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Renewable energy communities in Italy: policy, opportunities, and a feasibility case study in Valdigne Valley

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Sommario

Alla mia mamma.

1. Scope of work

This thesis sets out to determine whether a Renewable Energy Community (REC, CER in Italian) can be credibly established across the Valdigne Valley, formed by the municipalities of Courmayeur, Pré-Saint-Didier, La Thuile, Morgex, and La Salle, and, if so, under what technical and economic conditions it would deliver stable value for its members and for the municipalities involved. Rather than treating "potential" in the abstract, the work pursues an operational objective: to align locally deployable photovoltaic capacity, on rooftops and on public parking canopies, with the real electricity demand of residents, businesses, hotels, ski facilities, and municipal assets, within the regulatory perimeter of a single primary substation. The guiding question is whether the coincidence between local generation and local load can produce sufficient *shared energy* under Italian rules to justify investment and to sustain the community over time.

The study is framed by the national context in which RECs have operated since 2020 and, from 2023, may share energy on the medium-voltage network provided all members are connected to the same primary substation. In that framework, the Gestore dei Servizi Energetici (GSE) remunerates the energy that is effectively shared among members, while non-shared exports fall under RID, and on-site use retains the value of self-consumption. The objective here is to quantify these three value streams with hour-by-hour realism and to translate them into participant-level outcomes for consumers and prosumers, distinguishing how benefits evolve as membership grows.

To achieve this, the thesis develops an integrated methodology that links geospatial resource assessment with demand reconstruction and economic evaluation. High-resolution rooftop analysis in QGIS, complemented by conceptual layouts for solar canopies on suitable public parking areas, yields annual producibility and representative monthly hourly profiles for each primary substation. On the demand side, electricity use is estimated by category—primary residences, second homes typical of the tourist economy, commercial and industrial activities, hotels, and ski facilities—using regional and national benchmarks, ISTAT counts, and where available municipal data, adjusted for seasonality and time-of-use bands. These supply and demand layers are then reconciled at substation level to compute self-consumption, exports, shared energy, and residual grid exchanges at hourly resolution.

A further objective is to test feasibility over time rather than as a static snapshot. The analysis therefore models staged adoption at four milestones 8Years 1, 2, 5, and 10) so as to capture how the balance of benefits shifts as more households and enterprises join and as municipal assets are activated. This makes it possible to compare substations with different demand structures: Entrèves, where the Courmayeur lifts and the Skyway create substantial daytime loads; Pré-Saint-Didier, where the La Thuile ski area plays a similar but smaller role; and Morgex, where the absence of ski facilities alters early-stage outcomes. The objective is not only to estimate totals, but to identify the drivers of simultaneity (like seasonality, operating hours, and asset mix—and to indicate practical levers (member composition, sequencing of projects, internal allocation rules) that increase shared-energy volumes without changing the regulatory perimeter.

Finally, the thesis aims to deliver decision-ready outputs: a transparent accounting of annual revenues by category and by participant type (consumer/prosumer), an assessment of the relative performance of each primary substation under consistent assumptions, and guidance on siting, sizing, and phasing that municipalities and stakeholders can use to move from pre-feasibility to implementation. In short, the objective is to provide a robust, replicable basis for establishing one or more RECs in the Valdigne that are technically sound, economically viable, and consistent with local priorities.

2. Introduction

The global energy transition is accelerating in response to climate change, rising energy costs and the need for sustainable development. Centralized power systems are gradually giving way to decentralized and community-based models that emphasize resilience, local participation and renewable generation. Within this shift, the Comunità Energetiche Rinnovabili (CERs or Renewable Energy Communities) are emerging as effective instruments to promote clean, locally rooted energy strategies [2].

CERs enable citizens, public bodies and small and medium-sized enterprises (SMEs) to collaborate in the production, sharing and consumption of renewable electricity inside the same primary substation. Photovoltaics is the most widespread technology in CERs, but the framework also allows other sources such as small-scale hydro, biomass, and small wind [2]. By organizing energy exchanges under cooperative governance structures, CERs support climate objectives while generating economic and social benefits at the territorial level [2]. In Italy, CERs have been formally recognized since 2020. Legislative Decree 199/2021, transposing the EU Renewable Energy Directive (RED II), established the legal foundations [1][2]. Subsequent measures-most notably the Decreto CACER (7 December 2023), the Integrated Text on Widespread Self Consumption (TIAD) and the GSE Regole Operative, detail eligibility, incentives, and technical conditions [6][3][4][5]. As of 2023, members of a CER may include producers and consumers connected to low- or medium voltage distribution grids, provided they are located within the same primary substation (cabina primaria). Energy sharing is a virtual process: the CER does not manage the physical flow of electricity but functions as a legal and financial entity coordinating production and consumption. Shared energy is measured by the GSE in 15 minute intervals; the GSE then pays the related incentives to the community, which distributes benefits internally according to agreed rules [3][5].
Italy's incentive framework rests on two main mechanisms applied only to the shared portion of energy:

1. Incentive tariff (tariffa premio or TIP) for new or significantly repowered plants ≤ 1 MW commissioned after 16 December 2021. For photovoltaics, a geographical adder applies up to +10 €/MWh for Northern regions and +4 €/MWh for Central regions [6][5].

2. Valorization contribution defined annually by ARERA, which recognizes the system value of locally consumed renewable energy (about 8.5 €/MWh in 2023) [3][4]. Alongside operating incentives, the PNRR provides a capital grant covering up to 40% of eligible investment costs (subject to size class cost caps). Initially limited to municipalities under 5,000 inhabitants, this support was subsequently extended, broadening access for mountain and rural areas [6][5].

This thesis presents a prefeasibility study for establishing a Renewable Energy Community in the Valdigne area (Courmayeur, Pré-Saint-Didier, La Thuile, Morgex, La Salle) in the Aosta Valley. Characterized by mountainous terrain and dispersed settlements, Valdigne faces challenges, such as seasonal demand peaks due to tourism, while offering strong opportunities for distributed PV.
The two main objectives of this thesis are:

- Technical: estimate available rooftop surfaces, identify public parking areas suitable for PV canopies, and analyze local consumption patterns in order to compare the possible production and the demand.

- Economic: assess investment needs, expected savings, and available incentives. CERs are still evolving, yet they represent a powerful tool to foster local energy independence, improve sustainability, and enhance social cohesion. This work contributes a case specific evaluation that can serve as a template for other mountain or rural territories.

Within this framework, Italy's approach to CERs follows a clear economic logic: public support is strictly tied to the quantity of shared energy measured by the GSE [3][5].

2.1. Regulatory Framework and some examples in Italy

CERs mark a profound shift in the Italian and European power system. More than a technical configuration, they constitute a social and territorial innovation that allows citizens, municipalities, and SMEs to participate directly in the energy transition [2]. Certain actors are excluded (e.g., large energy consumers or companies whose primary business is energy trading). In the Valdigne area, this restriction excludes the Mont Blanc Tunnel, whose energy intensity disqualifies it from membership [6][5].

CERs are not-for-profit legal entities whose primary aim is to deliver environmental, social, and economic benefits. Participation must be voluntary and open, and control must remain local and democratic [1][2]. A cornerstone is the calculation of shared energy: in each 15-minute interval, shared energy equals the lower of the sum of production from all participating plants and the sum of consumption by all participating users. Based on these data, transmitted automatically by DSOs, the GSE awards the financial benefits (TIP and ARERA valorization) to the CER. The community's statute defines how benefits are allocated among members [3][5]. From a governance perspective, the CER adopts a statute that defines roles, decision making, and benefit distribution. A Referente (natural or legal person) acts as the single contact point with the GSE, responsible for compliance, applications, payments, and internal communication. CERs can also integrate storage systems and EV charging infrastructure; their energy flows are included in shared energy calculations, enhancing self-balancing and the local value of renewable production [3][5].

Participation is open to a broad range of actors, but governance must ensure democratic control and equitable benefit allocation. Surplus revenues should primarily benefit non-business consumers or be reinvested in social initiatives with positive territorial impacts [6][5].

2.2. Technical and Geographic Scope

Eligibility for national support is tied to technical and geographic constraints. All members must be located within the same primary substation area, identified via the GSE mapping tool. In non-interconnected islands, the entire island counts as a single area [3][5].

The incentive tariff (TIP) is reserved for eligible plants: new or significantly repowered, commissioned after 16 December 2021, capacity ≤ 1 MW. For PV, all components must be brand new and compliant with CEI standards; reused or refurbished materials are excluded. Plants installed before the cut off or exceeding 1 MW may still join a CER, but their output contributes only to shared energy, not to the TIP [6][5].

Moreover, the cumulative capacity of preexisting plants included in the configuration cannot exceed 30% of the community's installed capacity [6][5].

In practice, the primary substation perimeter functions as the spatial container for viable CER design. Feasibility screening should verify that all points of delivery (POD) fall within the same perimeter before sizing plants and recruiting members, since only those PODs contribute to shared energy and to the associated benefits [3][5].

2.3. Organizational Structure and Participants

A CER is established under Italian law via a constitutive act and a statute that reflect open participation, democratic governance, and fair benefit distribution. The statute should define decision-making rules, conflict resolution, and reinvestment mechanisms [1][6][5].

Key roles:

- Producers: own/manage renewable plants;
- Consumers: use electricity within their premises;
- Prosumers: both produce and consume;
- Referente: single interface with the GSE (applications, compliance, payments) [3][5].

The statute must codify the community purpose—delivering environmental, economic, and social benefits rather than financial profit—and the autonomy and openness of participation. Categories of controlling members should align with Legislative Decree 199/2021 and the CACER framework [1][6].

Producers who are not members may, through a mandate to the Referente, have their injected energy counted toward shared energy if all requirements are met. Conversely, PODs benefiting from "Scambio sul Posto" cannot be included as customers in a CER configuration to avoid double counting [3][5].

Members retain full freedom to choose their electricity supplier and may withdraw from the community at any time, subject to fair arrangements, especially where early exit follows shared investments [3][5].

2.4. Incentive Allocation Within the Community

Financial benefits originate from two mechanisms: the TIP and the ARERA valorization. The GSE calculates both based on 15-minute shared-energy data and pays the CER; the statute then governs internal redistribution [3][5].

- The TIP is granted for 20 years on energy produced by eligible plants (≤ 1 MW, post-16/12/2021). It combines a fixed baseline (by size class) and a variable premium (0–40 €/MWh) that increases as wholesale prices fall. For PV, a geographical adder applies (+10 €/MWh North; +4 €/MWh Center). Overall, the TIP ranges 60–120 €/MWh [6][5].
- The ARERA valorization remunerates the system benefits of local consumption and also applies to older plants; in 2023 it amounted to around 8.5 €/MWh [3][4]

Where the PNRR capital grant is used, the TIP is reduced to prevent double funding. The capital grant typically covers up to 40% of eligible costs (subject to per-kW caps) and is requested via the GSE portal during dedicated windows [6][5]

Internal allocation principles (to be defined in the statute):

- How much of the TIP is retained by producers (investment recovery) versus allocated to consumers [6][5];

- Whether consumers receive part of the ARERA valorization or benefit solely through bill reductions [3][5];
- Criteria for reinvestment of surplus revenues in social or territorial projects [6][5];
- Any thresholds that trigger allocating a share of premiums to non-business users and/or social purposes, as required by the CACER framework [6].

A well-designed allocation model balances investment signals for producers with fairness for consumers, including households and vulnerable users, so that shared energy becomes not only a technical metric but a lever for social cohesion and territorial development.

