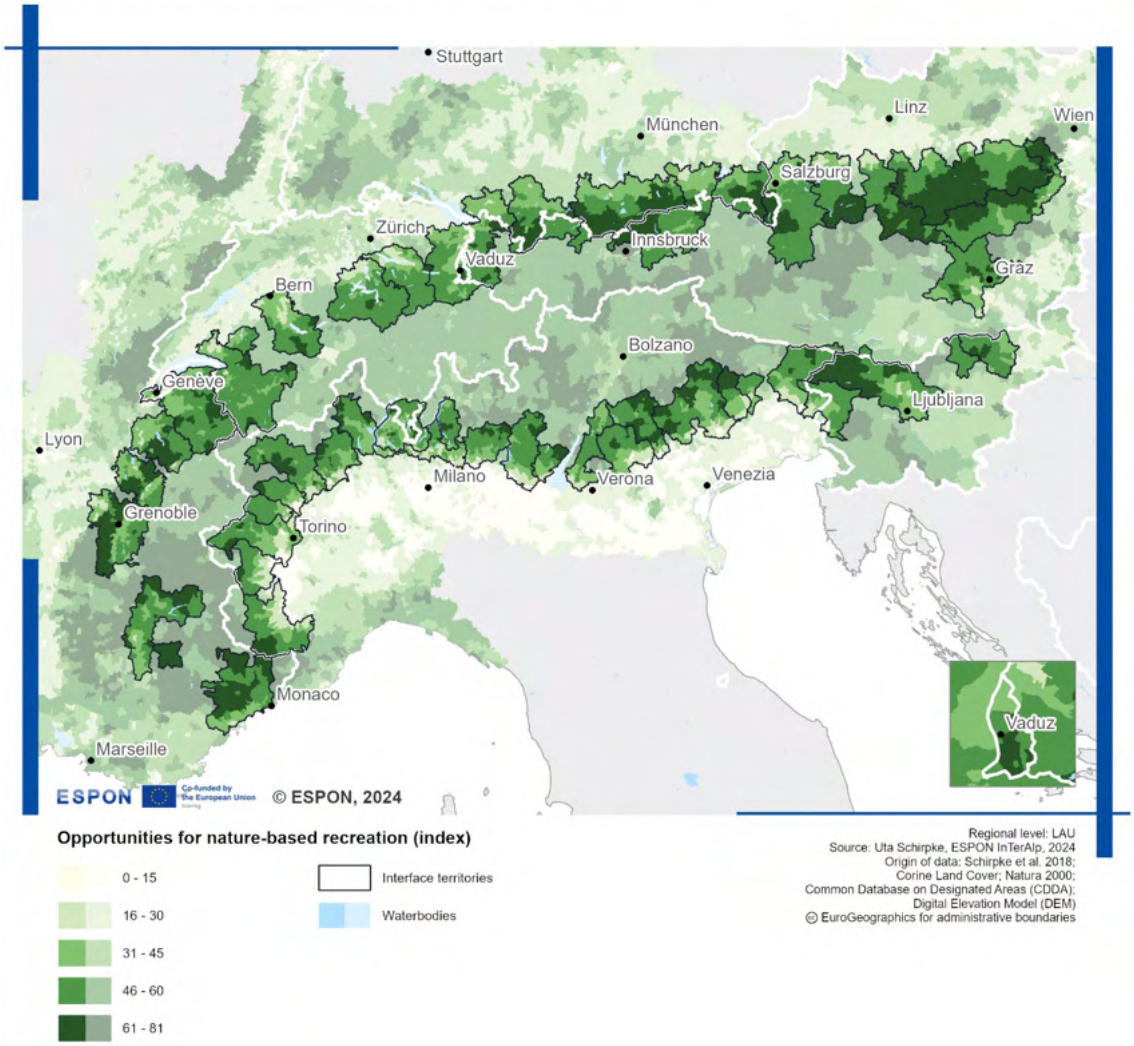


3.4.3.2 Nature-based recreation

Map 25 shows the opportunities for nature-based recreation. This indicator highlights the potential of green infrastructure for nature-based recreation, showing accessibility and potential contribution to the quality of life of the inhabitants. It is a combination of five landscape indicators, including naturalness (preference for more natural environments for recreational activities), protected areas (public recreation areas), landscape diversity (recreational and visual attractiveness of diverse landscapes), terrain ruggedness (recreational opportunities and visual attraction of rough landscapes), and density of mountain peaks (recreational opportunities, overview and visual attraction). The index is weighted by the level of accessibility through infrastructure determining whether suitable recreation areas can be used and how accessible they are. The level of accessibility is expressed through travel time from residential areas.

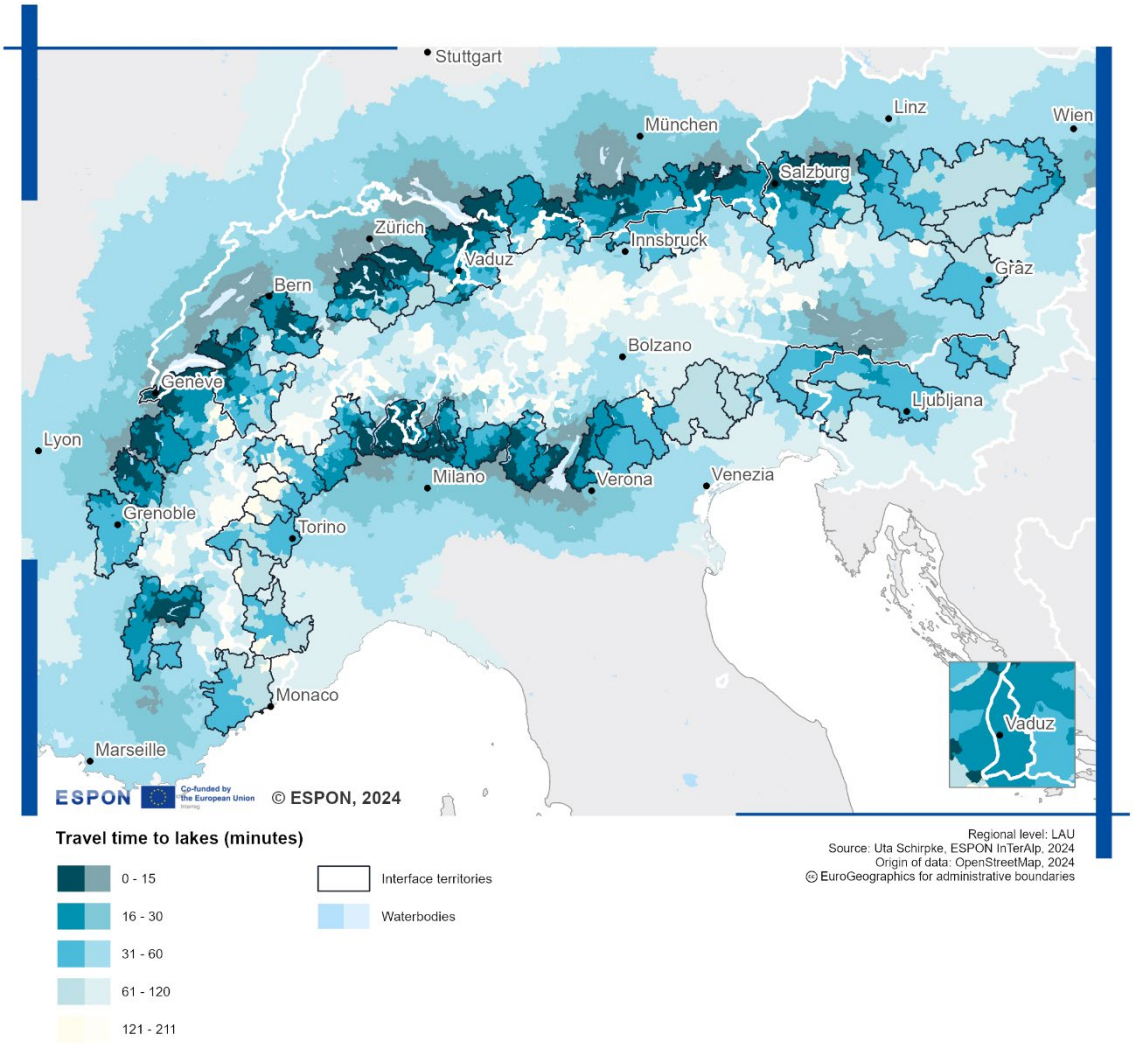
The indicator shows differences between inner-Alpine and peri-Alpine areas: mountain regions are generally characterized by more opportunities for nature-based recreation than lowland areas. The interface territories provide also above-average opportunities across all municipalities located in the Alpine Space area. Due to their high accessibility, they play an important role for the increasing demand for nature-based recreation of people living in the surrounding lowlands of the Alps.

Map 25
Opportunities for nature-based recreation



Map 26 shows the accessibility to water bodies, expressed by the distance from settlement areas through travel time. Water bodies are classified into (1) large lowland lakes (>= 10 km^2) reachable by car, providing opportunities for water-based recreation, e.g., boating, swimming, surfing, and (2) small water bodies (>= 0.02 km^2 and < 10 km^2), providing visual experiences during hiking trips in mountain areas and/or bathing opportunities in lowlands. Travel time to large and small water bodies is summed up at municipal level.

Map 26
Accessibility of water-based recreation



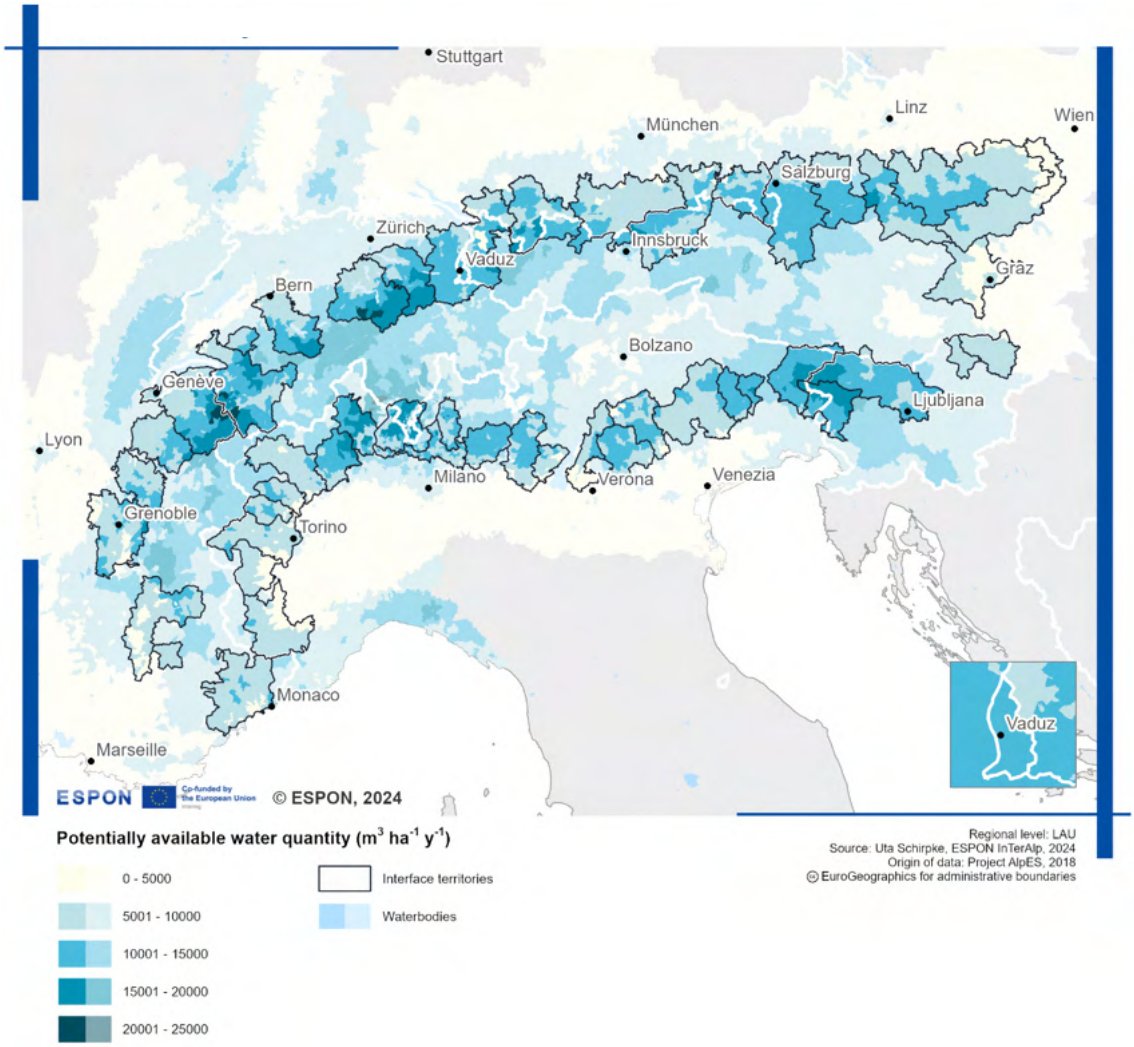
While inner-Alpine areas host a high number of small mountain lakes, which however are often very remote and difficult to reach, the large lowland lakes are predominantly located directly adjacent to and partly within the interface territories. Particularly the northern and southern interface territories offer high accessibility to lakes.

Water bodies are potential recreational centers. By indicating the accessibility and, thus, the potential use of water resources for recreational purposes, mobility needs in interface territories can be understood.

3.4.4 Areas of water infrastructure

Map 27 shows the spatial distribution of potential drinking water supply at municipality level. The index represents the amount of water that is provided by ecosystems, regardless of its actual use. It represents the quantity of water runoff from sub-catchments of the Alpine space estimated by the hydropower model from the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) toolbox based on root restricting layer depth (mm), plant available water content, average annual precipitation, average annual potential evapotranspiration and land use/land cover.

Map 27
Water availability



Due to the prevailing precipitation patterns, the interface territories are characterized by the highest amount of water that is potentially available compared to inner-Alpine and peri-Alpine areas. Mountains play an indispensable role in providing water for different purposes not only to the mountain regions but also to the surrounding lowlands. Urban agglomerations in the peri-Alpine areas such as Vienna, Milan, and Munich, are highly dependent on the water resources from the Alpine areas and, hence, vulnerable to changes in water resources (see also Meisch et al. 2019). Interface territories play a crucial role in providing water resources and they facilitate the distribution of available water resource to the areas of high demand.

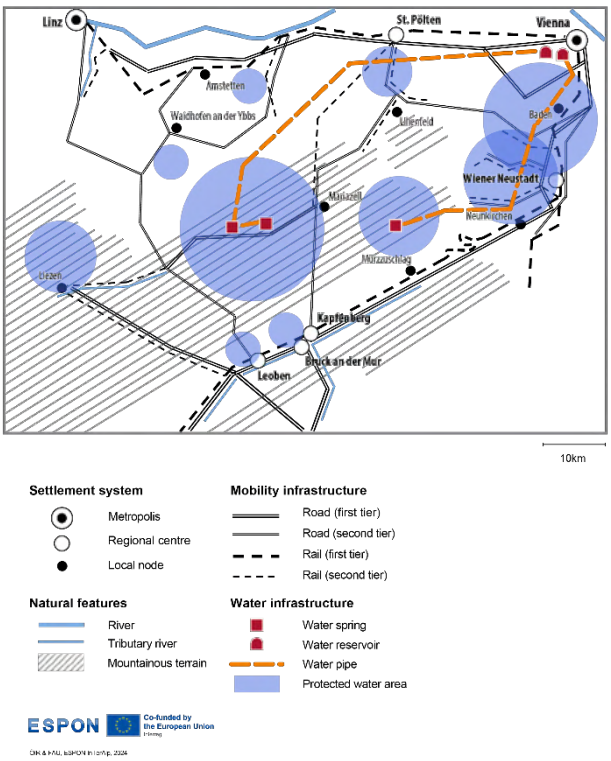
Box 4 shows the sectoral mapshot on water of the Vienna/Lower Austrian Alps interface territory. In the Vienna/Austrian Alps interface area, water for the densely populated city of Vienna mainly comes from the higher mountain areas and is transported through the interface territory.

Box 4
Sectoral mapshot on 'water for an exemplary InTerAlp case region

Water infrastructure in the interface territory of Vienna/Lower Austrian Alps

A specific feature of the city of Vienna is that it is entirely supplied with spring water from the Alps (except for periods of extremely high water consumption in summer). The water resource protection areas, where special rules apply to protect the water from contamination, cover a total area of 675 km².