2.5. CER in Italy, real examples in the North

2.5.1. Magliano Alpi (Piedmont)

Magliano Alpi, in the province of Cuneo, was the first Italian community to be constituted under the national framework. It formed in December 2020 with the town hall and a small cluster of public buildings as initial production sites. The configuration is clear: PV on visible municipal roofs, members drawn from households and local SMEs under the same primary substation, and a statute that sets open participation and fair distribution as baseline principles. The town used the community to make the accounting tangible-members receive statements that show what was produced on the shared plants, what was matched locally within each 15-minute window, and the economic value accrued to the community and to individual members. Beyond the numbers, the project has been a civic tool: school visits to the roof arrays, public dashboards, and a steady enlargement of the member base after the first year [7].

Figure 1 . Magliano Alpi

2.5.2. Turano Lodigiano (Lombardy)

Turano Lodigiano built a community around two modest PV arrays on municipal sports facilities (the locker-room building and the football field) totalling roughly forty-six kilowatts of peak capacity. The plants supply their host buildings during the day; the surplus is shared with a small circle of households, the parish and additional municipal loads that fall under the same substation. Geography is compact, which helps people see the panels they are connected to, and the accounting is easy to explain. The social dimension has been explicit from the start, with municipality giving priority to households in more fragile situations. Here again, the technical scheme is simple; what makes it work is the fitness between daytime public use and evening residential demand [8].

Figure 2 . Turano Lodigiano

2.5.3. Imola (Emilia–Romagna, as a northern SME pattern)

In the industrial district of Imola, the municipality supported the creation of a community for small and medium-sized enterprises. Three manufacturing firms located under the same primary substation pooled new PV capacity with existing rooftop arrays and formalised the sharing under the national rules. The aim was pragmatic: stabilise energy costs and give the companies a way to expand PV without wasting surplus at midday. Over the first operational year the configuration has widened to include additional firms, with the municipality keeping a light but useful role in communication and governance. Although the setting is different from a mountain valley, the logic of daytime anchor loads, and incremental expansion is directly transferable [9].

Figure 3 . Imola

2.5.4. Alto Vicentino (Veneto)

Around Thiene, fifteen municipalities in the Alto Vicentino area decided to coordinate the rollout of communities across their territories. They set up an umbrella foundation to standardize communication, member onboarding and procurement, while recognizing that each electrical basin must keep its own metering and accounting. The arrangement solves a practical problem: administrative borders rarely coincide with electrical perimeters. In the Veneto case, the umbrella approach provides a common identity and lowers transaction costs for small towns that would struggle to navigate procedures alone. For a multi-substation valley, this institutional architecture is especially relevant.

Across these places the mechanics are consistent. Production starts on municipal surfaces. Members are a mix of families, small commerce and a handful of anchor loads. Benefits are communicated plainly with periodic statements. After the first months of operation, communities add carports and, where it pays back, small batteries to improve sharing in winter evenings and shoulder seasons. Nothing in this sequence is exotic; it is simply the shortest line between an idea and a working configuration [10].

Figure 4 . Alto Vicentino municipalities

2.6. CER in the Aosta Valley

2.6.1. Châtillon (the first constituted community)

On 3 May 2024, in Châtillon, a group of citizens and local entities constituted the first community in the Region. The association's purpose is explicit: deliver environmental, economic and social benefits to members and to the local area, not financial profit. The initial production sites are deliberately modest, public rooftops and small private arrays within the same electrical basin, because the priority is to make governance and accounting work practice. The founding members formalized open participation, a simple allocation rule for shared-energy revenues, and a calendar of communications to the town. From a regional perspective, the key point is that the full path (tatute, recognition by the GSE and first member onboarding) has already been walked once in the Valley [11].

Figure 5 . Châtillon

2.6.2. The Plaine d'Aoste (Aosta and neighbouring municipalities)

In March 2025, the City of Aosta and a group of neighbouring municipalities in the Mont-Émilius area approved a convention to build a shared community across the plain. The convention identifies a lead authority, sets up a technical–administrative steering group, and—crucially—commits to pre-feasibility along the three primary substations that serve the area, with the Region covering preparatory costs up to formal constitution. The first stage concentrates on public rooftops (schools, gyms, offices) to activate sharing quickly and to provide concrete figures for citizens. The second stage opens to private members who fall within the same electrical basins. The approach mirrors the Italian learning curve: prove the mechanism with visible assets, then widen participation with data in hand [12].

Figure 6 . Aosta

2.7. The current situation in Valdigne

Electrically, the Valdigne is clearly divided by three primary substations: Entrèves (80 % of Courmayeur), Pré-Saint-Didier and Morgex. That split is a design aid: a sensible configuration is a coordinated trio of electrical "cells," one per substation, each with its own rooftops and members, under a shared identity and a common statute. The electrical basins become the real map for recruitment and for siting production.

The surfaces are those already identified in this thesis. Public roofs provide daytime demand and civic visibility. Sun-exposed public parking can host PV canopies that still make sense in winter, not only for energy but as snow protection for residents and visitors. Around those anchors, a base of households and small businesses provides the everyday profile that PV needs to be shared locally. Tourism adds winter/summer and holiday peaks; this is precisely why storage should be staged only when the measured data show that evening peaks are the bottleneck. In the first months, the priority is to commission quickly on the easier roofs, start sharing, and then expand in waves.

Operationally, early discipline matters more than early size. Map prospective members' points of delivery to the three substations before recruitment, so there are no surprises. Prioritize surfaces with straightforward permitting and predictable structural loads. Align commissioning schedules with alpine construction windows. Establish a monthly reporting routine (production, shared energy, value accrued to each member class) and stick to it. Communities stay alive when people receive clear statements in euros as well as kilowatt-hours.

2.8. What we can borrow and replicate in the case study

We adopt the sequence proven in the Italian experience. Implementation begins with visible public anchors within each substation catchment, coupled with a balanced portfolio of loads: municipal/tertiary demand during the day and households to absorb evening consumption. The statute remains lean yet complete, specifying roles, allocation rules, and entry/exit conditions in plain language. Communication is treated as a core function, enabling members to understand why they joined. Regular statements report production by shared plant, the share matched locally within each basin, and the value distributed across member classes.

Building on the generation potential assessed in this thesis, we translate resources into design rules suited to the Alpine context. For parking shedding governs geometry: module tilt is higher; clearances and spans are set for winter ploughing corridors and tourist flows; and structural checks for snow and wind loads precede any tender. Shading is evaluated with site photography and, where necessary, digital models. On residential and small-building roofs, we avoid imposing a fixed module tilt: we follow the roofs' native orientations and pitches, selecting mounting systems that respect the envelope; on sensitive roofs, we prefer mechanical anchoring over heavy ballasts. Our objective is a high shared-energy ratio rather than simply maximizing annual generation: PV is sized to daytime anchor loads, and storage is introduced only where the first months of data reveal evening peaks as the limiting factor. EV charging is metered explicitly as a community load so that midday production can be absorbed locally in summer.

Consistent with the basin-first approach set out in the introduction, we propose three sibling communities (Entrèves, Pré-Saint-Didier, and Morgex) are coordinated under a single umbrella for statute, procurement, and communication, while metering and accounting remain separate. This arrangement preserves eligibility and delivers economies of scale in tendering and in deploying an Energy Management System (EMS) that serves the portfolio with dedicated dashboards for each cell.

3. State of the Art

Renewable Energy Communities (RECs; Comunità Energetiche Rinnovabili, CER) have moved from policy aspiration to implementable practice within the European legal framework, chiefly through the recast Renewable Energy Directive (RED II) and the Electricity Market Directive, which together create space for collective self-consumption and local energy sharing while leaving critical design levers to Member States and distribution system operators [2][19]. For a mountain territory such as the Valdigne, where permanent residents, second homeowners, tourism enterprises, and municipal services share a constrained grid and seasonally variable loads, the state of the art suggests approaching the community not as a predefined entity but as an institutional arrangement that must be made legible from the outset. The literature is unambiguous that a community only becomes real through explicit boundary setting and credible rules about who may join, on what terms, and with which rights and obligations; absent this clarity, participation falters and disputes over fairness accumulate as projects mature [18]. A disciplined definition of membership classes (permanent residents, non-resident homeowners, small and micro enterprises, and public services) paired with explicit benefit sharing and voting rules thus becomes the enabling condition for everything else.

People do not join or remain in energy communities for a single reason, and the empirical evidence should shape both project design and communications. Quantitative and qualitative studies show mixed motives: economic savings and price stability matter, but so do environmental values, local identity, and the desire to act prosocially in a group that is perceived as fair and transparent [14]. A modern REC therefore stacks a clear financial proposition with a civic narrative that links local renewable generation to the resilience of essential services and to visible, place anchored assets (PV on schools, municipal buildings) capable of reinforcing social identity. The practical implication is to make contributions and benefits legible at the level of the member's bill and at the level of the town square: dashboards, periodic statements that isolate avoided energy charges from network components, and open reporting on how surpluses are reinvested (for instance, in targeted efficiency for low income households) sustain morale and reduce the perception that the project is captured by early adopters [14][17].

Behind the label of community lie different governance choices with different consequences for agency, risk, and scalability. Comparative typologies in the literature argue for keeping structures simple and legible: who owns the assets, who holds decision rights, and how value is created and shared are the three axes that determine how a REC behaves over time [15]. Member led cooperatives excel at local legitimacy and learning but may struggle with managerial capacity; municipal anchored partnerships can de risk early development and align public interest objectives but must secure guardrails that keep citizen voice meaningful; public–private hybrids can professionalize operations and unlock capital at the price of more formal contractual governance [15]. In practice, these are not abstract categories but concrete blueprints. For Valdigne, a municipality anchored cooperative using public roofs and essential service loads as a backbone is a robust default because it lowers development risk, signals civic leadership, and provides an inclusive platform for households and SMEs; a tourism oriented partnership variant, in which hotels, mountain huts, and ski area operators co invest with municipalities, can be layered where winter peaks and professional O&M capabilities justify it. Being explicit about these choices at the outset reduces later friction and speeds replication across neighboring municipalities [15].

Business models that endure in the literature and in practice are layered rather than single stream. Reviews identify four recurring pillars:

- collective self-consumption and energy sharing;
- community retailing or supply arrangements where regulation permits;

- demand side flexibility, especially EV charging and heat pump scheduling;
- energy efficiency services that reduce demand and free up headroom for new members [17].
  Two cross cutting lessons dominate. First, transparent cost allocation is not a back-office task but the very core of the model: members must see and trust how metered energy maps to benefit. Second, regulation places a hard ceiling on value capture: metering intervals, tariff structures, the interface with the DSO, and data exchange protocols can enable or disable a given revenue layer irrespective of technical potential [17][19]. A pragmatic sequencing follows from these constraints: start with collective self-consumption among municipal assets and early residential adopters; add flexibility in visible places like EV hubs at municipal car parks, thermal storage where it measurably raises self-consumption; and then evaluate ancillary services or community retailing conditional on regulatory green lights and DSO cooperation [17].

Institutional context matters as much as technology. Evidence from Spain shows that renewable energy cooperatives proliferated where cooperative traditions, enabling policy, and credible intermediaries lowered transaction costs for founders and new members [16]. Intermediaries (like regional energy agencies, cooperative federations, or trusted technical advisors) standardize documentation, create onboarding channels, and provide dispute resolution routines that individual volunteers cannot sustain alone. Their presence shortens timelines without dissolving local decision making, provided that bylaws and service contracts are transparent about roles, fees, and accountability [16]. In a multi municipal alpine area, an intermediary can coordinate shared templates for membership, allocation, and data governance while leaving each community to decide on local priorities and investment pacing.

On technology, the state of the art is best read as a set of design goals rather than a prescription of devices. Portfolios should:

- maximize coincidence between generation and demand;
- use flexibility (temporal shifting and controllable loads or raise self-consumption);
- distribute benefits fairly.
  In Valdigne we will not pursue public EV charging stations or storage systems, rather we will concentrate exclusively on distributed photovoltaics, with rooftop PV and photovoltaic carports as the core assets. The community will seek a deliberate balance between consumers and prosumers, welcoming ski area facilities where present, including lifts, service buildings, workshops, and hospitality structures, as active members who can align on site generation with local demand across seasons. The operational focus is practical, and meter driven, prioritizing self-consumption behind the meter, sizing PV to real daytime loads in municipal, service and tourism facilities, and coordinating production and use across member classes so that the aggregate profile remains stable, efficient, and easy to govern.

Governance comes first, since durable trust depends on clear rules. A transparent allocation and reporting framework will be established, covering metering, settlement, and benefit sharing, and this framework will be communicated in simple language to all members (municipal entities, private operators, residents). Once institutional clarity is in place, the technology choices follow naturally, namely simple modular PV on roofs and carports, deployed where it delivers measurable local value, without adding storage or EV infrastructure that would complicate operations or blur incentives. In short, institutional design and business model sequencing lead, technology configuration follows.

Seasonality requires particular care in defining boundaries and allocation rules, the presence of second homes and intermittently occupied dwellings raises equity questions, whether such owners are eligible as full members, how their intermittent consumption should be treated in allocation algorithms, whether their participation can be conditioned on contributions that reflect lower presence but higher per capita income, and how SMEs that anchor local employment yet face volatile seasonal loads are recognized. The literature's response is to codify membership classes with explicit rights and obligations, to link them to transparent allocation and settlement rules, and to embed review clauses that allow categories to evolve without reopening foundational conflicts, in practice this can mean differentiating voting or representation rights by class, using allocation keys that blend metered shares with fairness constraints for vulnerable households, and reserving a share of surpluses for targeted efficiency upgrades where payback horizons would otherwise exclude participation [18].

In our case, second homes are considered eligible to join the community, and they will be rewarded in proportion to their measurable contributions to generation and flexibility, avoiding opaque cross subsidies, moreover, if second homes join as prosumers, it is assumed that they will install smaller photovoltaic systems than primary residences in Valdigne, consistent with more intermittent usage profiles and with the aim of maximizing local self-consumption.

Data governance has become strategy, not plumbing. Trustworthy metering and auditable allocation sustain confidence and enable flexibility markets. Best practice assumes half hour or quarter hour metering where available; applies published, testable allocation algorithms; and issues periodic statements that separate avoided energy charges, network tariffs (to the extent applicable), and any ancillary service revenues. Clear data policies support both equity (members can see what they are getting and why) and system value by sending credible signals for shifting demand [17]. The same apparatus also underwrites legitimate research and policy evaluation: distributional equity indicators, such as the share of benefits captured by vulnerable households, SMEs, and public services, sit alongside classic technical metrics like self-consumption and self-sufficiency, and economic metrics such as net present cost and levelized cost [14][17][18]. Where regulators recognize network cost reductions from local coordination, the measurement logic must be co designed with the DSO from the start; without this, claims to system value remain rhetorical [19].

In Valdigne, for the pre-feasibility study we have adopted one hour intervals by design, this simplification reflects typical data availability for municipal and tourism loads at the scoping stage, reduces noise that does not change investment level conclusions, and keeps the focus on structural signals such as daytime alignment of PV with service sector demand and seasonal shifts in occupancy, the allocation methods and governance logic remain the same and can be applied at finer granularity when half hour or quarter hour data are available, and a detailed design phase will revisit the resolution where necessary to capture intra hour effects that matter operationally

Risk management in energy communities is largely institutional. The most common failure modes are predictable from comparative studies: legitimacy risks when membership boundaries blur or expectations diverge; motivation risks when non-economic motives are ignored and communications reduce the project to private savings; regulatory and revenue concentration risks when business models depend on one stream or underplay tariff and metering constraints; and coordination failures in the absence of capable intermediaries or standardized routines [14][16][17][18][19]. Mitigations are equally well understood: sequence commitments (letters of intent before binding contracts), adopt standardized bylaws and conflict of interest policies, procure professional O&M early, and engage the DSO at scoping to clarify metering perimeters and data exchange. Keeping the governance legible (a short list of archetypes rather than bespoke one offs) lowers legal and administrative overhead and eases replication.

All strands above converge on a pragmatic workplan for prefeasibility in Valdigne. Define membership classes and representation rules with public consultation, adopting a default municipality anchored cooperative blueprint and a tourism cluster variant to be deployed where appropriate [15][18]. Sequence the business model in layers: start with collective self-consumption for municipal assets and early adopters; add demand side flexibility through EV hubs, smart heat pump operation, and thermal storage; evaluate further layers (ancillary services, community retailing) only where regulation and DSO interfaces make them bankable [17][19]. Institutionalize an intermediary role, via a regional agency or cooperative federation, to standardize documentation, onboarding, and advisory support while preserving local decision rights [16]. Operationalize data governance by specifying metering intervals, allocation algorithms, and statement templates in advance; publish a data policy and schedule periodic distributional equity reviews [17][18][19]. Communicate to mixed motives: frame the economic value with civic and environmental benefits, make contributions visible, and earmark part of surpluses for targeted social objectives to anchor legitimacy [14]. Measure what matters locally using a compact indicator set that covers technical performance, economics, distributional equity, recognized network value where methodology exists, greenhouse gas abatement per euro invested, and resilience of critical services [15][17][19].

Read together, the evidence does not recommend a single ideal model, but it recommends a disciplined way to design one that fits local institutions, seasonality, and regulatory constraints. Motivation diversity is an asset to design for rather than a problem to solve [14]; boundaries and benefit rules must be explicit and revisited [18]; simple, legible archetypes ease implementation and replication [15]; revenue stacking and robust data governance provide the operational backbone [17]; and capable intermediaries make communities repeatable at reasonable transaction cost [16]. Within the European legal frame, these principles allow the Valdigne to build a community that attracts diverse members, remains financially resilient under current regulation, and is straightforward to replicate across neighbouring municipalities [2][19].

4. Maximum Production Potential in Valdigne: Private Rooftop PV

Estimating the potential of renewable energy sources' production requires a structured and consistent methodology, capable of connecting available datasets with the broader objectives of energy planning. This chapter illustrates the approach adopted to assess the photovoltaic potential of rooftops in the Valdigne area. Particular attention is given not only to the operational steps undertaken, but also to the strategic reasoning that has guided these methodological choices.

A key decision concerns the unit of analysis. The study is carried out at the building scale, rather than at the level of individual housing units. This choice reflects the fact that photovoltaic producibility depends primarily on the geometric and topographic characteristics of roof surfaces, such as orientation, slope, and usable area, which are attributes of the building as a whole. An analysis at the household level would not provide additional insight into the technical potential, while at the same time introducing unnecessary statistical and administrative complexity.

The chapter also focuses exclusively on solar photovoltaic energy on private rooftops, leaving aside other renewable sources such as wind and hydro. This decision stems from both the strong compatibility of rooftop PV with the existing built environment and the availability of detailed geospatial data that allows a reliable estimation of solar potential. Conversely, wind and hydro resources require different scales of analysis and specific datasets, which fall beyond the scope of this work. The process used to estimate the producibility of the roof-mounted Valdigne system is summarized in the following flowchart.

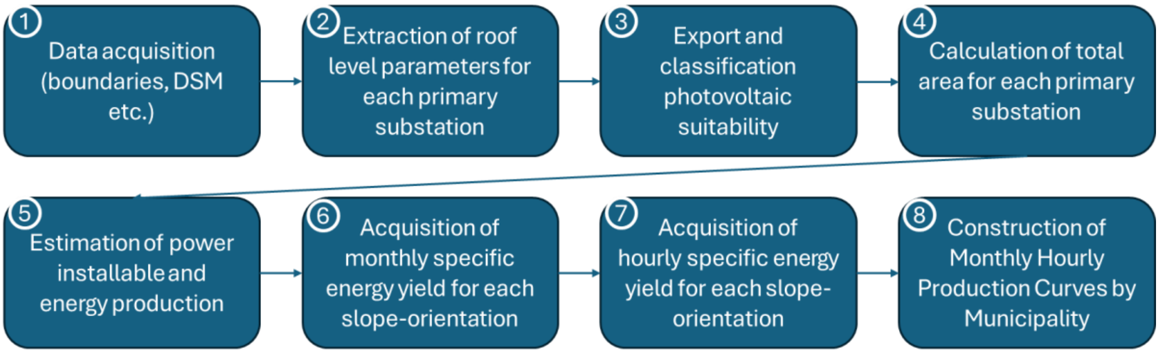

Figure 7 . Summarizing flowchart

4.1. Data Collection and Processing on Building Geometries

In order to estimate the theoretical potential about the photovoltaic energy production in the Valdigne area, a systematic geospatial analysis was carried out, aimed at identifying and characterizing the roofs present in the territory.

This activity involved the collection and processing of various geospatial datasets, followed by the extraction of geometric and topographic parameters relevant to the installation of photovoltaic systems, such as roof area, slope, and orientation, using QGIS software. The analysis was organized according to the operational boundaries of the three primary substations serving the Valdigne area: Entrèves, Pré-Saint-Didier, and Morgex. These service areas were used as the spatial reference for subdividing and aggregating the building data.

The ultimate goal was to associate each building with the service area of its respective primary substation and assess its suitability for photovoltaic installation based on topographic criteria.

4.1.1. Acquisition and Preparation of Geospatial Data

The first step involved collecting all the necessary spatial layers, obtained from publicly accessible regional geodatabases [20]. In particular, the following GIS datasets were downloaded from the official open data portal of the Autonomous Region of Aosta Valley:

- a vector layer of municipal boundaries, defining the administrative subdivisions of the regional territory;
- a vector layer of building footprints, containing geometries and attributes for all constructed structures within the area;
- a set of DSM (Digital Surface Model) raster files, representing ground elevation including buildings, vegetation, and infrastructure for the entire Valdigne region.

In parallel, the spatial coverage of the three primary electricity distribution substations was reconstructed using data provided by the regional power grid operator. Although this information was not directly available in a GIS-ready format, the service area boundaries were digitized and georeferenced from graphic maps provided by the operator [13].

An image extracted from QGIS with the layers used is shown below.