Water is a key resource for the whole interface area, with particular relevance for the city of Vienna. The water is transported from a number of alpine springs via two pipelines in free fall without pumping stations. The first pipeline (from Schneeberg, Rax and Schneealpe) delivers 220 million litres per day over a distance of 150 kilometres and 30 aqueducts. The second pipeline (from Hochschwab) supplies up to 217 million litres and is 180 kilometres long, including 100 aqueducts. The mapshot shows the main water protection areas and the infrastructure of the high spring pipelines between the Alpine region and Vienna. A secondary aspect of the pipelines is the (albeit small scale) production of energy.



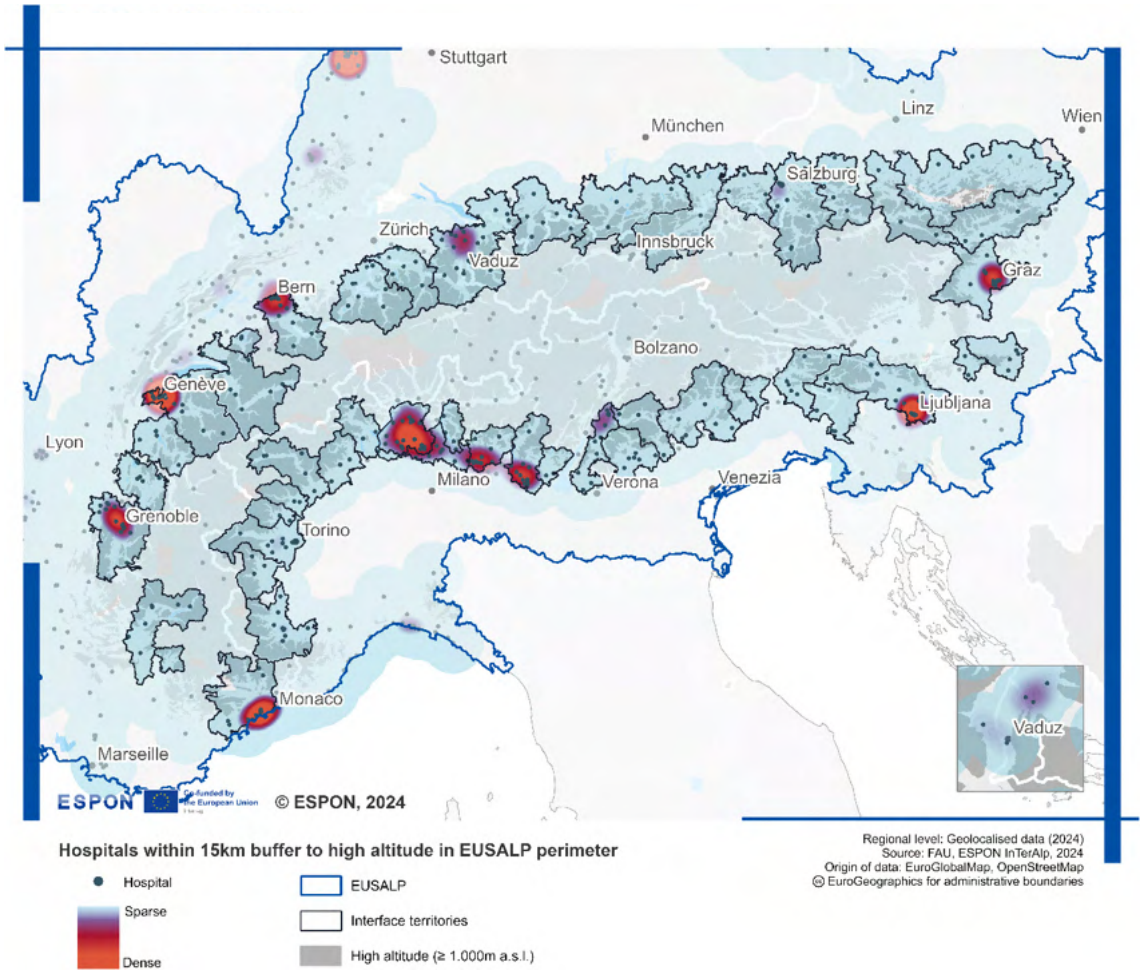
For more information on case studies, see the ***ESPON InTerAlp Case study portfolio***

3.4.5 Agglomeration areas of hospitals and universities

3.4.5.1 Hospitals

Recognising the relevance of services of general interest is crucial to ensuring equitable access to essential services such as health and education in difficult geographical conditions. Map 28 shows hospital locations within a 15-kilometre buffer to altitudes above 1,000 metres above sea level within the EUSALP perimeter. The data is based on OpenStreetMap and an extensive review of relevant OSM-tagging practices and several validation steps. This methodological approach is inspired by ESPON PROFECY and goes beyond the ESPON Alps2050 database. The map shows the locations of health care facilities that provide treatment by specialised staff and equipment, and typically provide care for longer-term patient stays. In total, after data cleaning and validation, the map includes about 700 facilities, defined as hospitals, clinics or doctors' offices with an emergency room.

Map 28
Location of hospitals



The map shows several hospital sites in the inner-Alpine area, mainly in the main valleys. However, the agglomerations of the hospital sites are located in Alpine interface areas. The more intense the red signature of the heatmaps, the higher the density of hospital locations. In particular, core-city and semi-urbanised interface areas show a high density of hospital locations, such as Graz, Ljubljana/Julian Alps, Nice, Grenoble/Rhône-Alpes, Genève, Bern/Thun, Alpine Rhine Valley, Trento and several interface areas in close proximity to Milan. This spatial pattern indicates a high relevance of interface areas for the health of the Alpine population. It also shows the role of small and medium-sized towns in the inner-

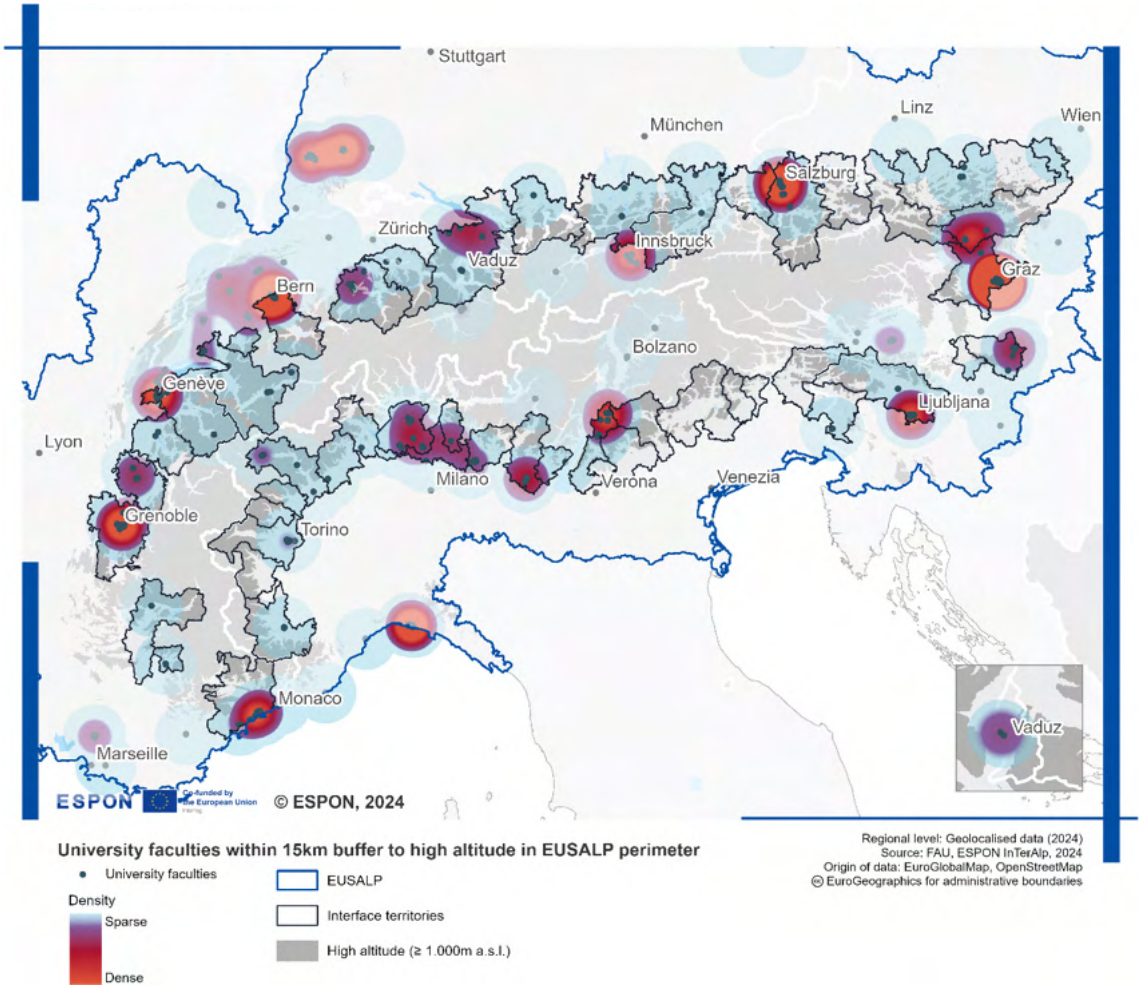
Alpine areas that provide relevant health emergency functions for their surrounding areas that actually exceeds these towns' usual supply functions.

3.4.5.2 Universities

Map 29 shows the locations of universities within a 15 kilometer buffer to altitudes of 1000 metres above sea level within the EUSALP perimeter. As with the hospital locations, the data is based on OpenStreetMap and an extensive review of relevant OSM tagging practices and several validation steps. The map shows the locations of higher education institutions designed to teach and/or examine students in many areas of higher education. In total, after data cleaning and validation, the map includes around 1300 institutions, defined as university campuses and separate university institutes.

Similar to the spatial pattern of hospital locations, the map shows a high density of university locations within Alpine interface areas. In addition to large university campuses, mainly in the core urban interface areas, there are also university locations in semi-urbanised and rural interface areas, such as in Aosta Valley, Vienna/Mürz Valley or Nice. This high density of university locations in interface areas depicts a significant relevance of higher education functions within interface areas. Compared to the high number of hospital locations in the inner-Alpine areas, there are only a few university faculties in the inner parts of the Alps.

Map 29
University locations

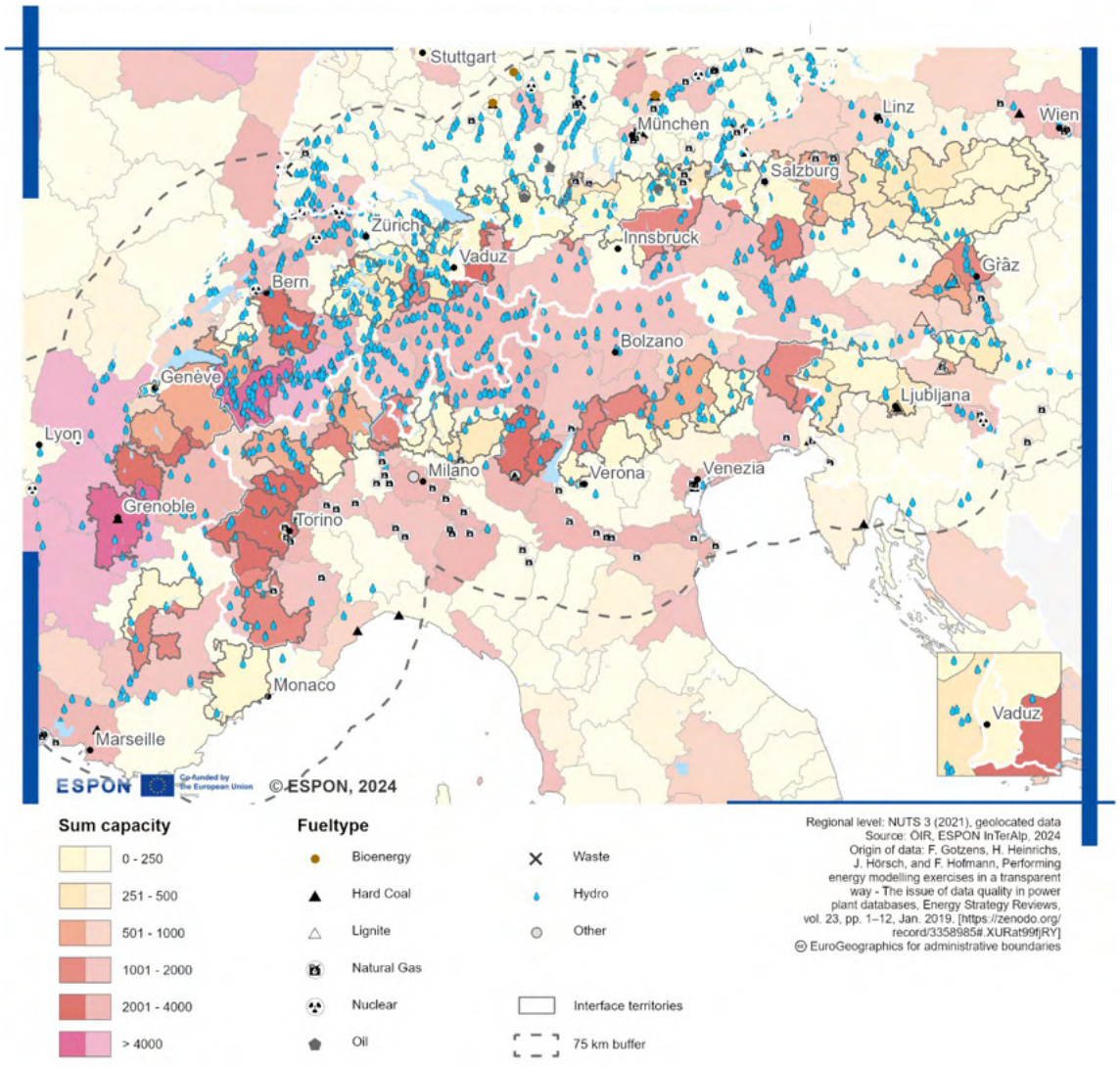


3.4.6 Energy production patterns

3.4.6.1 Powerplants

Map 30 shows the types and capacities of powerplants in the interface territories and neighbouring alpine and lowland regions. Powerplants, in particular hydropower plants represent the most significant 'supply' side information for the energy topic in interface territories. The data is available on EU level and brings together a variety of sources, most notably the Joint Research Centre (JRC) powerplants database. For large-scale energy production, the information is rather complete. Information is spotty for small-scale energy production (e.g. partially including, partially missing small-scale hydropower and small-scale wind/solar power). Where possible, the small-scale sources of energy are thus supplemented with information from different sources (such as Open Street Map (OSM)).

Map 30
Plant capacities (MW), plant types and locations by NUTS 3 region



At regional (NUTS3) level, some of the highest aggregated plant capacities are found within the interface territories, in particular in Swiss and French regions. These aggregated capacities exceed all alpine regions and even most lowland regions even outside of the immediate neighbourhood. In terms of

types of plants, a clear predominance of hydropower is found in alpine regions, which is mostly mirrored by interface territories as well. Only in some Austrian, German and Italian interface territories, other types of plants can be identified (mostly natural gas). Data analysis at a higher geographical level suggests interesting patterns. Energy demand is particularly high in the lowlands just beyond the interface areas, partly driven by industrial centres near large cities, and also due to the inhabitants' consumption. On the other hand, energy production capacities are particularly high in the Alpine regions encircled by the interface territories, but also partially the interface territories themselves.

Beyond interface territories, hydropower is being replaced as the most important source of energy by other forms of production. Broadly speaking, German and Swiss regions show a diverse energy mix including solar, natural gas, biomass and oil based power plants. Austrian regions are characterised by a focus on natural gas and wind power. Slovenian and Italian regions are mainly dependent on natural gas, and several other localised but mostly fossil-type power plants. French regions are strongly dependent on nuclear energy, in line with France's national policy.

In terms of energy supply, interface territories take very diverse roles depending on their location. Most Austrian, German and Slovenian interface territories, as well as many of the Italian and Swiss interface territories are on the lower end of the regional spectrum in terms of energy production. At the same time, besides some German regions they also are on the lower end of the regional spectrum in terms of energy consumption and industrial strength. Therefore, they take a stronger role as "funnels" for energy transport. On the other hand, some French, Swiss and Italian interface territories are among the strongest energy producers in Europe (even outside of the wider alpine area). Energy supply thus is a field, where interface territories cannot be characterized as close to alpine or close to lowland regions but take a very differentiated position.