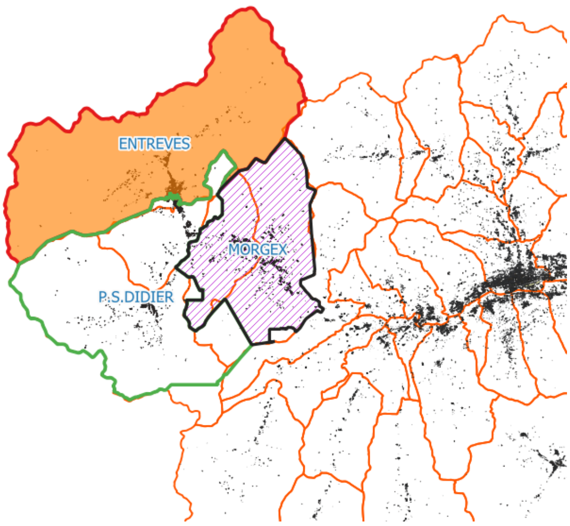

Figure 8 . Building, municipal, and primary substation layer

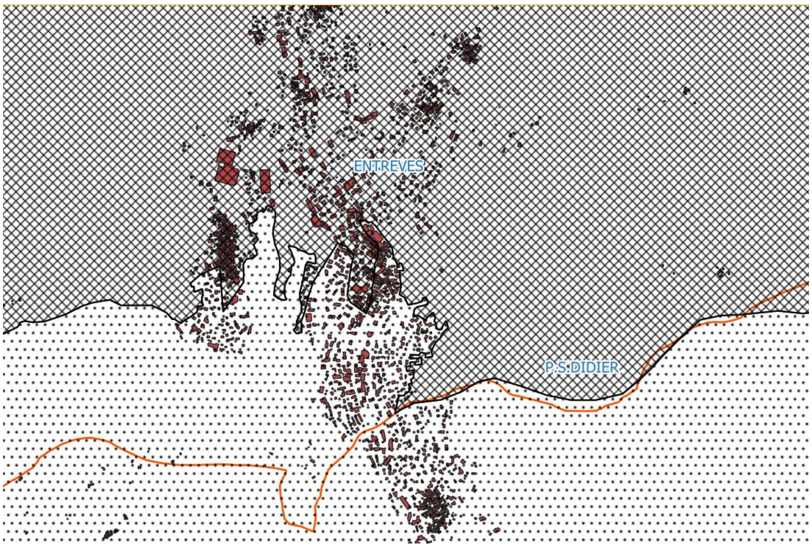

Figure 9 . Focus of Qgis buildings for Courmayeur and Pré Saint Didier

It's important to notice that in the image above, the red lines are the boundaries of the municipalities, while the areas with squares and points inside are the boundaries of the primary substations.

4.1.2. Spatial Filtering and Municipal Association

Once all the base layers were loaded into QGIS, the spatial analysis began by isolating the subset of buildings located within the area of interest.

This was achieved through a spatial intersection operation between the building footprint layer and the polygons representing the service areas of the primary substations. The result was a filtered dataset containing only the buildings falling within the geographical scope of the three substations.

To associate each building with its respective municipality, a spatial join operation was performed between the building layer and the municipal boundary layer. The municipality name was extracted from the "descrizione" attribute field in the municipal layer and linked to each building geometry.

	fid	clas_ispra	cod_ispra	classifica	Shape_Leng	Shape_Area	area_mq	descrizion	TXT1	slope_mean	aspect_mean	orientamento
1	1	Altri usi	LUA-6	Altri usi	49,6644604272	115,38601741	115,39	LA THUILE	ENTREVES	11,4872427110...	147,496839062...	SE
2	2	Altri usi	LUA-6	Altri usi	21,8601521961	27,6428517327	27,64	PRE-SAINT-DID...	ENTREVES	13,9178817272...	154,677715301...	SE
3	3	Reti di trasporto	LUA-4_1	Reti di trasporto	100,488137778	493,849960109	493,85	PRE-SAINT-DID...	ENTREVES	48,5355973622...	203,954965107...	SW
4	4	Altri usi	LUA-6	Altri usi	100,447893078	196,721272375	196,72	MORGEX	ENTREVES	13,1030562799...	149,400503976...	SE
5	5	Residenziale pe...	LUA-5_1	Residenziale	37,5758469446	79,3700504916	79,37	COURMAYEUR	ENTREVES	40,7352565765...	128,696605491...	SE
6	6	Residenziale pe...	LUA-5_1	Residenziale	45,5046207761	95,8095170477	95,81	COURMAYEUR	ENTREVES	34,6379835789...	128,551358002...	SE
7	7	Residenziale pe...	LUA-5_1	Residenziale	64,6270304069	209,425659515	209,43	COURMAYEUR	ENTREVES	39,7154048626...	198,797345267...	S
8	8	Residenziale pe...	LUA-5_1	Residenziale	26,8743348658	44,7949582814	44,79	COURMAYEUR	ENTREVES	29,1532917022...	94,1340427398...	E
9	9	Residenziale pe...	LUA-5_1	Residenziale	63,5804739884	228,991282531	228,99	COURMAYEUR	ENTREVES	30,4101092772...	243,196305500...	SW
10	10	Residenziale pe...	LUA-5_1	Residenziale	42,3009751026	100,581039082	100,58	COURMAYEUR	ENTREVES	33,4116867780...	109,346842447...	E
11	11	Residenziale pe...	LUA-5_1	Residenziale	82,1787074971	225,511523045	225,51	COURMAYEUR	ENTREVES	24,9275298459...	207,690486431...	SW
12	12	NULL	LUA-8888	Non classificato	25,4375207732	39,5777410806	39,58	COURMAYEUR	ENTREVES	35,0523057665...	265,743748256...	W
13	13	Altri servizi com...	LUA-3_1_4	Magazzini e loc...	33,6260843601	68,1985560033	68,2	COURMAYEUR	ENTREVES	24,3564229965...	213,241273498...	SW
14	14	Residenziale pe...	LUA-5_1	Residenziale	64,1306065135	170,562285009	170,56	COURMAYEUR	ENTREVES	24,7995089728...	168,605407528...	S
15	15	Servizi di allogg...	LUA-3_1_3	Servizi di allogg...	76,649747272	233,195070548	233,2	COURMAYEUR	ENTREVES	37,6466489727...	219,240487761...	SW
16	16	Residenziale pe...	LUA-5_1	Residenziale	28,9495200171	42,5348451822	42,53	COURMAYEUR	ENTREVES	27,0652543173...	172,711132049...	S
17	17	Residenziale pe...	LUA-5_1	Residenziale	25,8035446439	34,7989119111	34,8	COURMAYEUR	ENTREVES	22,7362226910...	151,960608588...	SE
18	18	Industria dei pr...	LUA-2_1_3	Industrie dei pr...	15,9905780609	14,3410905349	14,34	COURMAYEUR	ENTREVES	50,5543231964...	280,422605514...	W
19	19	Residenziale pe...	LUA-5_1	Residenziale	40,9100997991	94,5470687946	94,55	COURMAYEUR	ENTREVES	26,9387595176...	178,454739532...	S
20	20	Residenziale pe...	LUA-5_1	Residenziale	25,439873388	35,0695482194	35,07	COURMAYEUR	ENTREVES	27,3772336840...	149,890666537...	SE
21	21	Altri usi	LUA-6	Altri usi	26,5760466149	37,400526963	37,4	COURMAYEUR	ENTREVES	61,4626388549...	304,083297729...	NW
22	22	Residenziale pe...	LUA-5_1	Residenziale	46,4832578735	105,080368474	105,08	COURMAYEUR	ENTREVES	35,0632807199...	158,931490824...	S
23	23	Residenziale pe...	LUA-5_1	Residenziale	55,1606816391	162,775544827	162,78	COURMAYEUR	ENTREVES	32,7552884032...	206,459870501...	SW
24	24	Residenziale pe...	LUA-5_1	Residenziale	38,2505621656	78,2788203915	78,28	COURMAYEUR	ENTREVES	29,6118251255...	230,499034154...	SW

Mostra Tutti gli Elementi

Figure 10 . Table of Qgis dataset

The dataset is organized in the table above, where each column provides specific information about the land use polygons analyzed. The column **fid** represents a unique identifier automatically assigned to each record. The fields **clas_ispra** and **cod_ispra** correspond to the official classification system adopted by ISPRA (Italian Institute for Environmental Protection and Research), which allows for a standardized categorization of land use. The column **classifica** reports the descriptive name of the category of land use (e.g., residential areas, transport networks, or other uses).

Geometric attributes of the parcels are described by **Shape_Leng**, which indicates the perimeter of the polygon in meters, and **Shape_Area**, which corresponds to its surface area in square meters. The field **area_mq** also provides the area of each polygon, generally expressed in square meters, and is often derived from or standardized with respect to the Shape_Area.

The column **descrizion** specifies the municipality or locality in which the parcel is located, while **TXT1** includes additional descriptive information, such as the administrative unit or settlement name.

Topographic information is included through the parameters **slope_mean**, which indicates the mean slope of the terrain in degrees, and **aspect_mean**, which represents the average exposure of the slope, expressed in angular degrees where 0° corresponds to North, 90° to East, 180° to South, and 270° to West. Finally, the column **orientamento** translates the numerical aspect values into cardinal directions (e.g., N, NE, SW), providing a more intuitive interpretation of slope orientation.

The administrative subdivision by substation was as follows:

- **Entrèves Substation**: serves the majority of the municipality of Courmayeur, covering approximately 80% of its buildings. This percentage was derived in QGIS by comparing the total number of buildings in the municipality with the number of buildings located within the service area of the Entrèves substation.
- **Pré-Saint-Didier Substation**: covers the municipalities of La Thuile, Pré-Saint-Didier, and the remaining southern part of Courmayeur;
- **Morgex Substation**: includes all and only the municipalities of La Salle and Morgex.

The total number of buildings for each substation and municipality is reported in the table below. It is worth noting that a small number of buildings belonging to neighboring municipalities are also included within the boundaries of the primary substation. However, these cases are not relevant for the purposes of the present analysis and are therefore not considered significant.

The total number of buildings for each substation and municipality is reported in the table below. It is worth noting that a small number of buildings belonging to neighboring municipalities are also included within the boundaries of the primary substation. However, these cases are not relevant for the purposes of the present analysis and are therefore not considered significant.

Table 1 . Total number of buildings for each primary substation

Entréves	Total	2.427
	Courmayeur	2.423
	La Thuile	1
	Morgex	1
	Pré-Saint-Didier	2
Morgex	Total	4.148
	La Salle	2.448
	Morgex	1.700
P.S.Didier	Total	3.005
	Courmayeur	504
	La Salle	8
	La Thuile	1.278
	Morgex	4
	Pré-Saint-Didier	1.211

4.1.3. Integration of the Digital Surface Model (DSM) and Topographic Analysis

The initial DSM files consisted of several raster tiles, each covering a portion of the Valdigne area. These were mosaicked into a single raster using GDAL tools in order to create a continuous elevation model for the entire study area. This step was essential to ensure a consistent spatial scale and uniform reference system across the whole territory under investigation. The resulting DSM was then clipped according to the boundaries of the primary substation service areas, thereby restricting the analysis to the zones of direct interest.

The resulting DSM was then clipped based on the boundaries of the primary substation service areas, thus limiting the analysis to only the relevant zones.

From the DSM, two fundamental datasets were derived:

- a slope raster, representing the inclination (in degrees) of the surface at each pixel;
- an aspect raster, indicating the azimuthal orientation (in degrees from north) of the slope.

Both were calculated using the **gdal:slope** and **gdal:aspect** tools available in the QGIS processing toolbox.
The DSM raster was used as the input, with the *"Compute edges"* option enabled in order to preserve edge gradients and curvature details. An image of the complete DSM layer is shown below:

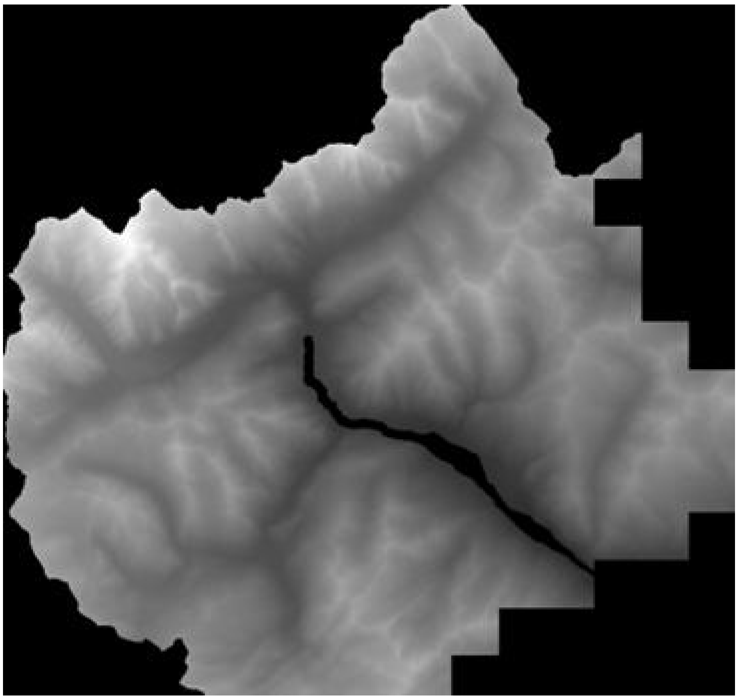

Figure 11 . DSM layer

In the visualization, darker tones correspond to lower elevations, while lighter tones represent higher elevations, providing an immediate perception of the topographic gradients across the area [20].

Extraction of Roof-Level Parameters

After deriving slope and aspect from the DSM, roof-level parameters were extracted by overlaying building footprints on these rasters and computing polygon summaries.

For slope, the mean value within each footprint was obtained via **qgis:zonalstatistics,** yielding the attribute **slope_mean (**degrees). Because aspect is an angular quantity, a simple average is not appropriate (angles wrap at 360°). We therefore computed a circular mean orientation:

Normalize to compass bearing. GDAL's aspect uses 0° = East, counterclockwise. We converted it to a compass bearing (0° = North, clockwise) with:

$$bearing = (450 - aspect) mod 360$$

Encode as unit vectors. For each cell we computed x=cos(bearing) and y=sin (bearing) using **gdal:rastercalculator**.

Aggregate by building. Using **qgis:zonalstatistics**, we extracted polygon means of those components (**cos_mean, sin_mean**).

Recover the mean direction. The circular mean bearing per building is

$$\theta mean = atan2\ (sin\_mean,\ cos\_mean)$$

Where "atan2(y,x)" is a mathematical function calculation the arctangent considering both the sine "y" and the cosine "x"

The intervals used to determine roof orientations are illustrated in the diagram below.

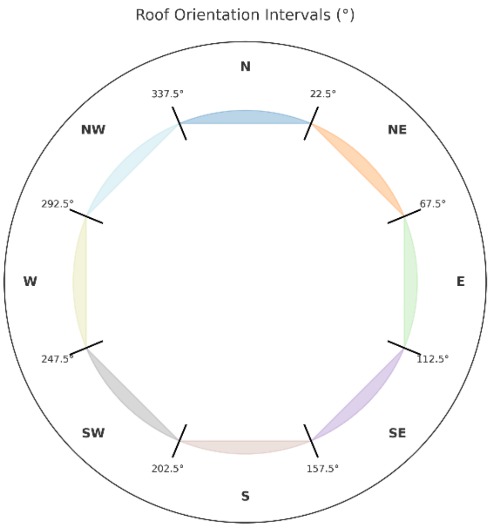

Figure 12 . Roof orientation intervals (°)

An example is reported: consider two roof facets oriented at 10° and 350° from North. The linear average

$$(10 + 350)/2(10 + 350)/2(10 + 350)/2$$

gives 180° (South), that's clearly wrong, because 10° and 350° are both near North on opposite sides of the 0°/360° seam.
If instead we average the vectors:

- cos10° ≈0.985, sin10° ≈+0.173
- cos350° ≈0.985, sin350° ≈-0.173

so the means are cos≈0.985, sin≈0. Then atan2(0,0.985) =0° is equal to the North, which is the correct "middle" direction. This vector (sine/cosine) approach removes the 0°/360° discontinuity and avoids the spurious biases you get from linear means or from a "majority" computed on continuous rasters.

As the orientation of the roof respect to the azimuth is not defined for horizontal roofs, buildings with slope-mean < 5° are flagged as Flat and treated separately.

Finally, for interpretation and mapping, the circular-mean bearing was classified into the eight cardinal/intercardinal directions using standard 45° sectors (N, NE, E, SE, S, SW, W, NW). The result is stored in a string field orientation; flat roofs receive orientation = "Flat". The intervals for the directions are reported in the following table.

Table 2 . Intervals-directions

Intervals [°]	Direction
337,5–22,5	N
22,5–67,5	NE
67,5–112,5	E
112,5–157,5	SE
157,5–202,5	S
202,5–247,5	SW
247,5–292,5	W
292,5–337,5	NW

4.1.4. Export and Classification for Photovoltaic Suitability

The final dataset (enriched with geometric, topographic, administrative, and electrical attribute) was exported to an Excel spreadsheet using QGIS's **native:exporttospreadsheet** tool. Each row of the spreadsheet corresponds to a unique building and includes the following attributes:

- Building area (in square meters);
- Municipality;
- Primary substation;
- Average roof slope;
- Average roof orientation (expressed both in degrees and in cardinal form).

To facilitate photovoltaic feasibility analysis, roofs were classified into discrete slope classes, defined as follows:

- 0–10°;
- 10–20°;
- 20–30°;
- 30–40°;
- 40–50°;
- 50° (*Out of scale*). This "Out of scale" class was introduced to exclude buildings with excessively steep roofs, which are generally unsuitable for standard photovoltaic installation due to both technical and economic constraints.

Cardinal orientation values were also grouped into eight directional categories:

- North (N),
- South (S),
- East (E),
- West (W);
- North-East (NE),
- South-East (SE),
- South-West (SW),
- North-West (NW).

These groupings allow for the rapid identification of roofs with favorable solar exposure, particularly those facing south (S, SE, SW), which are generally considered optimal in the northern hemisphere.

The Python code used for the extraction is shown below.

```
#CONFIGURAZIONE NOMI LAYER
fabbricati_layer = QgsProject.instance().mapLayersByName("Carta di uso del suolo VDA 2024 - Fabbricati")[0]
cabine_layer = QgsProject.instance().mapLayersByName("Cabine Primarie Valdigne")[0]
comuni_layer = QgsProject.instance().mapLayersByName("Confini comunali")[0]
dsm_raster = QgsProject.instance().mapLayersByName("DSM Valdigne")[0]

#FILTRA FABBRICATI DENTRO CABINE
intersect_fabbricati = processing.run("native:extractbylocation", {
    "INPUT": fabbricati_layer,
    "PREDICATE": [0],
    "INTERSECT": cabine_layer,
    "OUTPUT": "memory:fabbricati_filtrati",
```

```
})["OUTPUT"]

#CALCOLA AREA
fabbricati_area = processing.run("qgis:fieldcalculator", {
    "INPUT": intersect_fabbricati,
    "FIELD_NAME": "area_mq",
    "FIELD_TYPE": 0,
    "FIELD_LENGTH": 10,
    "FIELD_PRECISION": 2,
    "FORMULA": "area($geometry)",
    "OUTPUT": "memory:fabbricati_area",
})["OUTPUT"]

#JOIN COMUNI E CABINE
fabbricati_comuni = processing.run("native:joinattributesbylocation", {
    "INPUT": fabbricati_area,
    "JOIN": comuni_layer,
    "PREDICATE": [0],
    "JOIN_FIELDS": ["descrizion"],
    "METHOD": 1,
    "DISCARD_NONMATCHING": False,
    "OUTPUT": "memory:fabbricati_con_comune",
})["OUTPUT"]

fabbricati_completi = processing.run("native:joinattributesbylocation",
{
    "INPUT": fabbricati_comuni,
    "JOIN": cabine_layer,
    "PREDICATE": [0],
    "JOIN_FIELDS": ["TXT1"],
    "METHOD": 1,
    "DISCARD_NONMATCHING": False,
    "OUTPUT": "memory:fabbricati_con_cabina",
})["OUTPUT"]

#GENERA RASTER DI SLOPE, ASPECT, SIN, COS
tmpdir = tempfile.gettempdir()
slope_path = os.path.join(tmpdir, "fab_slope.tif")
aspect_path = os.path.join(tmpdir, "fab_aspect.tif")
cos_path = os.path.join(tmpdir, "fab_cos.tif")
sin_path = os.path.join(tmpdir, "fab_sin.tif")

processing.run("gdal:slope", {
    "INPUT": dsm_raster, "BAND": 1, "SCALE": 1.0,
    "AS_PERCENT": False, "COMPUTE_EDGES": True, "ZEVENBERGEN": False,
    "OUTPUT": slope_path,
})

processing.run("gdal:aspect", {
    "INPUT": dsm_raster, "BAND": 1,
    "TRIG_ANGLE": False, "ZERO_FLAT": False,
    "COMPUTE_EDGES": True, "ZEVENBERGEN": False,
    "OUTPUT": aspect_path,
})

# 0° di GDAL = Est; trasformiamo subito in bearing con 0° = Nord e in
radianti
# b = (450 - a) % 360 → rad = b * π / 180
RAD_CONV = 0.017453292519943295 # π / 180
formula_cos = "cos(((450-A)*{}))".format(RAD_CONV)
formula_sin = "sin(((450-A)*{}))".format(RAD_CONV)
```

```
processing.run("gdal:rastercalculator", {
    "INPUT_A": aspect_path, "BAND_A": 1,
    "FORMULA": formula_cos,
    "NO_DATA": -9999, "RTYPE": 6, # Float32
    "OUTPUT": cos_path,
})

processing.run("gdal:rastercalculator", {
    "INPUT_A": aspect_path, "BAND_A": 1,
    "FORMULA": formula_sin,
    "NO_DATA": -9999, "RTYPE": 6,
    "OUTPUT": sin_path,
})

#ZONAL STATISTICS (MEAN) SU slope, cos, sin ===
processing.run("qgis:zonalstatistics", {
    "INPUT_RASTER": slope_path, "RASTER_BAND": 1,
    "INPUT_VECTOR": fabbricati_completi, "COLUMN_PREFIX": "slope_",
    "STATISTICS": [2], # mean
})

processing.run("qgis:zonalstatistics", {
    "INPUT_RASTER": cos_path, "RASTER_BAND": 1,
    "INPUT_VECTOR": fabbricati_completi, "COLUMN_PREFIX": "cos_",
    "STATISTICS": [2],
})

processing.run("qgis:zonalstatistics", {
    "INPUT_RASTER": sin_path, "RASTER_BAND": 1,
    "INPUT_VECTOR": fabbricati_completi, "COLUMN_PREFIX": "sin_",
    "STATISTICS": [2],
})

#RICERCA CAMPI
fields = {f.name(): i for i, f in
enumerate(fabbricati_completi.fields())}
SLOPE_FIELD = "slope_mean"
COS_FIELD = "cos_mean"
SIN_FIELD = "sin_mean"

missing = [f for f in (SLOPE_FIELD, COS_FIELD, SIN_FIELD) if f not in
fields]
if missing:
    raise RuntimeError(f"Mancano i campi zonali: {missing}. Controlla
zonal statistics.")

#AGGIUNTA/AGGIORNAMENTO CAMPI OUTPUT
with edit(fabbricati_completi):
    for name in ("orientamento", "pendenza_cls"):
        if name not in fields:
            fabbricati_completi.addAttribute(QgsField(name,
QVariant.String))
    fabbricati_completi.updateFields()

    idx_orient = fabbricati_completi.fields().indexOf("orientamento")
    idx_cls = fabbricati_completi.fields().indexOf("pendenza_cls")
    idx_slope = fields[SLOPE_FIELD]
    idx_cos = fields[COS_FIELD]
    idx_sin = fields[SIN_FIELD]

    FLAT_THRESHOLD_DEG = 5
```

```
    for feat in fabbricati_completi.getFeatures():
        slope_val = feat[idx_slope]
        mean_cos = feat[idx_cos]
        mean_sin = feat[idx_sin]

        #Classe pendenza
        if slope_val is None or slope_val < 0:
            cls = None
        elif slope_val < 10:
            cls = "0-10"
        elif slope_val < 20:
            cls = "10-20"
        elif slope_val < 30:
            cls = "20-30"
        elif slope_val < 40:
            cls = "30-40"
        elif slope_val < 50:
            cls = "40-50"
        else:
            cls = "FuoriRange"

        #Orientamento
        direction = None
        if slope_val is not None and slope_val < FLAT_THRESHOLD_DEG:
            direction = "Piatto"
        elif mean_cos is not None and mean_sin is not None:
            # atan2 restituisce rad (0 = Est); convertiamo a bearing 0
= Nord
            ang_rad = math.atan2(mean_sin, mean_cos)  # 0 rad = Est, CCW
            bearing = (450 - math.degrees(ang_rad)) % 360   # 0 Nord
            if bearing >= 337.5 or bearing < 22.5:
                direction = "N"
            elif bearing < 67.5:
                direction = "NE"
            elif bearing < 112.5:
                direction = "E"
            elif bearing < 157.5:
                direction = "SE"
            elif bearing < 202.5:
                direction = "S"
            elif bearing < 247.5:
                direction = "SW"
            elif bearing < 292.5:
                direction = "W"
            else:
                direction = "NW"

        fabbricati_completi.changeAttributeValue(feat.id(), idx_orient,
direction)
        fabbricati_completi.changeAttributeValue(feat.id(), idx_cls,
cls)

#OUTPUT
QgsProject.instance().addMapLayer(fabbricati_completi)

desktop_path = os.path.join(os.path.expanduser("~"), "Desktop",
"fabbricati_output.xlsx")
processing.run("native:exporttospreadsheet", {"LAYERS":
[fabbricati_completi], "OUTPUT": desktop_path})
print("✔ Layer 'fabbricati_completi' salvato su Excel:", desktop_path)
```