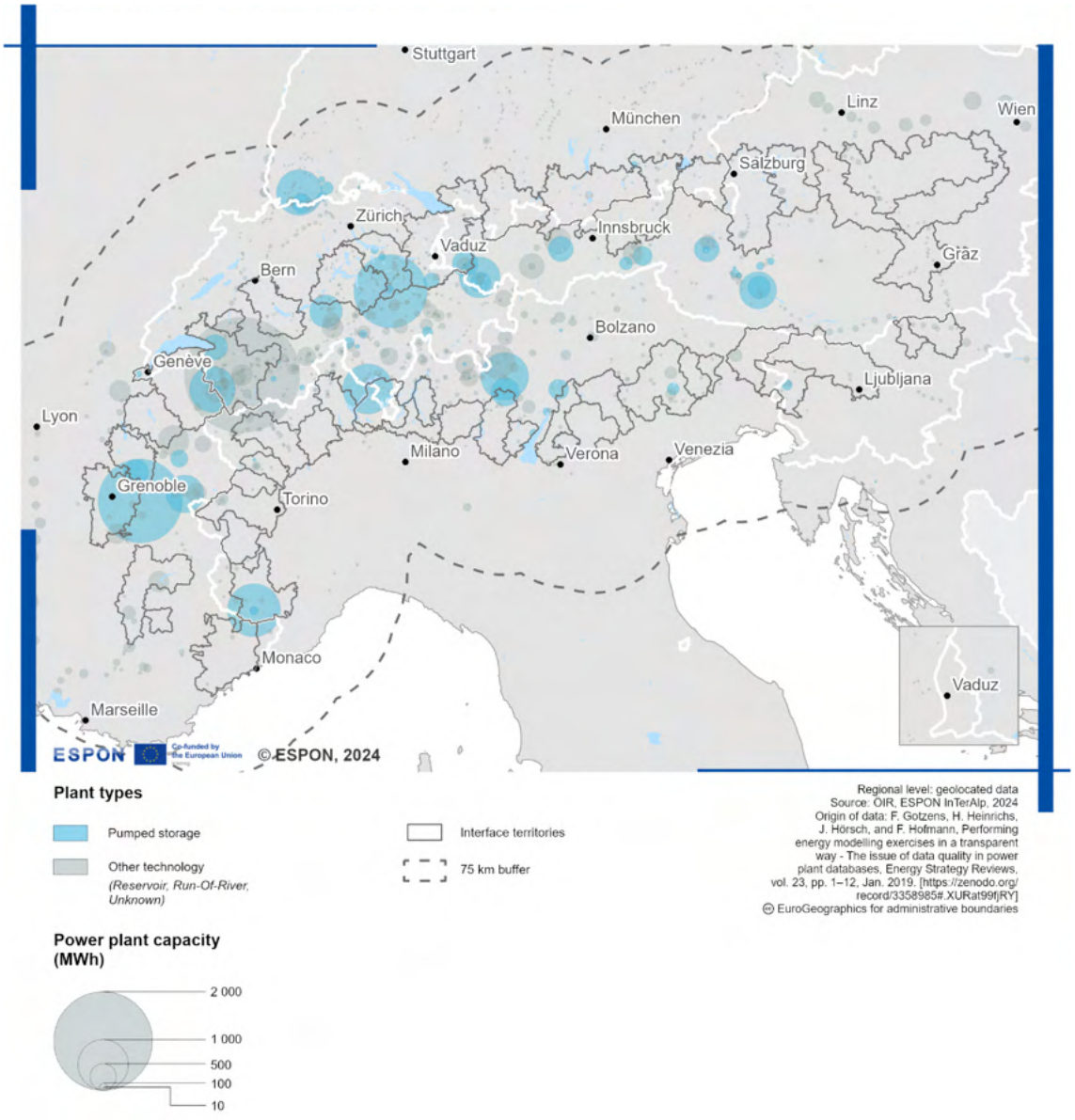
3.4.6.2 Hydropower

Map 31 shows a particular focus on the most important source of energy in the wider alpine area and in particular interface territories: hydropower. Powerplants, in particular hydropower plants represent the most significant 'supply' side information for the energy topic. The data for hydropower plants is available on EU level and brings together a variety of sources, most notably the JRC powerplants database. For large-scale energy production, the information is rather complete. Information is spotty for small-scale energy production (e.g. partially including, partially missing small-scale hydropower).

Pumped storage and Reservoir are by far the most widely used technologies in terms of plant capacity in interface territories. Within interface territories, hydropower is the main source of energy supply. Although only 10% of the hydropower plants are larger than 10 MW, they contribute 85% of the hydropower supply, indicating considerable importance of a few large plants. A very strong east-west differentiation is visible, with growing capacities towards western regions.

In line with the above assessment of energy production capacities and powerplant types on a more general level, the map underscores the particular relevance of (large scale) hydropower in interface territories. In particular, in the western parts of the study area, close structural proximity between alpine regions and interface territories are visible, which are highlighted by the dense infrastructure of hydropower plants. However, the strong dependence of total regional capacities on large-scale plants can be misleading, as such plants naturally provide capacities for areas much beyond their own regional boundaries.

Map 31
Hydropower – plant types and capacities

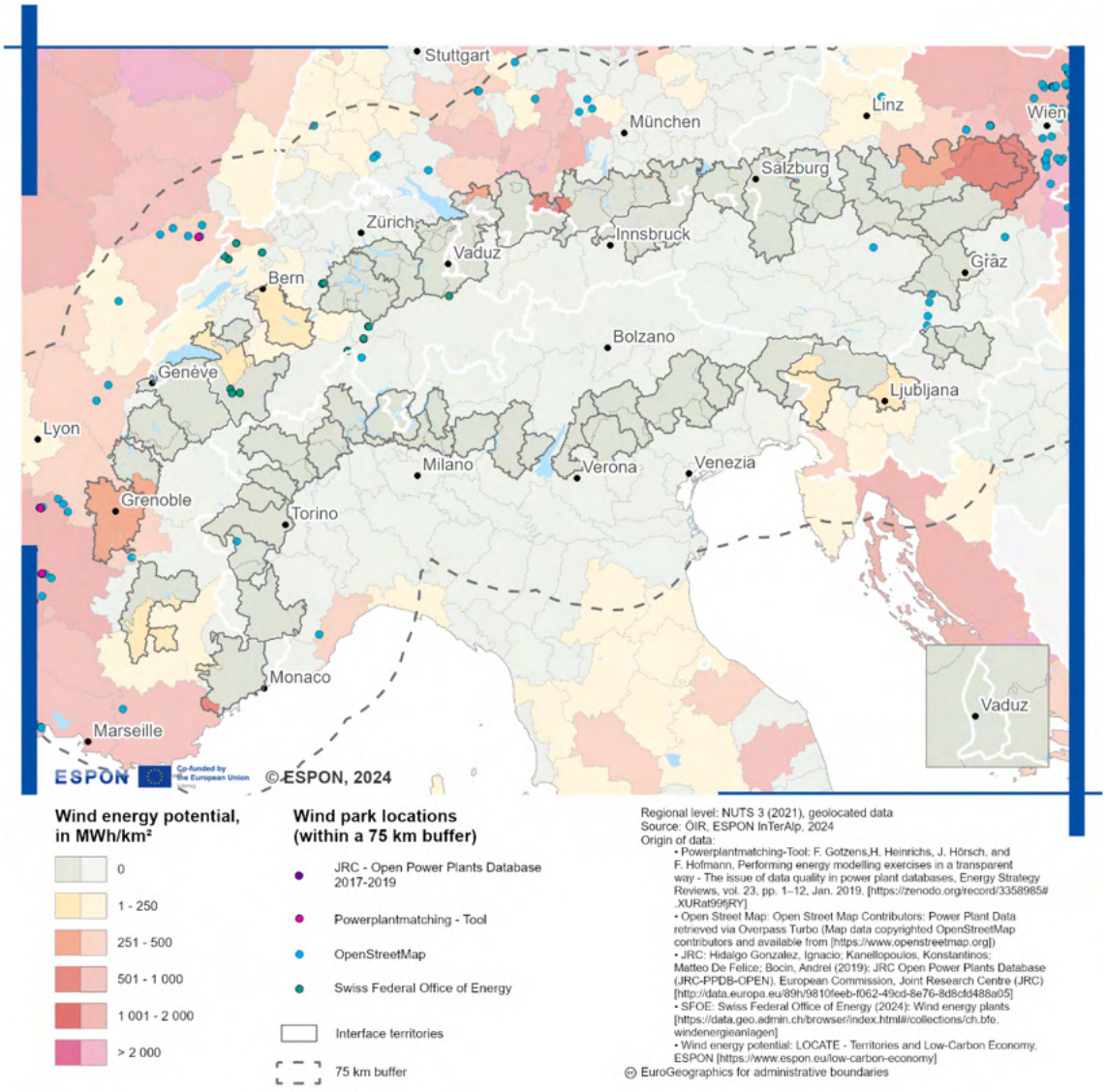


3.4.6.3 Wind energy

Map 32 shows the link between wind energy potential on NUTS3 level and the location of windparks in the study area. A potentially surprising finding is that the majority of interface territories only show a minimal wind energy potential in the European perspective. With the exception of a few, mainly Austrian, German and French regions, all interface territories show close to zero potential for wind energy. This pattern is similarly repeated by surrounding lowlands and by almost all alpine regions. Likewise, only a very limited amount of windparks and wind-turbines are located throughout the area.

Even though both, identification of windpark locations as well as calculation of wind energy potential show limitations in terms of data and methodology, the analysis shows a coherent picture of low potential and low uptake of wind as renewable energy source within interface territories. On the other hand, particularly adjacent regions in Austria show a very high potential for wind energy production and consequently a high exploitation rate. Thus, even though wind energy is a significant element of renewable energy production and partially also decentralised energy production in Europe, it is not of particularly high relevance for interface territories.

Map 32
Wind energy potential (in MWh/km2) and wind park locations



Wind parks and wind turbines due to their smaller nature are not fully covered by harmonised European level databases on powerplants. Location, number and installed capacity of wind turbines and wind parks are thus crucial information when assessing exploited potentials and demand-supply relations on regional level. Open data is available for the entire study area as geolocalised data. Due to the nature of open data it is not possible to fully validate the completeness of information. Information on larger windparks was available from the powerplantmatching tool and has thus been taken from this source. Information related to installed capacity is verified for all windparks included in the powerplantmatching database. Verification for information available on OSM, however, showed considerable gaps, outdated information or erroneous use of units. Thus, only information about locations, not about installed capacities can be used.

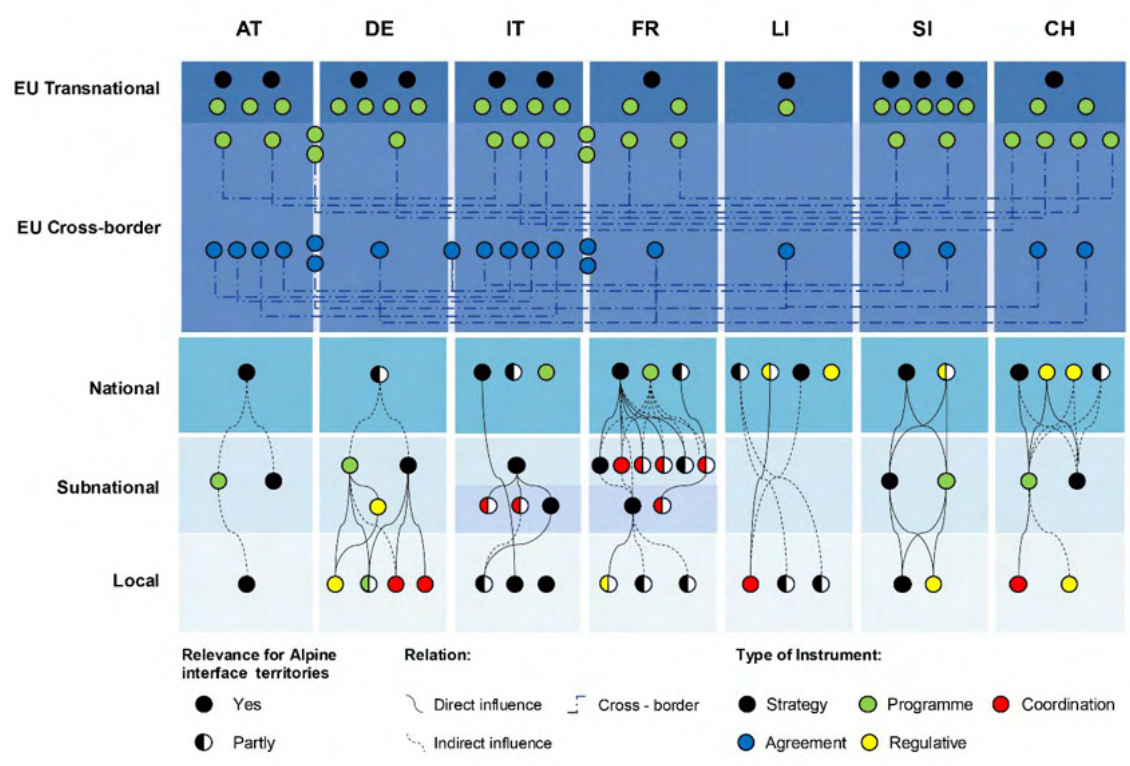
3.5 Territories with no specific governance

3.5.1 Interface territories and Alpine multi-level governance

Spatial governance and planning systems in the Alpine region show a wide range of approaches, reflecting the historical, institutional and cultural contexts of each country (Cotella et al. 2021). While some countries emphasize decentralization and local autonomy, others maintain a rather strong central oversight (see ***ESPON InTerAlp Spatial and sectoral governance in Alpine interface territories***).

Figure 6 provides an overview of the spatial planning instruments in the Alpine region that are relevant for Alpine interface territories. The figure illustrates the interrelationships between the various types of instruments (strategy, programme, coordination, agreement, regulative) and indicates whether they are fully applicable or only partially relevant for Alpine interface territories.

Figure 6
Multilevel institutional mapping of spatial governance and planning in the Alpine region



Furthermore, the figure presents a synthesis of the relevant instruments at the EU cross-border and EU transnational levels, in addition to local, subnational, and national instruments:

- The *transnational level*, in particular the Alpine Convention, the EUSALP macro-regional strategy, the Alpine Space Programme.
- The *cross-border level*, which is characterised by a high number of 'soft' cooperation formats and funding options, even if also the more formalized European Groupings of Territorial Cooperation (EGTCs) have to be institutionalised (Europaregion Tirol-Südtirol-Trentino, EGTC Go, Rhine-Alpine Corridor on a larger scale).
- The *national level*, involving seven countries (some of them with the complete territory, others only partly included): Austria, France, Germany, Italy, Liechtenstein, Slovenia and Switzerland;

- The *regional and provincial levels* (depending on the country: Cantons, Länder, Régions, Metropolitan Cities and provinces etc.).
- The *local level*, concerning a plethora of municipalities ranging from the dense urban areas of Torino and Munich to dispersed inner-mountain municipalities, that enjoy a rather large autonomy in the definition of their local development priorities and the regulation of land-use and spatial planning.

The figure clearly demonstrates the multitude of instruments at the European level that are fully applicable to interface areas. Within the multi-level governance system of the Alpine countries, a number of instruments are only relevant for specific parts of Alpine interface areas. The overview serves to illustrate the considerable complexity of the spatial planning and development instruments that are in play within the Alpine multi-level governance system. It demonstrates that interface areas are territories with no specific governance, situated within a landscape of several spatial planning and development instruments.

3.5.2 Spatial and sectoral governance and planning

The ESPON InTerAlp project reflects on the effectiveness of spatial and sectoral governance and planning in a multi-dimensional but pragmatic way, using a so-called **'degree of integratedness'** as a composite indicator subsuming six different dimensions[6]:

- *Attention to multilevel coordination*, that captures which relevant institutional levels are involved and in what way;
- *Attention to cross-sectoral coordination*, that captures the extent the different sectoral priorities are involved;
- *Stakeholders' engagement and participation*, that captures how the governance framework foresees to mobilise actors beyond the public sector, and opens the decision and policymaking arena to the private actors and the civil society;
- *Cross-border relevance*, which considers how cross-border issues like the interaction with institutions located beyond the national border are foreseen;
- *Congruency with functional patterns*, that measures to what extent the governance perimeters in place fit with functional integration spaces.
- *Alpine specificity*, that addresses how governance structures or instruments take into consideration the particular characteristics of the Alpine region. In other words, the question is if the governance approach foresees to capture the place-based specificities in territorial development.