The Python script automates the processing of geospatial data in QGIS to evaluate the suitability of rooftops for photovoltaic installation.

First, the building footprints are filtered to include only those located within the service areas of the primary substations. For each building, the roof area is calculated, and attributes from municipal boundaries and substation service zones are joined to the dataset.

Subsequently, the Digital Surface Model (DSM) is used to derive slope and aspect rasters. These are converted into cosine and sine components in order to allow a reliable estimation of average roof orientation. Zonal statistics are then applied to extract mean slope and orientation values for each building polygon. Based on these parameters, roofs are classified into slope categories and assigned a cardinal orientation. Flat roofs (slope < 5°) are flagged separately. The resulting enriched dataset is finally exported to an Excel file, which includes geometric, topographic, and administrative information for each building.

The output of this stage consists in a comprehensive dataset in which each roof is characterized by its geometric and topographic attributes. Specifically, the results provide the number of buildings, subdivided by municipality and by primary substation, together with the corresponding roof orientation (expressed in cardinal directions), area and tilt angle (classified into discrete slope categories). This dataset represents the basis for the subsequent estimation of photovoltaic suitability and installable capacity.

An example of distribution of tilt-orientation combination is reported in the radar graph below, considering the area.

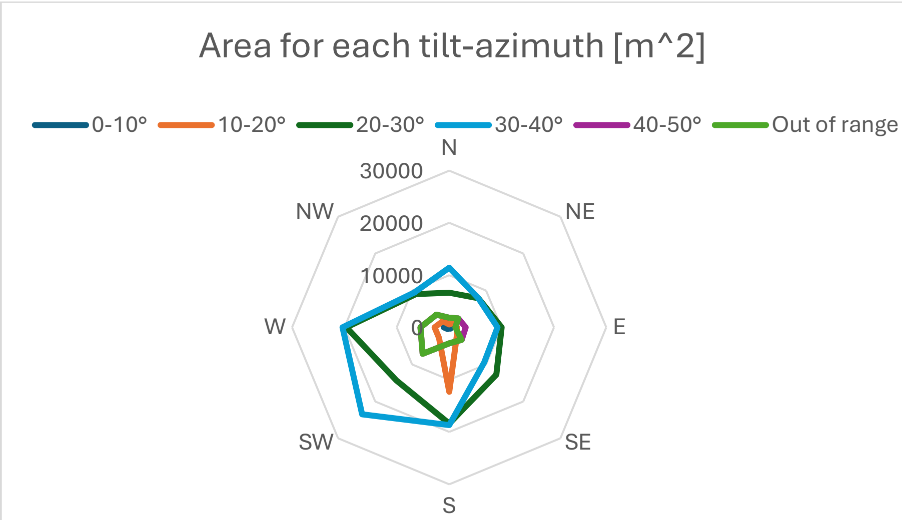

Figure 13 . Radar diagram of area for each tilt azimuth

4.2. Calculation of the Total Installable Photovoltaic Capacity on Roofs in the Valdigne, Broken Down by Primary Substation

4.2.1. Calculation of the Total Area for Each Slope–Orientation Combination

The total roof area for each category was calculated by aggregating the data using a pivot table.

For each primary substation, a dedicated pivot table was created to summarize the total roof area corresponding to each combination of slope class and cardinal direction.

This approach provided a clear and structured representation of the distribution of solar potential across the territory, highlighting not only the total amount of available surface area but also its spatial and directional characteristics.

The detailed results, organized into three separate tables (one for each primary substation), are presented below. Each table shows the total roof surface area (in square meters) associated with each combination of slope class and orientation.

Table 3 . Total area [m2] for each orientation-tilt and for every substation

Area [m^2]							
Entreves							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	62,89	1.492,44	10.019,15	9.232,92	3.152,00	1.167,05	23.959,40
N	125,04	568,95	6.648,25	11.437,83	1.844,82	1.844,82	20.624,89
NE	89,27	1.447,80	7.933,30	7.885,19	2.448,17	2.448,17	19.803,73
NW	111,04	1.715,08	9.008,97	9.433,57	3.463,27	3.463,27	23.731,93
S	-	12.301,00	18.384,85	18.671,85	3.023,95	3.023,95	52.381,65
SE	345,94	2.077,27	12.743,28	9.461,96	3.360,44	3.360,44	27.988,89
SW	429,59	2.788,01	14.284,32	23.516,47	7.119,85	7.119,85	48.138,24
W	1.051,69	2.788,01	19.636,00	20.369,47	5.483,08	5.483,08	49.328,25
Flat	25.403,47						25.403,47
Total substation	**291.360,45**						
Morgex							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	295,38	875,39	14.511,17	10.154,84	2.726,28	617,27	28.563,06
N	-	887,32	14.200,40	14.200,40	2.656,30	907,17	31.944,42
NE	342,08	1.356,51	15.452,97	9.202,63	1.283,28	1.327,28	27.637,47
NW	309,27	1.330,08	13.971,51	7.272,49	1.194,46	365,86	24.077,81
S	852,13	3.911,82	19.696,71	15.670,64	2.544,64	932,16	42.675,94
SE	201,85	201,85	18.643,31	15.130,83	1.846,99	1.152,72	36.024,83
SW	2.176,09	2.176,09	18.782,28	16.966,82	3.831,79	941,09	43.933,07
W	172,14	1.471,18	14.146,64	7.082,08	1.306,89	723,59	24.178,93
Flat	179.122,02						179.122,02
Total substation	**438.157,55**						

P.S.Didier							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	4.040,07	6.022,09	11.777,26	8.567,39	3.852,74	794,69	34.259,55
N	631,05	2.527,18	8.603,79	7.254,84	773,77	321,39	19.790,63
NE	681,66	2.081,34	7.990,23	11.265,15	2.612,77	1.197,62	24.631,15
NW	2.138,93	3.884,37	7.990,23	10.524,52	2.983,89	1.041,48	27.521,94
S	927,55	4.162,26	20.410,86	30.458,30	6.087,88	-	62.046,85
SE	311,79	6.119,77	13.370,07	21.587,95	4.564,83	565,46	45.954,41
SW	335,10	3.727,99	14.999,93	36.639,27	9.203,98	887,85	64.906,27
W	2.105,37	2.704,64	14.146,64	25.083,19	3.999,74	1.206,73	48.039,58
Flat	39.481,96						39.481,96
Total substation	**366.632,34**						

4.2.2. Estimation of Installable Photovoltaic Power by Slope–Orientation Category

The installable photovoltaic power for each combination of roof orientation and slope class was estimated using a simplified formula, designed to provide an approximation of the photovoltaic capacity that can be effectively utilized on the roofs in the Valdigne area.

The calculation was carried out according to the following expression:

$$P = (A / \rho) \cdot (1 - a$$

Where:

- P [kWp] is the installable photovoltaic roof-mounted power
- A [m^2] is the total roof area, expressed in square meters, corresponding to a specific combination of orientation and slope;
- ρ [kWp/m^2] is the specific installation density, i.e., the number of kilowatt-peak (kWp) theoretically installable per square meter,

For this analysis, the installation density was set at ρ = 10 m²/kWp, representing a conservative estimate of the surface required for standard photovoltaic panels, including spacing between modules and structural constraints;

α[-] is a reduction coefficient (expressed as a decimal value) that accounts for obstacles, shading, and other critical factors that typically reduce the effectively usable surface. For this analysis, the average percentage of unusable surface due to shading, obstacles (e.g., chimneys, dormers, antennas), and roof irregularities was estimated at a = 0.30, corresponding to a 30% reduction of the total available area.

This methodology allowed for the derivation of a theoretical installable capacity (expressed in kWp) for each roof category, previously classified by slope and orientation.

The calculated results are presented in the following tables, organized by the service area of the primary substations.
Each table shows the total estimated installable photovoltaic power for every combination of

slope class and orientation, highlighting the spatial and geometric diversity of roofs within the respective electrical zones.

Table 4 Total power installable for each orientation-tilt [kWp]

Power [kWp]							
Entreves							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	4,40	104,47	701,34	646,30	220,64	81,69	1.677,16
N	8,75	39,83	465,38	800,65	129,14	129,14	1.443,74
NE	6,25	101,35	555,33	551,96	171,37	171,37	1.386,26
NW	7,77	120,06	630,63	660,35	242,43	242,43	1.661,24
S	-	861,07	1.286,94	1.307,03	211,68	211,68	3.666,72
SE	24,22	145,41	892,03	662,34	235,23	235,23	1.959,22
SW	30,07	195,16	999,90	1.646,15	498,39	498,39	3.369,68
W	73,62	195,16	1.374,52	1.425,86	383,82	383,82	3.452,98
Flat	1.778,24	-	-	-	-	-	1.778,24
Total substation	**20.395,23**						

Morgex							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	20,68	61,28	1.015,78	710,84	190,84	43,21	1.999,41
N	-	62,11	994,03	994,03	185,94	63,50	2.236,11
NE	23,95	94,96	1.081,71	644,18	89,83	92,91	1.934,62
NW	21,65	93,11	978,01	509,07	83,61	25,61	1.685,45
S	59,65	273,83	1.378,77	1.096,94	178,12	65,25	2.987,32
SE	14,13	14,13	1.305,03	1.059,16	129,29	80,69	2.521,74
SW	152,33	152,33	1.314,76	1.187,68	268,23	65,88	3.075,31
W	12,05	102,98	990,26	495,75	91,48	50,65	1.692,53
Flat	12.538,54	-	-	-	-	-	12.538,54
Total substation	**30.671,03**						

P.S.Didier							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	282,80	421,55	824,41	599,72	269,69	55,63	2.398,17
N	44,17	176,90	602,27	507,84	54,16	22,50	1.385,34
NE	47,72	145,69	559,32	788,56	182,89	83,83	1.724,18
NW	149,73	271,91	559,32	736,72	208,87	72,90	1.926,54
S	64,93	291,36	1.428,76	2.132,08	426,15	-	4.343,28
SE	21,83	428,38	935,90	1.511,16	319,54	39,58	3.216,81
SW	23,46	260,96	1.050,00	2.564,75	644,28	62,15	4.543,44
W	147,38	189,32	990,26	1.755,82	279,98	84,47	3.362,77
Flat	2.763,74	-	-	-	-	-	2.763,74
Total substation	**25.664,26**						

Table 5 . Total power installable for each substation

Total power installable for each substation		
Entréves	20.395,23	[kWp]
P.S.Didier	25.664,26	[kWp]
Morgex	30.671,03	[kWp]

4.3. Total Annual Energy Production for Each Primary Substation

The total annual producible energy for each service area of the primary substations was estimated using site-specific photovoltaic yield data provided by the European PVGIS (Photovoltaic Geographical Information System) platform [21].