The performance of the different spatial governance level (i.e. national and subnational)[7] or sector (transport, energy, water) was assessed according to each dimension on the basis of a four-scores Likert scale, taking into account the scoring system presented in Table 3.

6 Four of the six dimensions take direct inspiration by the dimensions of good territorial governance developed in the framework of the ESPON TANGO project (ESPON, 2014). The other two, i.e. 'cross-border relevance' and 'Alpine specificity', have been introduced due to their particular relevance in relation to the subjects at stake. For more information on methods and data, please see the ESPON InTerAlp report on spatial and sectoral governance in Alpine interface territories).

7 Due to the impossibility to survey a representative number of local level instruments, we decided to avoid assessing the degree of Alpine integratedness of local spatial governance and planning, as the results could have been misleading and not necessarily representative of the real situation on the ground.

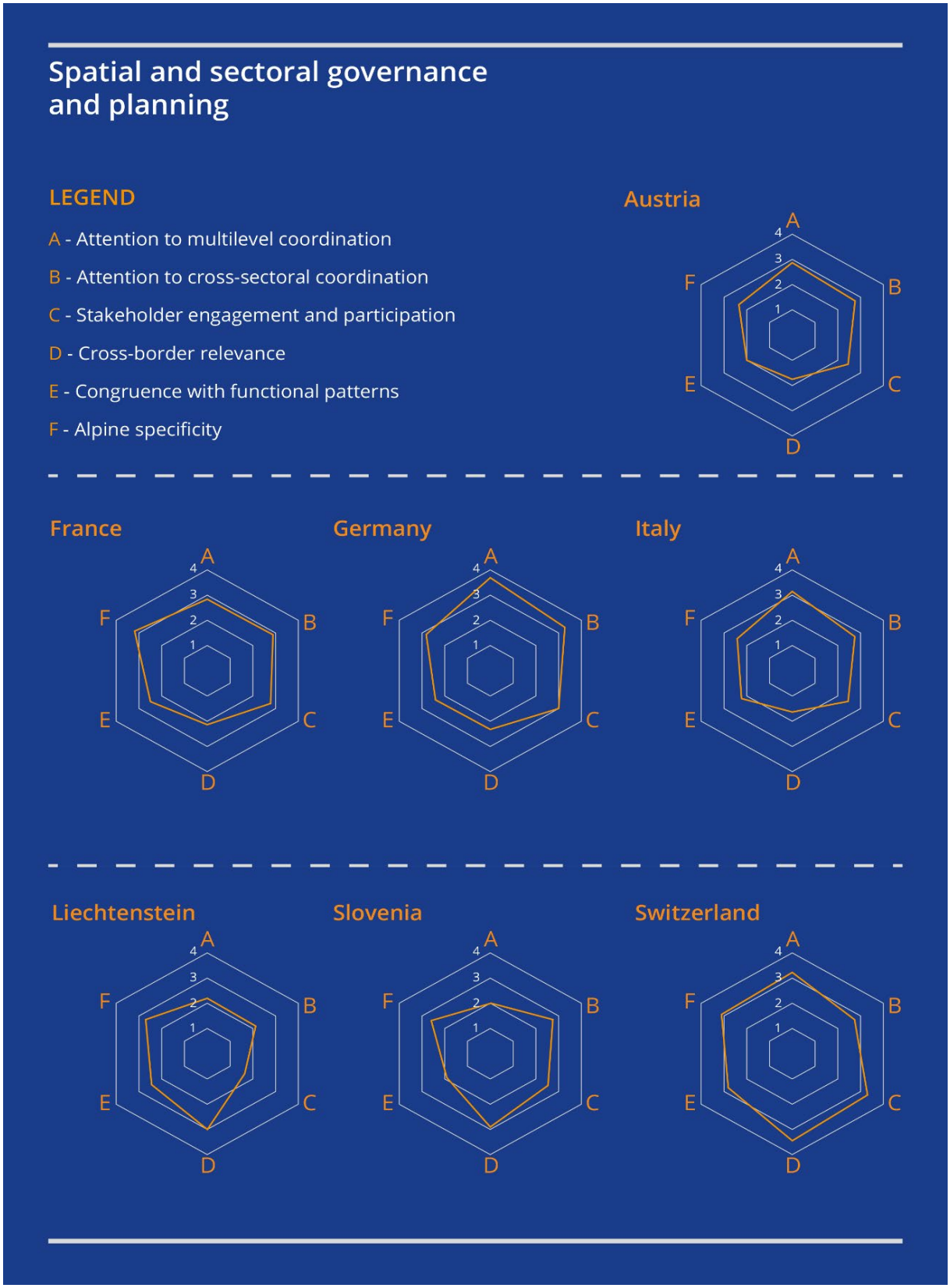
Table 3
Degree of Alpine integratedness – Scoring system

Dimensions	1 very low	2 low	3 high	4 very high
Attention to multilevel coordination	*No coordination between levels or hierarchical institutionalised arrangements*	*Mechanisms of coordination between two levels*	*Structures of coordination and consensus with relevant actors and institutions*	*Full multi-level coordination and cooperation between relevant actors and levels*
Attention to cross-sectoral coordination	*Mono-sector orientation*	*Focus on sectors, but acknowledging the relevance of and inter-dependencies with other policies*	*Attention is paid to addressing and coordinating with selected sectors*	*Multi-sectoral coordination and coherence with a spatial policy focus*
Stakeholders' engagement and Participation	*The role of the public sector is dominant; relevant stakeholders are informed*	*The role of the public sector prevails; selected groups of actors are consulted and/or engaged*	*More than one stakeholder group actively participate in decision/policy-making*	*Participation of broad public and private actors, e.g. final users, inhabitants and businesses.*
Cross-border relevance	*No cross-border logic or implications*	*Reference to cross-border implications is included in the documents/actions but has no direct implications*	*The instruments/actions present an explicit cross-border nature and have cross-border implications.*	*The instruments/actions present an explicit cross-border nature, produced in interaction with actors on the other side of the border.*
Congruence with functional patterns	*Based on jurisdictional criteria / administrative boundaries*	*Open for further spatial considerations based on institutional agreements*	*Integrating functional / case-based criteria*	*Defined by functional criteria and considering potential functional configurations*
Alpine specificity	*No mention of the Alpine area or mountain areas in general*	*Selected instruments/actions refer to the Alpine or mountain areas.*	*The Alpine or mountain areas constitute the focus of selected instruments/actions*	*The Alpine area constitutes the main focus of all instruments/actions*

The results of the assessment were then represented and illustrated through spider graphs that take inspiration from those developed in the framework of the ESPON ACTAREA project (ESPON, 2014). They can be seen as a particular form of institutional mapping, which facilitate a clear and concise representation a complex governance context.

The 'Degree of Alpine integratedness' of governance in Alpine interface areas is based on several testing and validation steps with country experts and a cross-weighting of the assessment (for detailed methodological information, please see ***ESPON InTerAlp Spatial and sectoral governance in Alpine interface territories***). Drawing on the consolidated transnational and country reports (please see **Scientific annexes III to X**), as well as on the adjusted scorings included in the latter, the information collected through the analysis were aggregated and compared, resulting in the comparative analysis presented in this report. Figure 7 shows the summary assessment of spatial and sectoral governance in the Alpine region. After examining the overall performance of the different countries in relation to the six dimensions of Alpine integratedness that have underpinned the analysis, a number of takeaway points are presented for the reader's benefit.

Figure 7
Summary assessment of spatial and sectoral governance in the Alpine region



Attention to multi-level coordination

Germany stands out in relation to the attention to multilevel coordination, featuring a solid and well-structured comprehensive, integrated territorial governance system. Federal, regional, and local governments collaborate effectively, ensuring policies are consistent and cohesive across levels. This integrated approach has proven especially effective in addressing Alpine governance challenges, where alignment across administrative tiers is essential for coherent spatial development strategies. In this light, Switzerland mirrors at least partly Germany's strength as a federal republic, constitutionally guaranteeing vertical and horizontal coordination. Swiss governance fosters the harmonisation of national directives while empowering lower-level entities to implement strategies tailored to local contexts. Examples include the effective role of cantonal governments in integrating national and municipal plans.

Italy also emphasises multi-level coordination, leveraging instruments like the *Strategia Nazionale per le Aree Interne* (SNAI), which bridges national, regional, and local levels. Regional and metropolitan institutions are important in aligning municipal goals with broader strategies. However, occasional gaps in mutual coordination can create inefficiencies. Austria and France demonstrate substantial but uneven attention to multi-level governance. Austria's federal system promotes vertical integration, but its hierarchical tendencies sometimes hinder mutual collaboration. France's focus on inter-municipal cooperation fosters synergies at local levels, yet cross-level integration is less consistent. On the other hand, Liechtenstein's governance shows limited emphasis on coordination beyond the national level, except in specific cases like transport planning. Slovenia's lack of a regional governance tier further hampers its ability to coordinate across scales, creating significant implementation challenges.

Attention to cross-sectoral coordination

When it comes to cross-sectoral coordination, Germany's system appears better suited to align key sectors like transportation, environment, and water management through a collaborative approach that ensures sustainable solutions to Alpine challenges, transcending traditional silos to address complex regional issues effectively. Thanks to the role played by tools like *Schémas régionaux d'aménagement, de développement durable et d'égalité des territoires* (SRADDET), which also streamlines sectoral policies into regional strategies, France's spatial governance system dedicates relatively high attention to multi-sectoral integration, notably in relation to climate, transport, and energy planning, promoting a unified approach to regional development.

Also, Austria, Italy, Slovenia, and Switzerland display moderate efforts in aligning policies across sectors. Austria and Italy integrate cross-cutting policies at regional levels, with Italy's *Piano Territoriale Regionale d'Area* (PTRA) serving as a notable example of linking spatial, infrastructural, and environmental strategies. Slovenia shows a promising development, particularly in coordinating tourism, environment, and transportation policies, although its efforts are uneven at the local level. Switzerland demonstrates cross-sectoral integration in national and subnational planning, particularly with climate and transport policies, though sectoral instruments often operate in isolation. In Liechtenstein, the issue appears to be addressed less prominently, and while some subnational instruments incorporate cross-sectoral elements, national-level strategies rarely emphasise alignment across policy domains, leading to fragmented governance.

Stakeholders engagement and participation

Switzerland is renowned for its participatory governance model, characterised by a longstanding tradition of public consultation and referendums. Almost all spatial planning processes include mechanisms for citizen involvement, ensuring that local voices shape policy decisions. This inclusivity extends to sectoral policies, which are regularly subjected to public input. Albeit to a lesser extent, also Germany emphasizes inclusivity and representation by engaging diverse stakeholders, including local communities, NGOs, and private enterprises, in Alpine governance. Such participation fosters legitimacy and acceptance, creating policies that reflect the interests of all affected groups.

France and Italy show more moderate levels of stakeholders' engagement, with strengths at specific levels. France's collaborative governance is particularly evident in Alpine instruments like *Schéma Interrégional du Massif des Alpes* (SIMA) and *Convention interregional du Massif des Alpes* (CIMA), as well as in

water management. Italy emphasizes bottom-up approaches in local-level instruments like Local Development Plans and SNAI Area Strategies, involving communities in decision-making. However, both countries face limitations at higher governance levels, where top-down approaches dominate.

Austria fosters stakeholder engagement primarily at the subnational level. Participation is most evident in transport planning, while other sectors need more outreach beyond public institutions. Slovenia promotes stakeholder engagement in planning documents but struggles with citizen involvement, particularly in spatial governance. Finally, Liechtenstein shows rather low attention to the issue, and participation is often restricted to voluntary consultations in local-level planning.

Cross-border relevance

Switzerland's territorial governance system focuses on cross-border cooperation and interaction, leveraging initiatives like the Federal Agglomeration Policy and partnerships with neighbouring countries such as France, Germany, and Liechtenstein. These collaborations address shared challenges like water management in international catchment basins and coordinated urban development in cross-border agglomerations like AggloBasel. Also, Liechtenstein and Slovenia demonstrate strong engagement in transnational cooperation. Liechtenstein's Werdenberg-Liechtenstein Agglomeration Association exemplifies its commitment to joint development and public service delivery. Slovenia benefits from its active participation in European Alpine projects, although these efforts could be more evident at the local level.

Conversely, Germany, France, Austria, and Italy show a less prominent cross-border focus. Germany participates in initiatives addressing environmental and infrastructural challenges in the Alps but needs comprehensive strategies on the matter. France and Austria emphasise cross-border cooperation nationally, but local implementation is only sometimes consistent. Italy's cross-border efforts could be more cohesive, with regional strategies offering limited concrete outcomes.

Congruence with functional patterns

Switzerland's territorial and sectoral governance system focuses on integrating functional patterns and dynamics. This mostly occurs through its Agglomeration Policy, which bridges administrative boundaries to address real-world geographic and economic patterns. Local instruments also consider the unique challenges of Alpine territories, promoting cooperation among adjacent areas. Also, France and Liechtenstein emphasise the relevance of functional logic in relation to specific contexts. France’s Alps Massif Committee, basin authorities, and the activity of the LAGs reflect an awareness of functional living spaces. Liechtenstein’s instruments align well with functional patterns, particularly in natural area management. Germany, Italy, Austria, and Slovenia display lower levels of alignment. Germany and Italy acknowledge functional territories in selected regional plans but often fail to incorporate this perspective comprehensively. Austria’s focus on functional spaces is evident in transport planning but not in broader territorial governance frameworks. Slovenia addresses functional patterns in national strategies but struggles with their implementation at the lower levels.

Alpine specificity

Finally, when it comes to the assessment of the Alpine specificity of the analysed instruments and mechanisms, France and Switzerland seem to be best positioned. Switzerland integrates this focus across governance levels, particularly in transport policies and regional development plans. France demonstrates Alpine specificity through national policies and local measures tailored to unique territorial characteristics. Also, Germany and Liechtenstein prioritise Alpine issues, though their efforts are less comprehensive. Germany’s policies address environmental and socio-economic challenges in the Alps, while Liechtenstein incorporates Alpine considerations in instruments like its Climate Strategy 2050.

Slovenia, Austria, and Italy exhibit a more moderate attention. Slovenia and Austria incorporate Alpine considerations selectively in transport and water management but lack overarching strategies. Italy’s regional plans touch on Alpine preservation, but national policies dilute their focus by treating the Alps as part of broader rural or mountainous areas.

3.5.3 Challenges and opportunities for Alpine interface territories from a governance perspective

3.5.3.1 Transnational and cross-border level

Cooperation in regions like the Alpine territories offers significant potential but also brings particular challenges. As communities, governments, and organisations work together to bridge diverse national and cultural landscapes, they must navigate coordination, environmental protection, economic disparities, and funding sustainability complexities. These challenges underscore the intricacies of fostering unified, sustainable development in areas where political boundaries intersect with shared natural resources and cultural ties. Identifying and addressing these obstacles is essential for maximising the impact of cross-border initiatives and ensuring equitable development for all participating regions. Based on that, a selection of challenges is provided (for more information, please see the ***Scientific annex III Transnational and cross-border governance***).

Challenges

- **Coordination across different stakeholders and borders:** Coordinating efforts between local governments, NGOs, businesses, and citizen groups from different countries can be challenging due to varying regulations, administrative processes, and priorities. Achieving alignment requires intensive communication and negotiation, especially in initiatives that span multiple jurisdictions.
- **Environmental and resource management in shared ecosystems:** Environmental issues such as water quality, biodiversity preservation, and climate adaptation are complex in cross-border regions, as natural resources do not adhere to political boundaries. This creates challenges in implementing unified conservation strategies and ensuring sustainable resource use across borders.
- **Economic and social disparities:** Economic and social inequalities between neighbouring regions can make it difficult to implement cohesive development strategies. Differences in economic development, access to resources, and social services require tailored approaches to ensure equitable progress and mutual benefit.
- **Funding and sustainability of grassroots initiatives:** Many grassroots initiatives lack steady funding and formal structures, hindering long-term sustainability. Securing funding from cross-border programmes such as Interreg or maintaining local stakeholder support can be challenging, especially for smaller, voluntary efforts without institutional backing.