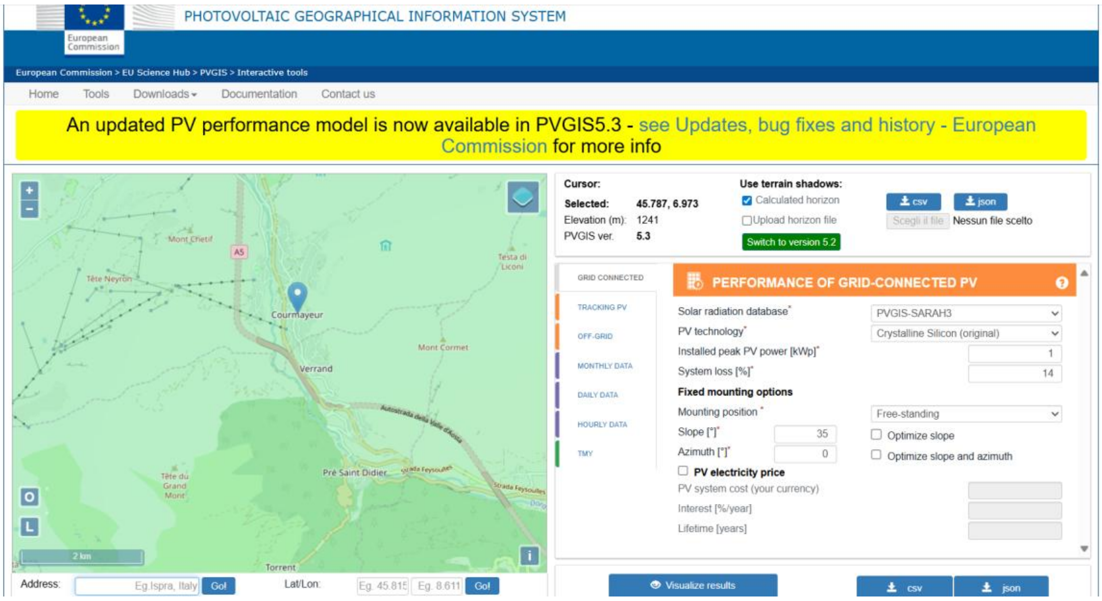

Figure 14 . European Photovoltaic geographical information system

To obtain accurate and representative production values, the following configuration parameters were adopted:

- Each municipality located within the Valdigne area was selected individually;
- The solar radiation database used was PVGIS-SARAH3, which provides high-resolution satellite data on solar irradiation in Europe;
- The photovoltaic technology considered was crystalline silicon, consistent with the most widely used photovoltaic modules currently on the market;
- All previously defined combinations of slope (tilt) and orientation (azimuth) were used, in order to reflect the geometric diversity of roofs observed in the study area.

The resulting dataset provided the value of specific annual energy production [kWh/kWp/year] for each slope–orientation combination and for each municipality considered. These values represent the amount of energy that can be generated in one year for every kilowatt-peak of installed capacity, under average meteorological conditions.

The results are shown in the following table:

Table 6 . Annual specific energy for each orientation-tilt

Specific annual energy [kWh/kWp]						
	0-10	10-20	20-30	30-40	40-50	Out of range
E	1.080,84	1.057,43	1.019,53	972,61	915,92	-
N	1.024,62	890,86	757,74	631,99	513,11	-
NE	1.042,08	940,6	824,77	720,3	625,49	-
NW	1.038,82	935,95	828,99	728,06	637,55	-
S	1.132,29	1.209,3	1.257,07	1.276,35	1.267,6	-
SE	1.118,14	1.166,95	1.191,33	1.191,8	1.171,66	-

SW	1.114,94	1.158,06	1.173,11	1.161,8	1.130,34	-
W	1.076,17	1.043	990,64	934,39	873,15	-
Flat	1.120,28					

Once the specific yield values were obtained, it was possible to calculate the total annual producible energy for each primary substation area using the following formula

$$E_{(TILT=t,ORIENTATION=o)} = Y_{(TILT=t,ORIENTATION=o)} * P_{(TILT=t,ORIENTATION=o)}$$

Where:

- $E_{(TILT=t,\ ORIENTATION=o)}$ is the total producible energy in one year for the generic couple tilt=t and orientation=o roofs;
- $Y_{(TILT=t,\ ORIENTATION=o)}$ is the specific annual energy yield [kWh/kWp/year], obtained from PVGIS data for the generic couple tilt=t and orientation=o roofs;
- $P_{(TILT=t,\ ORIENTATION=o)}$ is the total installable photovoltaic power [kWp], calculated as described in the previous sections for the generic couple tilt=t and orientation=o roofs.

This calculation was performed for each primary substation (Entrèves, Pré-Saint-Didier, and Morgex) by summing the energy contributions from all slope–orientation combinations present in their respective service areas.

Table 7. Energy production for each orientation-tilt - Entreves

Entreves							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	4.758,18	110.470,56	715.037,68	628.602,12	202.088,59	-	1.660.957,13
N	8.968,29	35.479,84	352.635,15	506.001,59	66.261,69	-	969.346,56
NE	6.511,85	95.326,05	458.020,35	397.579,16	107.191,41	-	1.064.628,82
NW	8.074,54	112.366,04	522.784,22	480.774,35	154.560,55	-	1.278.559,70
S	-	1.041.291,95	1.617.773,04	1.668.227,10	268.321,13	-	4.595.613,22
SE	27.076,65	169.684,92	1.062.701,62	789.373,47	275.610,52	-	2.324.447,19
SW	33.527,70	226.007,80	1.172.995,50	1.912.500,44	563.349,59	-	3.908.381,03
W	79.225,81	203.552,61	1.361.654,49	1.332.312,04	335.128,59	-	3.311.873,54
Flat	1.992.129,96	-	-	-	-	-	1.992.129,96
Total substation	21.105.937,14						

Morgex							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	22.348,10	64.796,46	1.035.620,12	691.368,93	174.793,81	-	1.988.927,40
N	-	55.333,45	753.214,78	628.215,76	95.408,19	-	1.532.172,17
NE	24.953,23	89.315,33	892.160,22	464.005,81	56.187,52	-	1.526.622,11
NW	22.489,31	87.142,19	810.756,95	370.636,63	53.306,96	-	1.344.332,03
S	67.540,08	331.139,47	1.733.210,03	1.400.085,50	225.791,00	-	3.757.766,07
SE	15.798,76	16.488,42	1.554.723,42	1.262.304,62	151.483,10	-	3.000.798,32
SW	169.834,68	176.402,99	1.542.357,63	1.379.843,60	303.185,79	-	3.571.624,70
W	12.967,63	107.410,85	980.995,92	463.219,73	79.877,77	-	1.644.471,91
Flat	14.046.677,16	-	-	-	-	-	14.046.677,16
Total substation	32.413.391,88						

P.S.Didier							
	0-10°	10-20°	20-30°	30-40°	40-50°	Out of range	Total area
E	305.666,85	445.755,70	840.508,89	583.291,04	247.016,11	-	2.422.238,60
N	45.261,05	157.595,45	456.360,51	320.949,04	27.792,04	-	1.007.958,09
NE	49.724,10	137.039,59	461.307,14	568.000,13	114.398,31	-	1.330.469,26
NW	155.537,43	254.490,33	463.667,45	536.373,74	133.166,53	-	1.543.235,49
S	73.517,89	352.339,47	1.796.051,58	2.721.281,58	540.189,77	-	5.483.380,30
SE	24.403,74	499.902,59	1.114.971,58	1.800.996,32	374.390,01	-	3.814.664,24
SW	26.153,15	302.206,53	1.231.759,75	2.979.725,27	728.253,87	-	5.268.098,57
W	158.601,52	197.465,77	980.995,92	1.640.623,73	244.466,11	-	3.222.153,05
Flat	3.096.159,51	-	-	-	-	-	3.096.159,51
Total substation	27.188.357,12						

Table 8 . Total energy production for each substation

Produzione energetica annuale per cabina primaria		
Entréves	**21.105.937,14**	[kWh]
P.S.Didier	**27.188.357,12**	[kWh]
Morgex	**32.413.391,88**	[kWh]

4.4. Construction of Monthly Hourly Production Curves for Each Primary Substation

4.4.1. Specific Monthly Energy Yield by Slope–Orientation Combination

The first step in constructing the hourly profiles consisted of retrieving specific monthly energy yield data [kWh/kWp] for each relevant combination of slope and orientation (tilt–azimuth), using the European PVGIS (Photovoltaic Geographical Information System) platform.

For each municipality served by the Entrèves, Pré-Saint-Didier, and Morgex primary substations, the following parameters were configured in PVGIS:

- Solar radiation database: PVGIS-SARAH3, based on high-resolution satellite data on solar irradiation;
- Photovoltaic technology: crystalline silicon modules;
- Tilt and orientation: all slope and azimuth classes previously defined in the geometric analysis.

The resulting data represent the average monthly energy production per kilowatt-peak installed (specific energy) [kWh/kWp], calculated under average weather and climatic conditions, as a function of surface tilt and orientation.

As an illustrative example, the following figure shows the average hourly production profile for roofs with a slope between 0° and 10° and an east-facing (E) orientation. The curve highlights the typical generation trend for this configuration, with production concentrated in the summer months, a decline in winter months, and intermediate values during the transitional seasons.

Table 9 . Month, kWh/kWp

Month	kWh/kWp
January	35,63
February	56,12
March	96,4
April	116,78
May	136,9
June	139,62
July	145,63
August	125,97
September	95,74
October	66,66
November	37,03
December	28,36
Total	1.080,84

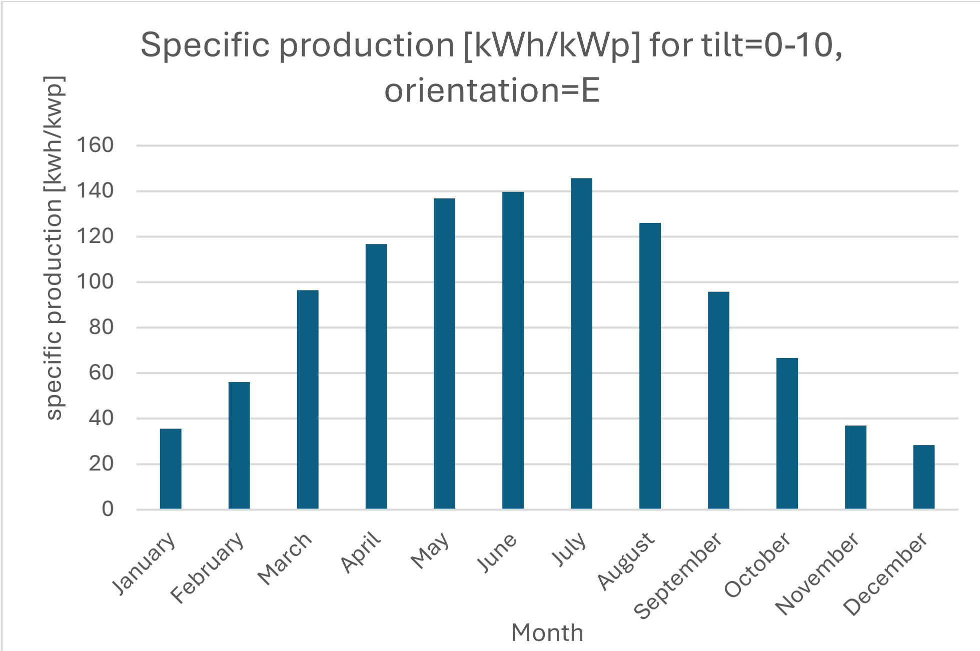

Figure 15 . Example graph of kWh/kWp for each month (tilt= 0–10°, orientation= E)

To develop accurate models for the temporal distribution of photovoltaic energy production, it is essential to determine the average hourly global irradiance for each combination of roof orientation and slope in the Valdigne area.