Interreg continues to shape regional dynamics in the 2021-2027 phase with an even stronger emphasis on sustainability and climate adaptation. For instance, the Interreg VI-A France-Italy (ALCOTRA), facilitates cooperation between France and Italy's Alpine regions. ALCOTRA has promoted sustainable development through investments in local innovation, environmental protection, and social inclusion, with a special emphasis on addressing the socio-economic and geographical challenges unique to the mountainous Alpine landscape. A key feature of ALCOTRA is its PITER initiative, which offers a model of integrated territorial cooperation, focusing on areas like cultural heritage, sustainable tourism, and regional cohesion. The PITER initiative serves as an example of how cross-border strategies can address shared needs and foster a unified Alpine identity (see Box 5).

While cooperation brings challenges, it also opens doors to many opportunities for growth, resilience, and shared prosperity. Community-led approaches like Community-Led Local Development (CLLD) and frameworks such as EGTCs allow border regions to take control of their development, fostering locally-driven solutions attuned to unique regional needs. Collaborative efforts in environmental conservation, economic partnerships, and cultural exchanges strengthen regional ties and promote innovative governance and sustainable economic growth.

Box 5
Territorial integrated plan (PITER) Alcotra Interreg

PITER

The PITER (*Piani Integrati Territoriali*) territories are part of the Interreg ALCOTRA program, which aims to foster integrated territorial cooperation between regions in France and Italy. PITER focuses on a range of themes, including sustainable tourism, environmental protection, cultural heritage, and socio-economic development in cross-border areas. The goal is to enhance regional cohesion and resilience through coordinated initiatives. The main characteristics of PITER are:

- Integrated approach: Unlike isolated projects, PITER initiatives focus on integrated strategies that address broader regional needs.
- Multi-stakeholder inclusion: PITER promotes the comprehensive inclusion of key stakeholders, ensuring that all relevant voices are heard.
- Participatory strategy development: Each PITER strategy is developed through an inclusive and participatory process. Importantly, each PITER is formalized as an Integrated Territorial Investment (ITI), which is a contract signed by all involved parties, clearly defining objectives and strategic goals.

How Can PITER initiatives inspire Alpine interface territories?
Key lessons that Alpine territories could adopt include:

- **Developing cross-border strategies**: Creating a strategy based on shared local needs, even when those needs span multiple regions and national boundaries.
- **Building a "Sense of Belonging"**: Encouraging collaboration among stakeholders to foster a collective sense of identity and shared responsibility.
- **Establishing a strong territorial identity**: Shaping a cohesive and attractive image of the territory to strengthen regional branding.
- **Integrating multiple projects**: Merging isolated projects into a comprehensive and coherent strategy allows for more significant impact and resource efficiency.

For more information, see the ***Scientific annex III Transnational and cross-border governance***

These opportunities provide a pathway for border communities to thrive together, creating stronger, more resilient regions that benefit from shared resources and mutual support.

Opportunities

- **Enhanced regional resilience through local empowerment:** CLLD and LAGs foster local decision-making, which allows regions to address unique needs more effectively and strengthens community ownership. This bottom-up approach promotes resilience by empowering communities to take charge of their sustainable development, environmental management, and economic growth.
- **Cross-border environmental management and conservation:** Initiatives like River Basin and Wetland Area Contracts might provide a framework for joint environmental stewardship, allowing regions to address ecological challenges collaboratively. This cooperative approach is essential for managing shared resources, mitigating climate change impacts, and protecting biodiversity.
- **Innovative governance models and institutional learning:** EGTCs and other cross-border frameworks offer new governance models that transcend traditional boundaries, enabling local authorities to collaborate more seamlessly. These frameworks provide valuable lessons in multi-level governance, which can be adapted to other regions seeking to improve cross-border cooperation.
- **Increased cultural exchange and social cohesion:** Grassroots initiatives, particularly those focused on social services and health, strengthen ties between communities and foster a shared identity. By addressing social challenges collectively, border regions can build trust and cohesion, enhancing stability and mutual understanding across borders.

These challenges and opportunities come along with several potential contributions of the Alpine Convention, EUSALP and INTERREG that are of high relevance for pan-Alpine spatial development with a particular focus on interface territories (see Box 6, for more information, see ***ESPON InTerAlp report on spatial and sectoral governance in Alpine interface territories***).

Box 6
Pan-Alpine potentials for spatial development in Alpine interface territories

Alpine Convention

The Alpine Convention is conceived as an intergovernmental treaty for the protection and sustainable development of the Alps. It has the potential to significantly contribute to the agenda setting and recognition of interface territories. Across the different sectoral and working groups and activities, the Convention could emphasise the importance of these interface territories as part of a new spatial and governance geography. Amongst others, Alpine interface territories can also be considered in Reports on the State of the Alps. This geography could be central in fostering a more place-based and territorially sensitive approach:

- Identifying territorial dynamics that stem from existing planning and cooperation practices (whether formal or informal) within interface territories.
- Investigating and testing the existence of any political convergence (explicit or implicit) towards this new geographical framework.
- Involving local actors in the Alpine Convention's governance process through specific tools, such as establishing a "Forum of Alpine interface territories."
- Encouraging local actors to adopt a proactive approach, raising awareness of the strategic and operational importance of Alpine interface territories.

EUSALP

The EUSALP offers an important platform for discussing Alpine interface territories, in particular as its perimeter comprises all interface territories. By promoting transnational cooperation, this strategy can develop a common approach to support the Alpine interface territories through a cooperative perspective. Across the EUSALP's sectoral Action Groups, it might contribute to:

- Providing technical and political support to solidify the role of Alpine interface territories, in line with EU strategies and policies.
- Building a common (transnational) approach to this new “geographic category” by acknowledging their unique status.
- Understanding and promoting their needs and potential in terms of fair and balanced territorial development.
- Targeting these territories with specific, ad hoc initiatives. This could become easier if they are included in post-2027 discussions.

INTERREG Alpine Space and cross-border programmes

The Alpine Space programme as well as the cross-border cooperation programmes offer relevant platforms of territorial cooperation: this can actively promote tailored-made projects within interface territories. The programmes' scale and objectives align well with the geographic distribution of many Alpine interface territories. In this respect, territorial cooperation programmes can support the Alpine interface territories when it comes to:

- Promote new forms of formal (or informal) cooperation values through which emerge or consolidate existing cooperation initiative formats.
- Promote ad hoc projects or a set of projects that specifically target these territories.
- Funding new emerging governance experiences which implement various models (see the case of PITER promoted by the ALCOTRA programme).

For more information, see the ***Scientific annex III Transnational and cross-border governance***

3.5.3.2 National level

Assessing spatial planning systems across the Alpine countries reveals several key challenges and opportunities for the Alpine interface territories.

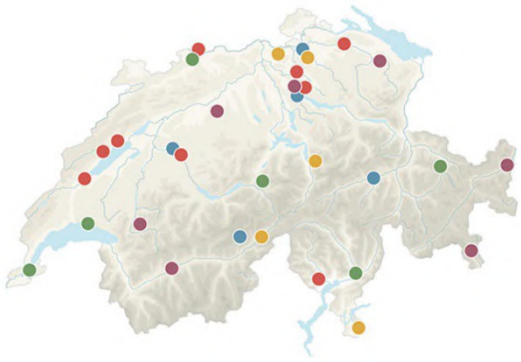
Multilevel governance and coordination complexities: The diversity in governance structures across Alpine countries - from strong federal systems in Switzerland and Austria to more centralised approaches create coordination challenges. These territories are influenced by various national, regional, and local policies that may not always be aligned. Accordingly, ensuring coherent planning across national and regional borders remains challenging, especially when addressing shared resources like water, biodiversity, and land use. However, with solid federal-local cooperation, countries like Austria and Switzerland provide models for improved multilevel governance. In particular, the *Swiss Agglomeration policy* logic can be used to support collaboration (see Box 7). In addition, multilevel coordination could be improved through better use of EU frameworks and funding mechanisms (e.g., INTERREG, Alpine Space Programme), which promote collaboration across governance levels.

Box 7

Federal Agglomeration Policy, Switzerland

Politica degli agglomerati / Politique des Agglomérations / Agglomerationspolitik (AggloPol) (Federal Agglomeration Policy), Switzerland

2001 - Regulative



2020-2024 Sustainable Land Development Model Projects.
Source: Ufficio federale dello sviluppo territoriale (ARE)

With the Agglomeration Policy the Swiss Federal Government aims to promote the sustainable development of agglomerations, including the cities and municipalities that are part of them. This transversal policy is implemented with a series of specific measures and instruments that complement other sectoral policies (i.e., transport policy or social policy) and that, in turn, contribute significantly to the development of agglomerations. Implementation requires the involvement of actors at the level of the Confederation, cantons, regions, cities, municipalities, and the bodies and organisations responsible for development in functional spaces. Together and in collaboration with private actors, they contribute to the development of agglomerations and the coherent territorial development of the country. The updated Federal Agglomeration Policy has a "networks of cities" approach. It is based on a tripartite system including confederation, cantons, cities, and local governments.

What are the benefits of Agglomeration Policy for Alpine interface territories?

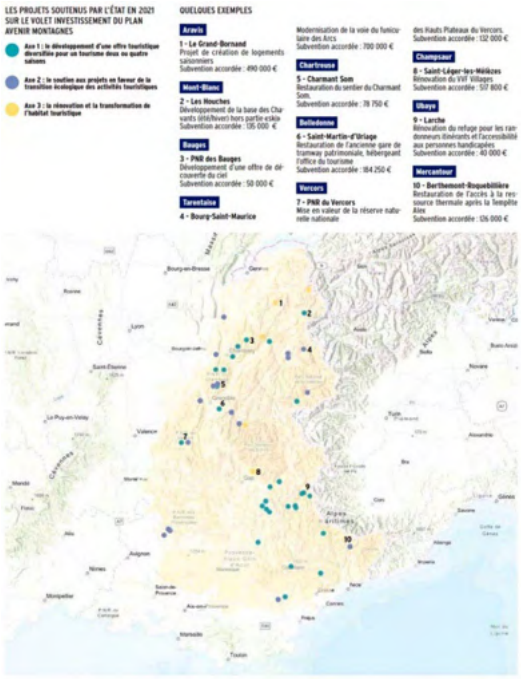
- **Improved coordination of settlement development and transport:** The Alpine interface territories can benefit from better integrating transport infrastructure with settlement planning, ensuring more efficient and sustainable mobility options supporting regional development.
- **Comprehensive development support:** Through specific measures and instruments that complement sectoral policies (such as transport and social policy), *AggloPol* provides holistic support for the development of Alpine territories, fostering sustainable growth.
- **Enhanced collaboration and governance:** The policy promotes efficient collaboration across multiple levels of governance (Confederation, cantons, cities, municipalities) and private stakeholders, enabling more coordinated and effective territorial development for the Alpine regions.

For more information, see the ***Scientific annex X Governance report for Switzerland***

Attention to cross-sectoral coordination: In several Alpine countries, spatial planning often occurs in sectoral silos, with limited integration across sectors like transport, energy, tourism, and environmental conservation. This fragmentation can undermine holistic regional development strategies. In these territories, economic development goals in sectors like tourism or transport may conflict with environmental conservation efforts, especially in sensitive Alpine ecosystems. In contrast, the introduction of integrated planning models can help. Countries like France and Switzerland demonstrate how cross-sectoral coordination can be achieved, particularly through programs like *Avenir Montagnes*, which balance economic development with environmental sustainability (see Box 8). In this respect, there is potential for Alpine interface territories to integrate sustainable sectors (e.g., renewable energy, eco-tourism) into spatial planning. This can harmonise environmental preservation with economic growth.

Box 8
Future Mountains Programme, France

Programme Avenir Montagne (Future mountains programme), France
2021 - Programme



The *Programme Avenir Montagnes* is a national funding programme (2021) to support mountain areas in transition. The programme, which joins other inter-ministerial programmes managed by the ANCT (National Agency for Territorial Cohesion), provides operational support to some sixty mountain areas wishing to rethink their development strategy and move towards a diversified tourism offer, suitable for all seasons, sustainable, respectful of biodiversity and landscape, and with sparing use of natural resources and land. The five principles guiding State action for *Avenir Montagnes* are as follows: Starting from the regions and their projects; Providing a tailored response adapted to the strategies of the different mountains; Mobilising the *Comité de Massif* in supporting the regions; Combining national and local approaches; Giving time to transition (action in synergy with the *Contrats de Transition Écologique – CTEs*, Ecological Transition Contracts).

Projects supported by the state in 2021 under the investment section of the Programme Avenir Montagnes. Source: https://www.montagnes-magazine.com/actus-avenir-montagnes-quel-futur-les-territoires

What are the benefits of *Programme Avenir Montagne* for Alpine interface territories?

- **Support for sustainable and diversified tourism:** It provides funding and operational support for Alpine territories as they transition toward a more sustainable and diversified tourism model, conserving natural resources and respecting biodiversity.
- **Tailored and collaborative regional support:** It offers solutions adapted to the strategies and needs of different mountain regions, promoting collaboration between national and local entities in shaping development strategies.
- **Strengthened territorial cohesion:** Managed by the National Agency for Territorial Cohesion, the programme enhances economic and social resilience in Alpine areas, equipping them to face economic and environmental challenges.

For more information, see the ***Scientific annex V Governance report for France***

Stakeholders' engagement and participation: Supporting public engagement should become a priority: In some countries (e.g., Liechtenstein, Italy), there is limited mobilisation of stakeholders, particularly non-institutional actors, in spatial planning. Strengthening participatory models can be beneficial for establishing the Alpine interface territories. Countries like Switzerland, where direct democracy tools such as referendums are integral to decision-making, offer models for increasing the effectiveness of stakeholder participation in spatial planning. When possible, expanding participatory techniques beyond formal consultations could lead to more inclusive and innovative planning solutions. This initiative should be addressed to leverage local knowledge and help identify context-specific challenges and solutions, particularly in rural and environmentally sensitive Alpine regions.

Cross-border relevance: Despite the geographic interconnectedness of the Alpine region, cross-border cooperation is hindered by different national legal systems and planning frameworks. This is particularly challenging in countries with limited cross-border engagement (e.g., Italy, Slovenia). Managing shared natural resources (e.g., water, forests, and biodiversity) across borders can be difficult without aligned policies, resulting in fragmented conservation efforts. To better explore the potentialities of Alpine interface territories, when needed, strengthening cross-border frameworks might become a priority. Promoting joint governance bodies and projects that can facilitate the management of transnational resources and infrastructure might be an opportunity.

Yet, the limited use of a functional approach and the lack of an exclusive Alpine approach make the exploitation of Alpine interface territories' potentialities unexplored. Spatial planning that adheres strictly to administrative borders often fails to reflect the functional realities of how people live, work, and move across regions. This is particularly problematic in the Alpine context, where functional areas like economic corridors or ecological networks may not align with national or regional borders. On the other side, some countries (e.g., Italy, Slovenia) do not have specific spatial planning policies tailored to the unique challenges and opportunities of the Alpine region. This limits the ability to address issues like tourism management, climate resilience, and biodiversity conservation coherently.

3.5.3.3 Subnational level

In managing the complex and unique Alpine interface territories, spatial planning systems across Austria, France, Germany, Italy, Slovenia, and Switzerland face both challenges and opportunities. Each region's diverse governance structures and geographic needs create varied approaches to multilevel coordination, stakeholder engagement, and cross-border collaboration. As climate change, tourism pressures, and economic shifts reshape the Alpine region, strategic, integrated planning becomes essential for sustainable development. Below are key challenges and opportunities to consider for improving cohesion and resilience in Alpine spatial planning at the subnational level.

Challenges

- **Inconsistent multilevel and cross-border coordination:** Variability in governance and coordination mechanisms across Alpine regions creates challenges in implementing cohesive, cross-border strategies, especially where regional autonomy is high and disparities can become relevant.
- **Limited stakeholder engagement in certain regions:** While France and Switzerland engage a wide range of stakeholders, some regions rely on more formal and limited consultation processes, potentially missing valuable local insights for sustainable Alpine development.
- **Fragmented cross-sectoral coordination:** Sectoral silos remain, particularly at local levels, where areas such as transport, tourism, and environmental protection may lack integrated approaches, leading to potential inefficiencies in managing shared resources and infrastructure.

Opportunities

- **Pan-Alpine Strategy** through considering the set of planning documents, even though non-formally, building a cohesive (territorial) Alpine strategy could improve cross-border collaboration and resource sharing across the Alpine space, addressing shared challenges such as climate change and sustainable tourism.
- **Enhanced functional and cultural identity in regional planning:** Integrating Alpine cultural and functional identities in spatial plans (see the case of Turin's Metropolitana plan) can help promote a different territorial narration envisioning new territorial geographies.

Box 9
Turin's Strategic Metropolitan Plan, Italy

Piano Strategico Metropolitano di Torino (Turin's Strategic Metropolitan Plan), Italy

2014 – Strategy



Metropolitan and mountain relations. Source: PSM 2024-2026, Torino Metro(poli)montana

The Strategic Metropolitan Plan (SMP) defines the social, economic and environmental development of the metropolitan territory. The SMP of the Metropolitan City of Turin 2024-2026, named *METRO(POLI)MONTANA*' proposes a sustainable development model based on a new vision of interdependence and mutual collaboration between towns and mountains. The Plan intends to strengthen the metro-mountain (or rather, metro-rural-mountain) relations system, reducing dependencies and favouring equal access to resources and services throughout the metro-mountain territory.

What are the benefits of *SMP* for Alpine interface territories?

- **Fostering metro-mountain collaboration:** The *SMP* promotes a new vision of interdependence and collaboration between metropolitan, rural, and mountain areas. This "metro-mountain" approach encourages Alpine interface territories to build stronger ties with urban areas
- **Cross-border and inter-regional cooperation:** The *SMP* underscores the importance of strengthening cross-border cooperation with neighbouring French territories and collaboration with other European metropolitan areas facing similar challenges.
- **Innovative metro-mountain thinking:** The *SMP* introduces an innovative method for reimagining the "metro-mountain" relationship, which the Alpine interface territories could apply. This approach encourages new thinking about development incorporating urban and rural mountain dynamics.

For more information, see the ***Scientific annex VII Governance report for Italy***

3.5.3.4 Local level

At the local level, a variety of spatial planning and development strategies emerge. For cross-border regions, these result in diverse administrative and governance structures, creating challenges and opportunities for achieving cohesive and sustainable regional growth. Each country within the Alpine region has developed specific planning documents and frameworks to address local development needs, often focusing on balancing economic progress with environmental preservation.

These documents, while diverse in name and scope, share a common commitment to multilevel governance and strategic alignment with national and EU objectives. However, challenges persist, including limited cross-border integration, balancing development pressures with conservation imperatives, and fostering effective stakeholder participation. Yet, these same regions hold significant potential: through strengthened cross-border cooperation, enhanced multilevel planning, and active community engagement. Alpine territories can work towards a common vision that respects both the ecological integrity and the socio-economic vitality of the Alps. This leads to challenges and unique opportunities that Alpine interface territories might face in their pursuit of sustainable development and regional resilience.

Challenges

- **Cross-border coordination:** Administrative discrepancies hinder cohesive regional development across Alpine interface territories, with many local plans focusing primarily on the territory within the respective national borders. Overall, cross-border cooperation at the local level is inconsistent across Alpine interface territories. While some regions (e.g., France and Italy via the *Plan Intégré Transfrontalier*) have established mechanisms for local cross-border planning, many Alpine municipalities primarily focus on their national frameworks, limiting the scope for collaborative cross-border initiatives.
- **Stakeholder participation and integration:** Divergent stakeholder priorities and limited cross-sectoral integration in planning documents can prevent cohesive strategies, especially in complex Alpine interface areas.
- Overall, local governance frameworks do not yet seem to align well with the functional realities of Alpine interface territories. Functional patterns, such as commuting and shared tourist destinations, often transcend municipal boundaries, yet local plans are frequently restricted to administrative perimeters. This misalignment complicates inter-municipal cooperation and can reduce the effectiveness of local plans in addressing issues like transport connectivity, housing, and ecological conservation. Inspiring practices such as Switzerland's Agglomeration Projects are still not widely adopted at the local level across the Alpine region (see Box 10).

Box 10
Verein Agglomeration Werdenberg-Liechtenstein

Verein Agglomeration Werdenberg-Liechtenstein

2009 – Coordination



Buchs-Vaduz cycle and pedestrian bridge. Source: Agglomeration Werdenberg-Liechtenstein

Between the Alvier and the Liechtenstein Alps, the Werdenberg-Liechtenstein agglomeration stretches over a length of around 30 kilometres in the Rhine Valley. Large agglomerations have a leading role as service centres since they perform specific functions in their sector for other regions and medium and large centres. At the same time municipalities in Switzerland and Liechtenstein have a high degree of autonomy. Founded in 2009 according to the Swiss Law, the Werdenberg-Liechtenstein Agglomeration Association is an example of the cross-border strategy aimed at addressing the constantly growing challenges in this strongly networked region. The members of the Association are the six Werdenberg and eleven Liechtenstein municipalities, the municipality of Sargans as well as the canton of St. Gallen and the Principality of Liechtenstein, while the city of Feldkirch (Austria) is also involved in the decisions as an observer. The purpose of the Association is to strengthen cooperation, joint development of future perspectives, and implementation for the agglomeration, as well as the efficient fulfilment of public tasks. In addition, the Werdenberg-Liechtenstein agglomeration project aims at a greater coordination of cross-sectoral transport and settlement within the functional area of Werdenberg-Liechtenstein and was adopted by the Swiss Parliament in 2014 and 2019.

What are the benefits of the *Verein Agglomeration Werdenberg* for Alpine interface territories?

- **Enhanced cross-border cooperation:** The Werdenberg-Liechtenstein Agglomeration Association is an exemplary model of cross-border collaboration, involving multiple municipalities from both, Switzerland and Liechtenstein. Alpine interface territories can benefit from similar cooperative frameworks to address shared challenges that extend beyond national borders, improving governance and coordination.
- **Territorial strategy for joint development:** The association's focus on developing joint future perspectives and strategies highlights the importance of a unified approach to regional development. Alpine interface territories can leverage such strategies to harmonize their growth plans, ensuring cohesive development that benefits the entire region, rather than isolated municipalities.
- **Functional area management:** By addressing key regional issues such as transport, settlement planning, and landscape management within a functional area framework, the association ensures that decisions are aligned with the needs of the entire region. The Alpine interface territories can adopt this approach to manage interconnected landscapes and resources efficiently, promoting sustainable development.
- **Strengthened public service delivery:** The association's focus on the efficient fulfilment of public tasks demonstrates how collaboration can improve the delivery of public services across regions. Alpine interface territories can adopt similar methods to enhance service provision and address regional challenges collectively.

For more information, see the ***Scientific annex VIII Governance report for Liechtenstein***

Opportunities

- **Strengthening cross-border cooperation:** Expanding frameworks like France's *Plan Intégré Transfrontalier* (PIT) across other Alpine regions could enhance regional cohesion and resource-sharing, promoting sustainable infrastructure and ecological initiatives. The Agglomeration projects can offer a good example of how to frame potential cooperation in the sector of spatial planning in cross-border areas, but not only.
- **Leveraging multilevel governance:** Aligning local, regional, and national goals can pool resources and improve policy coherence, fostering resilience and sustainable economic development in Alpine territories. The case of the Mayor Meetings can be applied in other contexts that require a more open and transparent decision-making process (see Box 10).
- **Fostering stakeholder engagement:** Encouraging participatory planning allows communities to co-create solutions specific to Alpine needs, strengthening local ownership and adaptability to environmental and economic challenges.

Box 11
Mayors' meetings, Germany

Bürgermeistertreffen (Mayors' meeting), Germany

Coordination

The *Bürgermeistertreffen* (Mayors' Meeting) is an event in Bavaria (Germany) that brings together mayors from various Bavarian municipalities to discuss local challenges, advocate for their communities, and collaborate with representatives from the Bavarian Parliament. It provides a platform for mayors to raise awareness of current issues affecting their regions and to network with other local leaders and state officials. Through thematic panel discussions, local and regional delegates engage in intensive exchanges of ideas and best practices, tackling a wide range of topics such as urban development, infrastructure, environmental protection, and social services. The meeting emphasizes the importance of multi-level governance, cooperation between local and state entities, and the development of joint solutions for regional issues. For the Alpine interface territories, which often span multiple countries and are home to unique environmental and economic conditions, adopting a similar approach could help address complex, cross-border issues more effectively.

What are the benefits of the *Bürgermeistertreffen* for Alpine interface territories?

- **Enhanced cross-border and regional cooperation:** The *Bürgermeistertreffen* promotes collaboration between municipalities, which can inspire stronger cross-border cooperation between Alpine interface territories and neighbouring regions like France, Switzerland, and Austria. This can lead to joint solutions for shared challenges such as tourism management, infrastructure, and environmental conservation.
- **Advocacy for local concerns and stronger local-regional relationships:** The meeting provides a platform for local leaders to bring their concerns directly to higher-level authorities. Alpine interface territories can adopt this model to ensure their specific challenges—such as seasonal tourism and environmental preservation—are heard in national or regional policy discussions. Additionally, it fosters stronger cooperation between local governments and regional-level authorities, helping to align local needs with broader regional or national strategies.
- **Sharing best practices and solutions for sustainable development**: By facilitating the exchange of ideas and strategies among municipalities, the *Bürgermeistertreffen* can help Alpine interface territories learn from other regions' experiences in sustainable development, infrastructure planning, and community services, ensuring a balance between economic growth and environmental protection.
- **Collective problem-solving for complex regional issues:** Alpine interface territories can benefit from a similar platform to tackle shared issues such as climate change adaptation, cross-border environmental protection, and sustainable tourism strategies.

For more information, see the ***Scientific annex VI Governance report for Germany***

3.5.3.5 Sectoral planning

Transport

In analysing Alpine transport planning systems within interface territories, certain recurring challenges and opportunities become clear. These can reveal areas where integration and coordination can improve, as well as strengths that could serve as models for other Alpine regions. Below are three key challenges and three corresponding opportunities to foster a more cohesive and sustainable transport planning approach for the Alpine region.

Challenges

- **Fragmented multilevel coordination:** In countries like France, Italy, and Slovenia, transport planning suffers from fragmented coordination across governance levels, leading to inconsistent policy implementation and misalignment between national and regional priorities. This lack of a cohesive multilevel framework hampers effective decision-making in Alpine transport.
- **Inadequate cross-sectoral integration:** Limited integration of transport planning with other critical sectors—such as environmental, tourism, and economic policies—is a barrier in countries like Austria, Germany, and Switzerland. This restricts the potential for holistic solutions to address the complex needs of Alpine regions, particularly in balancing environmental protection with economic development.
- **Low stakeholder engagement in transport planning:** Countries like Austria, France, and Liechtenstein demonstrate limited engagement of non-institutional stakeholders, such as local communities and private entities. This limits the effectiveness of transport policies, as local insights and needs are often not adequately represented in decision-making processes.

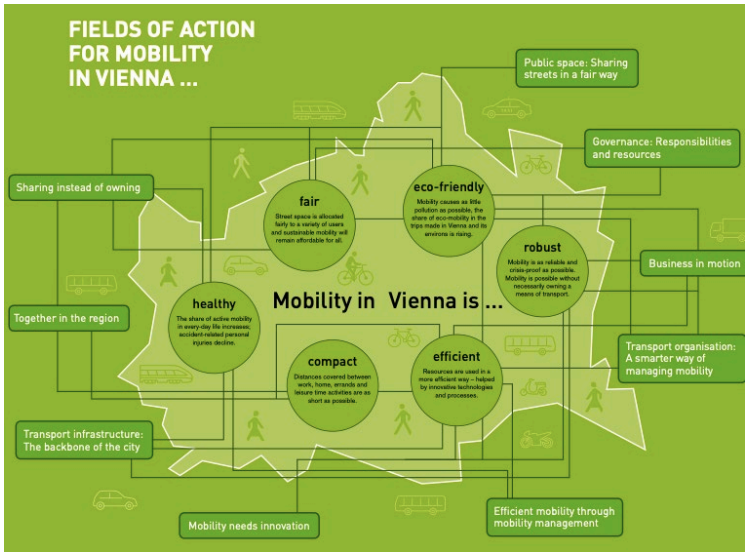
Opportunities

- **Modelling effective multilevel coordination:** Germany and Austria offer strong examples of multilevel coordination, aligning national and regional transport priorities through clear frameworks and communication channels. Expanding such models across the Alpine region could foster more integrated governance, enhancing consistency and cooperation in transport policy.
- **Leveraging cross-sectoral synergies:** Slovenia and France effectively integrate transport planning with environmental, social, and economic policies, creating comprehensive frameworks that address Alpine challenges such as sustainable tourism and ecological conservation (see Box 12). Adopting these cross-sectoral approaches more widely could improve the balance between mobility needs and environmental protection in Alpine interface territories.
- **Expanding stakeholder participation models:** Slovenia and Switzerland emphasize participatory planning, particularly at the local level, allowing for more adaptive and community-responsive transport policies. Implementing similar practices across Alpine regions could yield policies that are better suited to local contexts and more responsive to Alpine-specific needs, fostering a more inclusive governance culture.

Box 12
Local Mobility Concepts, Austria

Local Mobility Concepts, Austria

2013. – Strategy, Coordination



Thematic Concept STEP 2025. Source: Urban Mobility Plan Vienna

In Austria, strategic transport governance and planning at the local level, such as the Vienna Urban Mobility Plan (*Wiener Fachkonzept Mobilität*), serves as a model of sustainable urban mobility planning, meeting Europe's SUMP (Sustainable Urban Mobility Plan) requirements. It reflects a consistent implementation of the city's vision, as enshrined in the Urban Development Plan STEP 2025. This vision emphasizes the importance of close coordination and cooperation in transport and spatial planning across the entire Eastern Region. For the first time, the plan includes a regional mobility strategy that was developed in collaboration with the provinces of Burgenland, Vienna, and Lower Austria, forming a strong basis for both local and regional mobility measures. This collaborative approach is particularly relevant for Alpine interface territories, where cross-municipal cooperation and regional integration are key to addressing transport challenges in mountainous and rural areas. For Alpine territories, which often face unique transport challenges due to geographic constraints, such inclusive planning can ensure that local needs and concerns are addressed while aligning with broader regional strategies.

What are the benefits of *Local Mobility Concepts* for Alpine interface territories?

- **Regional coordination and integrated planning:** Similar to how the Vienna Urban Mobility Plan promotes coordination between Vienna, Lower Austria, and Burgenland, Alpine territories can benefit from regional cooperation. By aligning mobility plans with broader spatial development goals, Alpine municipalities can ensure that mobility solutions are integrated with land-use planning, environmental conservation, and economic development strategies. This regional and integrated approach helps address both local and cross-border mobility challenges.
- **Sustainable mobility solutions for sensitive areas:** The Vienna plan's focus on sustainable mobility—promoting walking, cycling, and public transportation—can directly benefit the Alpine interface territories. Given the environmental sensitivity of the Alps, Local Mobility Concepts in these regions can prioritize low-impact, eco-friendly transport solutions.
- **Tailored mobility for Alpine conditions:** Local Mobility Concepts can focus on enhancing public transport in remote or mountainous areas, managing seasonal tourism traffic, and promoting transport modes suitable for the Alpine geography, such as cable cars or electric vehicles, to ensure both practicality and sustainability.

For more information, see the ***Scientific annex IV Governance report for Austria***

Energy

In assessing energy governance across the Alpine interface territories, some major challenges and significant opportunities as well emerge.

Challenges

- **Fragmented multilevel and cross-border coordination:** The fragmentation in multilevel coordination (notably in Italy, Austria, and Liechtenstein) and limited cross-border energy collaboration in the Alpine region create barriers to cohesive energy policy implementation. This inconsistency limits the potential for shared infrastructure, resource optimization, and aligned policies necessary for managing energy across complex borders and sensitive mountain environments.
- **Limited cross-sectoral and stakeholder engagement:** Many countries (including Liechtenstein, Italy, and France) display limited cross-sectoral integration and minimal stakeholder engagement, especially beyond the public sector. This isolation hinders a holistic approach to energy governance, preventing the effective incorporation of local needs, environmental concerns, and regional economic considerations that are essential in Alpine areas.
- **Insufficient focus on Alpine-specific energy policies:** Most countries lack policies tailored to the Alpine region's distinct needs, such as renewable energy potential and climate sensitivity. Without a dedicated Alpine-specific focus, energy strategies risk overlooking essential environmental and climatic factors, reducing their efficacy in addressing the vulnerabilities and potential of these mountainous territories.

Opportunities

- **Enhancing cross-border and regional energy collaboration:** The existing cross-border collaboration in Switzerland and Liechtenstein presents a model for expanding Alpine-wide partnerships on energy infrastructure, resource sharing, and policy alignment. Developing such frameworks can address the shared energy challenges of the region, making energy systems more resilient, efficient, and cohesive across borders (see an example in Box 13).
- **Leveraging renewable energy potential in Alpine areas:** The Alpine region holds unique renewable energy opportunities, including hydroelectric, wood, and solar energy adapted for mountainous terrain. By fostering policies that encourage the development of low-impact renewables, countries can promote sustainable energy sources that also protect fragile Alpine ecosystems.
- **Adapting energy policies to climate change impacts in Alpine regions:** With Alpine ecosystems particularly vulnerable to climate change, targeted energy policies that address seasonal variations and ecological protection can significantly enhance regional climate resilience. Expanding policies that integrate climate adaptation for energy use in Alpine contexts (e.g., as seen in Switzerland and France) can help mitigate environmental impacts while securing energy needs.

Effective energy governance in the Alpine region requires integrated multilevel frameworks that connect national, regional, and local governance. Countries like Germany and Switzerland demonstrate strong multilevel coordination, but others, particularly Italy and Liechtenstein, could benefit from policies that encourage more robust alignment across governance levels. Additionally, increased cross-border collaboration—building on Switzerland and Liechtenstein's existing models—can foster shared resource management and policy harmonization, which are essential in a region with shared environmental and infrastructural challenges.

A cross-sectoral approach to energy policy, as seen in Austria and Slovenia, supports the integration of climate, social, and economic priorities, creating comprehensive energy solutions that meet the region's diverse needs. Expanding this approach across all Alpine territories can better address the multifaceted impacts of energy policies, particularly by incorporating environmental protection, tourism, and local economic considerations. Furthermore, increased stakeholder engagement, exemplified by Germany and Switzerland, allows for a more inclusive governance process that aligns policies with local

needs, fosters community support, and encourages innovation. The Alpine region's unique environmental and climatic conditions demand energy policies tailored to its specific characteristics, such as renewable energy potential and climate vulnerability. While Switzerland, France, and Germany include some Alpine-specific considerations, other countries, like Austria and Slovenia, could strengthen this focus. Policymakers should prioritize renewable energy projects suited to mountainous terrains (e.g., hydroelectric and wood energy) and develop adaptive strategies to address climate impacts on Alpine ecosystems. This targeted approach will ensure that energy policies contribute to both sustainability and resilience in the face of climate change.

Box 13
Local Energy Concept, Slovenia

Lokalni Energetski Koncept (Local Energy Concept), Slovenia

2000 – Strategy, Regulative



LEK Celje. Source: Energy Renovation and Management in the Municipality of Celje

The Slovenian Municipal or Local Energy Policy is based on a strategic document called Local Energy Concept (*lokalni energetski concept - LEK*), which is the most important tool for planning a long-term local energy policy strategy because it encompasses ways in which local communities can tailor solutions for efficient, economical, and environmentally friendly energy services in homes, businesses and public institutions. Based on LEK, the spatial and economic development of the local community is planned, the development of local energy utilities, the efficient use of energy and its saving, the use of renewable energy sources and the improvement of air quality in the local community. The objectives and measures defined in LEK must be in accordance with the Energy Concept of Slovenia (EKS) and other action plans and operational programs for the supply and use of energy.

What are the benefits of the *Local Energy Concept* for Alpine interface territories?

- **Tailored local solutions:** The LEK emphasizes the customization of energy services for local needs, making it particularly relevant for the diverse and unique conditions in the Alpine territories. With its focus on efficient, economical, and environmentally friendly energy solutions, the LEK can guide Alpine municipalities in creating strategies that address the specific challenges of remote, mountainous areas where traditional energy infrastructure may be less feasible.
- **Alignment with national and EU policies:** By ensuring that local energy policies align with national frameworks like the Energy Concept of Slovenia (EKS) and broader EU goals, the LEK provides a structured approach that can harmonize energy initiatives across borders in the Alpine region. This coordination is key for cross-border projects and integrated energy systems in the Alpine interface territories.
- **Long-term strategic planning:** The LEK's role in planning the spatial and economic development of local communities fits well with the Alpine region's need for long-term, sustainable growth. Its methodical approach can help Alpine municipalities develop infrastructure that balances energy needs with environmental preservation, crucial for maintaining the region's ecological integrity.

For more information, see the ***Scientific annex IX Governance report for Slovenia***

Water

Shared water resources are vital for local communities and ecosystems, yet they are increasingly stressed by factors such as climate change, seasonal variability, tourism demands, and agricultural needs. Effective water management in the Alpine region requires a coordinated approach that crosses national borders, aligns with natural ecological patterns, and integrates input from multiple levels of government, diverse sectors, and stakeholders. However, each Alpine country approaches these challenges from different policy, governance, and administrative perspectives, making cohesive water governance across the region a challenging but essential goal.

By comparing each country's approach, the comparative analysis highlights the varying degrees of integratedness in Alpine water governance, identifying areas where policies align well with regional needs and where gaps persist. Understanding these differences is key to identifying best practices, potential synergies, and areas for improvement across the Alpine countries.

Challenges

- **Fragmented multilevel and cross-border coordination:** Inconsistencies in coordination between national, regional, and local authorities—particularly in Switzerland, Liechtenstein, and France—hinder unified water management efforts. Fragmentation also appears in cross-border efforts, with minimal collaboration in countries like France and Austria, impacting the effective management of shared water resources across borders.
- **Limited cross-sectoral integration:** The separation of water governance from other related sectors, such as agriculture, energy, and tourism, is evident in Austria, Liechtenstein, and Switzerland, leading to siloed policies. This lack of integration can create resource conflicts and missed opportunities for holistic planning, particularly in the face of environmental challenges like seasonal variability and resource demands from tourism.
- **Inconsistent stakeholder engagement:** In many countries, particularly Slovenia and Liechtenstein, limited involvement of local communities, NGOs, and non-institutional actors restricts the flow of local knowledge and buy-in from affected communities. Without comprehensive stakeholder engagement, water governance risks being out of touch with local needs and lacking necessary public support for sustainable management practices.

Opportunities

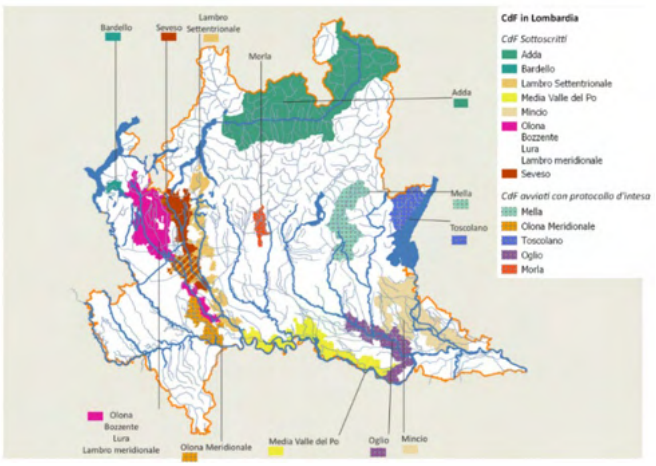
- **Strengthening cross-border and multilevel coordination:** Improving coordination across levels of government and between countries—drawing on examples from Germany, Italy, and Slovenia—could enhance the region's ability to manage water resources effectively (see Box 14). Establishing common frameworks and leveraging EU or Alpine Convention platforms could foster consistent policy application across the Alpine region.
- **Expanding cross-sectoral collaboration:** Aligning water policies with those of related sectors presents an opportunity for more comprehensive resource management, as seen in Germany and Italy's moderate cross-sectoral efforts. By coordinating with agriculture, climate, and tourism sectors, water governance can address interconnected resource needs, ensuring a more resilient approach to water scarcity and ecosystem health.
- **Enhancing stakeholder engagement for localized solutions:** Broadening stakeholder participation to include local communities, industries, and environmental groups, as observed in Germany and Switzerland, can improve adaptability and foster innovation. This approach encourages local ownership and resource pooling, making water governance more responsive to the specific needs and challenges within Alpine communities.

Box 14
River/Lake/Wetlands Contracts, Italy

Contratti di fiume/lago/zone umide (River/Lake/Wetlands Contracts), Italy

2006 – Contract

The "*Contratti di Fiume*" (River Contracts), "*Contratti di Lago*" (Lake Contracts), and "*Contratti di Zone Umide*" (Wetland Area Contracts) in Italy are voluntary agreements aimed at the strategic and negotiated planning of water management, signed between public and private actors that define cooperation activities for the protection and management of specific water bodies. These initiatives bring together stakeholders responsible for water use, spatial planning, and environmental protection to promote the sustainable management of water resources and the enhancement of river, lake, and wetland territories. Typically, they include an action plan that outlines the management strategy. In the Italian Alpine region, the Piedmont region stands out with the highest number of river contracts (13), as well as one lake contract and one wetland area contract. The flexibility of these agreements allows territories to operate independently of their administrative boundaries, enabling a more holistic approach to water management. An example of this is the Olona - Bozzente - Lura - Southern Lambro River Contract, which integrates the ecological significance of the river with the broader goals of sustainability, natural conservation, and water management. One notable initiative under this contract is *'I LAGHI IN BICICLETTA'* (Lakes by Bicycle), which promotes environmental quality alongside sustainable mobility, highlighting how these contracts can combine ecological preservation with practical, community-driven projects.



Olona - Bozzente - Lura - Southern Lambro meridionale River Contract. Source: https://www.contrattidifiume.it/it/contratti-di-fiume/olona-bozzente-lura-lambro-meridionale/

What are the benefits of *River/Lake/Wetlands Contracts* for Alpine interface territories?

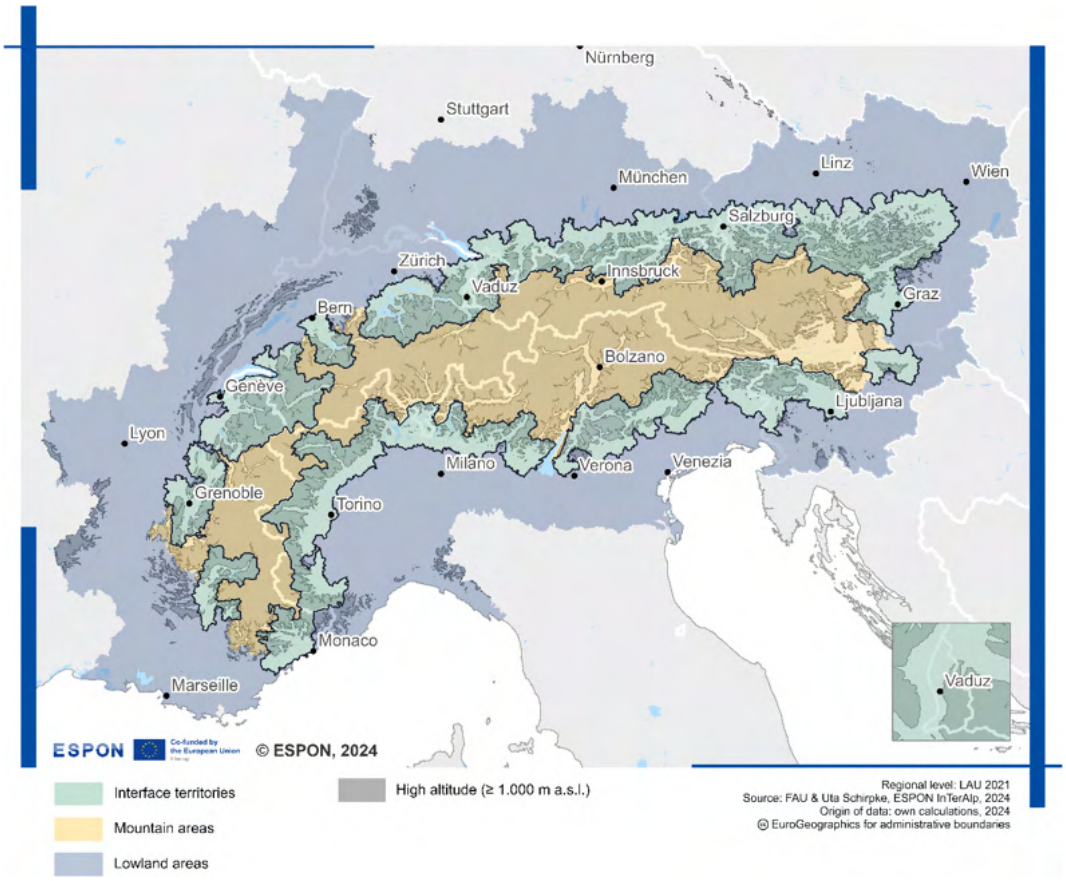
- **Cross-border and regional cooperation:** In the Alpine region, where rivers, lakes, and wetlands often span multiple countries, cross-border agreements (such as the Roia/Roya French-Italian Transboundary River Contract) can promote coordinated water management, benefiting all involved territories by addressing shared environmental and water resource challenges.
- **Integrated water management:** The contracts foster a holistic approach to water management that incorporates ecological preservation, spatial planning, and hydraulic risk prevention. This is particularly important for the Alpine region, where fragile ecosystems and mountainous terrain require careful management to prevent issues like flooding, erosion, and biodiversity loss. Integrated planning can protect these vital ecosystems while supporting local development.
- **Flexibility across administrative boundaries:** The flexibility of these contracts allows them to operate independently of strict administrative borders, which is ideal for the Alpine territories, where ecological zones and water bodies often overlap various municipalities and regions.

For more information, see the ***Scientific annex VII Governance report for Italy***

4 Positioning the spatial category of interface territories

The previous chapters have discussed interface territories from different perspectives, underlining the territorial diversity. Interface territories comprise sharp contrasts within their perimeters, and can differ largely amongst each other, as shown with the spatial typology. Nevertheless, as interface areas show common characteristics, it is important to position them towards other geographical categories. We do so by merging the different interface territories. Map 33 presents the merged delineation of interface areas across the Alpine region. This map shows interface areas in between the mountain and lowland areas. This spatial category captures the transit zones in between the peri-Alpine lowlands and inner-Alpine highlands (see definition in chapter 2.1). Mountain areas are defined as municipalities within the perimeter of the Alpine Convention[8], while lowland areas are defined as municipalities within the perimeter of the Alpine Space[9] that are neither interface areas nor mountain areas.

Map 33
Interface territories, mountain and lowland areas

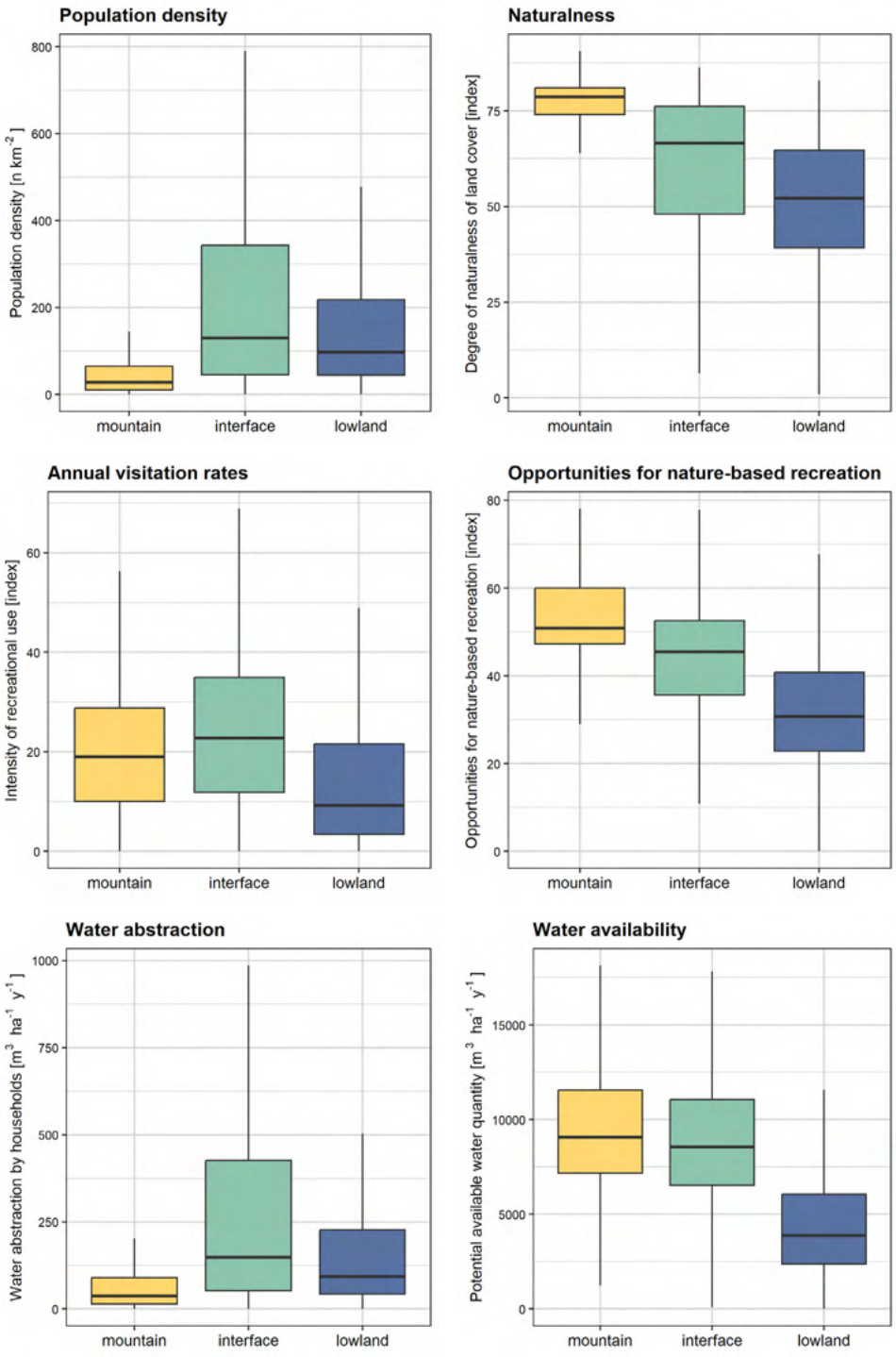


8 Isolated mountain municipalities located between interface areas are assigned to lowland areas; if interface areas are not adjacent to lowlands but are completely surrounded by mountain municipalities, those mountain municipalities with a mean altitude below 1,000 meters are assigned to lowland (see Scientific annex I).

9 Interreg Alpine Space (2014-2020)

Recognizing this new geography means to understand interface areas as a relevant spatial category in the Alpine region, alongside Functional Urban Areas (FUAs), high mountain areas, metropolitan regions and transnational corridors. Merging the separate 48 interface areas facilitates the positioning of interface areas, mountain areas and lowland areas. Figure 8 shows a positioning approach based on environmental and socio-economic indicators that highlights the specific spatial characteristics of interface areas. The boxplots illustrate the spatial variation of data at municipality level for population density, naturalness, visitation rates, opportunities for nature-based recreation, water abstraction and water availability.

Figure 8
Positioning of interface territories across the Alpine region



The boxplots show the median and the range of the data, as well as the dispersion within each spatial category. The interquartile range, i.e. the size of the box, shows 50% of the data values. Whiskers (lines at the top and bottom of the boxes) provide information on the range of the data (minimum and maximum), in this case the boxplots have been cleaned of outliers in order not to distort the pattern of the data by extreme values. The indicators of population density, annual visitation and water abstraction are indicators that reflect a perspective of 'use' of Alpine natural resources and landscape (indicators in Figure 8, left side). In these boxplots, the interquartile range is largest for the interface territories, the median value is the highest and the range of data is widest. Thus, for all indicators, the interface areas show the highest dispersion of data. This illustrates and confirms the identified characteristics of interface territories as areas of sharp territorial contrasts.

The indicators of naturalness, opportunities for nature-based recreation and water availability are those that provide a perspective on the 'natural capacities' of the Alps (indicators inFigure 8, right side). In these boxplots, the highest level of the interquartile ranges is found in the mountain areas and the lowest in the lowland areas. In all three cases, the boxes of interface areas lie 'in between', i.e. the 'natural capacities' generally decrease from the inner-Alpine highlands towards the peri-Alpine lowlands. This gradient emphasises the common challenges of interface areas for Alpine spatial development mentioned before. Interface areas have less 'natural capacity' than mountain areas, but more than lowland areas. This characterises interface territories as areas that provide attractive and necessary resources for human activities and at the same time are vulnerable areas for environmental protection.

5 Summary: The geographical specificities of interface territories

Based on the territorial evidence developed in the ESPON InTerAlp project, the spatial concept of interface territories shows geographical specificities that can be summarised as follows:

1) Interface territories are areas with sharp mountain-lowland contrasts

Alpine interface territories are areas of high territorial diversity, where lowland meets mountains and the degree of urbanisation is heterogeneous. As a result of this geographical structure, the areas show sharp socio-economic and environmental contrasts (e.g. in ecological connectivity, opportunities for recreation, population density). Interface areas serve as "connectors," situated between high mountain regions and the surrounding lowlands. This corresponds with to one of the main findings of the 9th Report on the State of the Alps (cf. Chilla et al. 2022), which identifies Alpine towns as 'brokers' between rural areas and the main metropolises in and around the Alps.

2) Interface territories are geographic funnels and transalpine gateways

Alpine interface areas are characterised by funnel positions and gateway functions. Throughout the Alpine region, interface territories are those areas where space is getting ‘narrower’. Only a limited number of road and rail axes carry flows, often in rather small corridors. In this situation, interface areas tend to be 'hot spots' of transport and mobility policy.

In a nutshell, there is 'double the demand in half of the space'. This also reflects the fact that the demand for transport infrastructure in interface areas is often much higher than in most other spatial categories. It is also an indication of the fact that in interface areas there is a high intensity of recreation demand and a high intensity of recreation opportunities in close proximity to each other.

In addition, interface areas have a special role as gateways in the European spatial structure. They are areas where the main European transport infrastructure enters the inner-Alpine highlands. The most frequented transalpine corridors originate and terminate in interface areas (e.g. Brenner, Gotthard, Fréjus).

3) Interface territories are areas with common challenges and specific roles

The spatial setting of sharp territorial contrasts between mountain and lowland areas and geographical funnel situations leads to a series of challenges and specific roles for interface areas in Alpine spatial development, which can be grouped as follows:

First, transport facilities and technical infrastructure face peaks in demand. The high density of important functions, flows, and dynamics is a characteristic feature of interface territories. Transport infrastructure connects places at different spatial scales; freight flows form the backbone of an integrated economy; and settlement systems typically develop along the topographic valley axes. In addition, interface areas are highly attractive magnets for different types of flows (e.g. tourism, recreation, commuting). Given the limited space for and the high financial burden of infrastructure development, there are no simple spatial development solutions in most interface areas.

Second, the balance between tourism, transport infrastructure and the environment is a multifaceted issue. As interface territories have a high degree of territorial diversity, the challenges of green infrastructure, transport, tourism and natural hazard management are very much in parallel. In several Alpine tourism hotspots, there are tendencies towards overuse of natural sites (e.g. lakes, mountain peaks, hiking trails, ski resorts, etc.). At the same time, interface areas are hazard prevention areas as they are areas where steep relief and human infrastructure are in close proximity to each other. In addition, traffic flows to and from tourist attractions can lead to congestion in residential areas and trigger the planning of bypass roads. At the same time, these dynamics of transport infrastructure expansion come along with severe habitat fragmentation processes.

Third, energy and drinking water are sensitive issues in interface territories. They are areas of water resources/transport and serve as energy transit zones, which require efficient networks. Power lines

in close proximity to Alpine settlements in valley locations are a sensitive planning issue. At the same time, the dependence of cities in peri-Alpine lowlands on water and energy sources from mountain areas is also a prominent infrastructure issue in most of the interface areas. Furthermore, the cross-cutting issues coming along with climate change further increase the challenges of sustainable Alpine spatial development and planning.

Fourth, many interface territories are economically successful areas embedded in a highly attractive natural environment. This makes them attractive locations for economic development. At the same time, ensuring effective organisation of services of general interest, affordable housing and interregional accessibility can easily become a challenge - but is a prerequisite for attracting skilled labour.

6 Policy implications

The ESPON InTerAlp project is strongly oriented towards stakeholder and policy needs. The project aims to facilitate the integration of policy uptake, in particular in spatial development and planning across the system of multi-level governance, as well as sectoral policies related to transport, energy, and water management. The policy implications of the project for Alpine interface areas are based on the existing knowledge base on Alpine spatial development, drawing on the findings of key initiatives such as the ESPON Alps2050 project, the EUSALP Joint Paper on Spatial Planning, the 9th Report on the State of the Alps (RSA), focusing on Alpine Towns, the RSA10 on Quality of Life, and the Interreg Alpine Space Programme.

The project's participatory process identified key challenges faced by Alpine interface territories, including land use, environmental protection, and socio-economic dynamics. The scarcity of available land, combined with overlapping administrative boundaries, makes spatial planning in these areas complex. In addition, climate change is a major driver of change in both ecological and socio-economic systems, exacerbating existing vulnerabilities. Governance mismatches were also highlighted, noting that existing structures are often not aligned with the functional realities of interface areas. Successful governance models, particularly in cross-border regions, were also discussed. The participatory process revealed examples such as the interface area of the Alpine Rhine Valley, where cooperation across national borders has led to effective governance in addressing common challenges in mobility, infrastructure, and environmental management. These examples underline the potential of multi-level governance frameworks that foster cooperation at different administrative levels. Findings of the project's participatory process also highlight the importance of political awareness and commitment to the challenges faced by Alpine interface territories. Political leaders need to fully recognise the unique functions and characteristics of these regions in order to develop and implement effective policies. A recurring theme in stakeholder workshops and the project's online survey was the need for greater political support for governance models that address the specific territorial challenges faced by interface areas. In terms of opportunities, Alpine interface territories have the potential to act as pioneers in sustainable spatial planning, integrating advanced technologies such as smart grids, green infrastructure, and eco-friendly transport systems. These regions are seen as ideal testing grounds for sustainable practices that could be scaled up for wider application. Cross-border cooperation was also identified as a relevant opportunity to address common challenges in mobility, climate adaptation, and resource management.

The lessons learnt from the project's participatory process have led to three key policy postulates for Alpine interface territories. First, it is essential to **recognise interface areas as a specific geographic category**. Interface territories are a unique spatial category due to their funnel positions, gateway functions, and high territorial diversity, which often leads to significant socio-economic and environmental contrasts. Recognising this specific geography is necessary to develop effective policies and strategies tailored to the needs of these regions.

Second, it is crucial to **address the common challenges faced by interface areas**. These regions are characterised by a high density of important functions, flows, and dynamics, such as transport infrastructure and services of general interest, but often face limited space for development. Spatial planning strategies need to address the challenge of 'double demand on half the space', balancing development with environmental protection and conservation.

Third, the **governance of Alpine interface areas requires a tailor-made approach**. Administrative boundaries in these regions often do not correspond to functional flows and interdependencies, making governance particularly challenging. The concept of 'soft spaces' is crucial for managing interface territories, as it emphasises flexibility and the importance of cooperation between different administrative levels (Allmendinger et al. 2015, Marot et al. 2019). Inter-municipal and cross-border cooperation, as well as multi-level governance, must be fostered to address the unique challenges of these regions.

Overall, the ESPON InTerAlp project contributes with its findings and territorial evidence to the Alpine Spatial Development Perspective (ASDP), initiated by the Alpine Convention Working Group on Spatial Planning and Sustainable Development (AC WGSPSD). The first possibilities of integrating the results of the project into the ASDP have already been explored in an online meeting with members of the AC WG SPSD (13/11/24). The ASDP aims at developing a common vision for the long-term spatial development of the Alpine area. This perspective emphasises the need for policy recommendations and practical implementation strategies to address the unique challenges and opportunities across the Alpine region, promoting sustainable development and cross-border cooperation. The findings of the ESPON InTerAlp project are an element for shaping the future of Alpine spatial planning and development with a special perspective on Alpine interface areas.

7 List of annexes

This final report includes the following annexes, published as separate items:

- Case study portfolio
- Policy brief
- Spatial and sectoral governance in Alpine interface territories
- Scientific annex I: Definition and delineation of Alpine interface territories
- Scientific annex II: Metadata overview
- Scientific annex III: Transnational and cross-border governance
- Scientific annex IV: Governance report for Austria
- Scientific annex V: Governance report for France
- Scientific annex VI: Governance report for Germany
- Scientific annex VII: Governance report for Italy
- Scientific annex VIII: Governance report for Liechtenstein
- Scientific annex IX: Governance report for Slovenia
- Scientific annex X: Governance report for Switzerland

8 References

Allmendinger, P., Haughton, G., Knieling, J., & Othengrafen, F. (Eds.). (2015): Soft spaces in Europe: Re-negotiating governance, boundaries and borders. Routledge.

Alpine Convention (2017): Climate Change – How it affects the Alps and what we can do. https://www.alpconv.org/fileadmin/user_upload/Publications/AlpineConventionFolder_Climate_Change_2017_EN_reverse.pdf

Bertram, D., & Chilla, T. (2023a): Polycentricity and accessibility in mountain areas: the Alpine case. European Planning Studies, 1-21. https://doi.org/10.1080/09654313.2022.2145874

Bertram, D., Chilla, T., & Lambracht, M. (2023b). The Alpine settlement system: capturing relevance beyond size. Journal of Maps, 19(1), 2164229. https://doi.org/10.1080/17445647.2022.2164229

Chilla, T., & Streifeneder, T. (2018): Interrelational space? The spatial logic of the macro-regional strategy for the Alps and its potentials. European Planning Studies, 26 (12), 2470-2489. https://doi.org/10.1080/09654313.2018.1532493

Chilla, T., Bertram, D. and M. Lambracht (2022): Alpine Towns – Key to Sustainable Development in the Alpine region. Part 1: Facts, Maps and Scientific Debates. 9th Report on the State of the Alps. http://dx.doi.org/10.13140/RG.2.2.36022.98880/1

Cotella, G., Janin Rivolin, U., Pede, E., & Pioletti, M. (2021): Multi-level regional development governance: A European typology. European Spatial Research and Policy, 28(1), 201-221. https://doi.org/10.18778/1231-1952.28.1.11

ESPON Alps2050 (2018): Alps2050 – Common Spatial Perspectives for the Alpine Area. Towards a Common Vision. Final report. Online: https://www.espon.eu/Alps2050

ESPON COMPASS (2018): Comparative Analysis of Territorial Governance and Spatial Planning Systems in Europe. Luxembourg: EPSON EGTC. Available at: https://www.espon.eu/planning-systems

ESPON LAKES (2022): LAKES - territorial analysis of spatial progress and integrated development opportunities of large lakes in Europe. Online: https://www.espon.eu/lakes

ESPON METRO (2021): ESPON METRO | The role and future perspectives of Cohesion Policy in the planning of Metropolitan Areas and Cities. Online: https://www.espon.eu/metro

ESPON PROFECY (2017): PROFECY - Inner Peripheries: National territories facing challenges of access to basic services of general interest. Final report. Online: https://www.espon.eu/inner-peripheries

Lambracht, M. (2024): Spatial development in the European Alps: Topographic Potential Area as a basic indicator for policy debates. Papers in Applied Geography, 10(1), 81-88. https://doi.org/10.1080/23754931.2023.2264289

Marot, N., Penko Seidl, N., Kostanjšek, B., & Harfst, J. (2019): Study on the green infrastructure and ecological connectivity governance in the EUSALP area. Ljubljana, University of Ljubljana, Biotechnical Faculty.

Meisch, C., Schirpke, U., Huber, L., Rüdisser, J., Tappeiner, U. (2019): Assessing freshwater provision and consumption in the Alpine Space applying the ecosystem service concept. Sustainability 11(4), 1131. https://doi.org/10.3390/su11041131

Schirpke, U., & Ebner, M. (2022): Exposure to global change pressures and potential impacts on ecosystem services of mountain lakes in the European Alps. Journal of Environmental Management, 318, 115606. https://doi.org/10.1016/j.jenvman.2022.115606

Schirpke, U., Meisch, C., Marsoner, T., Tappeiner, U. (2018): Revealing spatial and temporal patterns of outdoor recreation in the European Alps and their surroundings, Ecosystem Services 31, 336-350. https://doi.org/10.1016/j.ecoser.2017.11.017

ESPON



Co-funded by the European Union
Interreg

espon.eu

ESPON 2030

ESPON EGTC
11 Avenue John F. Kennedy
L-1855 Luxembourg
Grand Duchy of Luxembourg
Phone: +352 20 600 280
Email: info@espon.eu
www.espon.eu

The ESPON EGTC is the Single Beneficiary of the ESPON 2030 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States and the Partner States, Iceland, Liechtenstein, Norway, and Switzerland.

Disclaimer
This delivery does not necessarily reflect the opinion of the members of the ESPON 2030 Monitoring Committee.