This analysis was carried out using the same solar radiation database adopted in the previous sections, retrieving historical irradiance data for each of the five municipalities served by the three primary substations.

The dataset used covers the period from 2005 to 2023, enabling the calculation of a long-term hourly average. For each municipality and for each slope–orientation combination, the following steps were performed:

1. **Data retrieval** – Hourly irradiance data [W/m²] were downloaded from PVGIS for each day in the reference period.
2. **Monthly grouping** – The data were organized by month in order to represent seasonal variations in solar availability.
3. **Hourly averaging** – For each month, a pivot table was created to calculate the average irradiance for each hour of the day, using the full set of daily observations.
4. **Normalization** – The hourly values obtained were normalized by dividing each value by the total annual irradiance. In this way, hourly irradiance was expressed as a percentage of the annual total, allowing the creation of monthly distribution profiles useful for time-based energy modeling.

This process was repeated independently for each slope and orientation class, and for each municipality, producing a statistically robust and meaningful representation of the average hourly solar availability throughout the year.

As an illustrative case, the following table presents the average hourly irradiance profile, expressed as a percentage of the annual total, for roofs with a slope between 0° and 10° and an east-facing (E) orientation, located in the municipality of Courmayeur. It can also be noted that the results reflect the typical "bell-shaped" generation pattern of a photovoltaic system, with a production peak between 12:00 and 13:00.

Table 10 . Hourly distribution of specific production [%] for each month

Hour	January	February	March	April	May	June	July	August	September	October	November	December
0	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
1	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
2	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
3	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
4	0,00%	0,00%	0,00%	0,00%	0,04%	0,20%	0,05%	0,00%	0,00%	0,00%	0,00%	0,00%
5	0,00%	0,00%	0,00%	0,28%	0,90%	1,10%	0,89%	0,50%	0,02%	0,00%	0,00%	0,00%
6	0,00%	0,00%	0,46%	1,43%	1,79%	1,92%	1,71%	1,53%	1,28%	0,49%	0,00%	0,00%
7	0,01%	0,93%	1,78%	3,71%	7,13%	7,29%	7,12%	4,64%	2,51%	2,52%	1,46%	0,03%
8	2,54%	8,59%	9,67%	9,66%	9,46%	9,58%	9,54%	9,72%	10,15%	10,77%	11,40%	3,58%
9	16,17%	14,22%	12,63%	11,69%	11,17%	11,05%	11,15%	11,64%	12,59%	14,07%	15,95%	17,25%
10	20,81%	16,89%	14,13%	12,78%	11,75%	11,72%	11,85%	12,71%	14,03%	16,18%	19,28%	21,15%
11	21,40%	17,81%	14,72%	13,14%	12,10%	11,86%	11,91%	13,03%	14,51%	16,56%	19,69%	22,22%
12	19,80%	15,77%	13,20%	12,58%	11,68%	11,36%	11,40%	12,36%	13,73%	15,08%	18,25%	20,96%
13	11,42%	15,68%	12,84%	11,83%	10,49%	10,08%	10,24%	10,97%	11,93%	12,82%	7,18%	7,76%
14	5,01%	6,01%	10,68%	9,73%	8,85%	8,52%	8,68%	9,04%	9,22%	7,25%	4,53%	5,09%
15	2,73%	2,85%	7,49%	7,43%	6,96%	6,81%	6,87%	6,91%	6,56%	3,16%	2,26%	1,97%
16	0,12%	1,26%	1,88%	4,49%	4,68%	4,79%	4,87%	4,58%	2,80%	1,08%	0,00%	0,00%
17	0,00%	0,00%	0,51%	1,18%	2,45%	2,84%	2,88%	1,99%	0,66%	0,00%	0,00%	0,00%
18	0,00%	0,00%	0,00%	0,07%	0,56%	0,86%	0,84%	0,37%	0,00%	0,00%	0,00%	0,00%
19	0,00%	0,00%	0,00%	0,00%	0,00%	0,01%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%
20	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
21	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
22	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
23	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

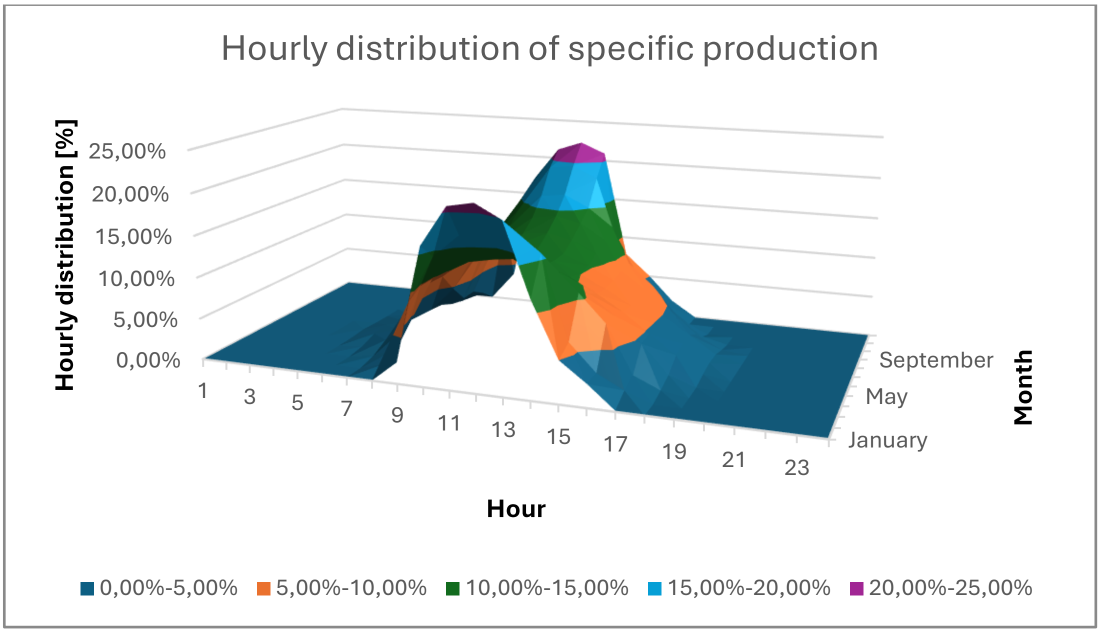

Figure 16 . Hourly distribution of specific production diagram

4.4.2. Construction of Monthly Hourly Production Curves by Municipality

To develop a detailed temporal model of photovoltaic production, monthly hourly production curves were generated for each municipality in the Valdigne area. These curves represent the average energy production [kWh] for each month and for each hour, based on the combination of specific production values and the normalized hourly irradiance distributions.

The specific hourly energy production [kWh/kWp] for each month was calculated using the following equation:

$$E_{(Hourly,TILT=t,ORIENTATION=o)} = \frac{E_{(Monthly,TILT=t,ORIENTATION=o)} * G_{(month\%)}}{n_{days}}$$

Where:

- $E_{((Hourly,TILT=t,ORIENTATION=o))}$: specific monthly energy production [kWh/kWp], obtained from the tables developed in section 4.4.1 ;
- $G_{((month\%))}$ [%] percentage of hourly irradiance for the month in question, derived from the normalized distribution tables discussed in section 4.4.2;
- n_{days} : number of days in the month analyzed.

This formula allows the proportional distribution of the monthly production potential over the hours of the day, according to the observed hourly profile of solar irradiance.

Once the specific hourly productions were calculated, they were scaled to absolute energy values by multiplying each value by the total installable photovoltaic power (in kWp) of the relevant primary substation (Entrèves, Pré-Saint-Didier, or Morgex), as previously determined in section 4.3:

$$E_{(TILT=t,ORIENTATION=o)} = E_{(Hourly,TILT=t,ORIENTATION=o)} \cdot P_{(TILT=t,ORIENTATION=o)}$$

This made it possible to estimate the actual hourly production curves (in kWh) for each substation, for every hour of every month, taking into account both the available roof surface and the local solar resource.

As an illustrative example, the following figure shows the average hourly photovoltaic production curve for the month of January, for roofs with a slope between 0° and 10° and an east-facing (E) orientation. The curve represents the energy profile for one of the municipalities in the Valdigne area and shows the typical generation pattern during a winter day for this specific configuration

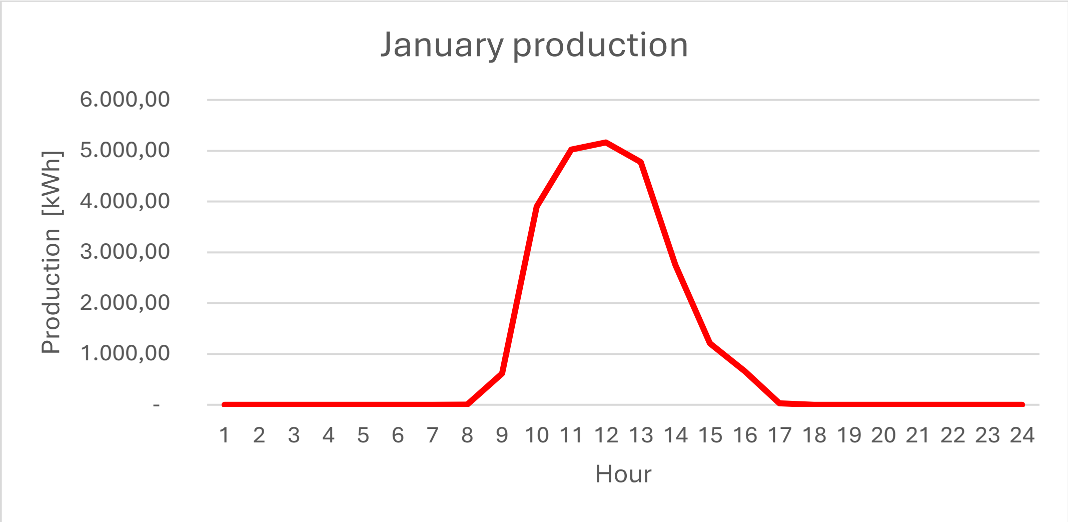

Figure 17 . Example production curve for the month of January (E, 0–10°)

This methodology was systematically applied to all combinations of slope and orientation, as well as to all municipalities considered, generating a complete set of monthly production curves that form the basis for more advanced temporal and economic analyses.

5. Photovoltaic Production on Canopies Installed over Parking Areas, Municipality Rooftops and Ice Rink

This chapter describes the methodology and tools used to estimate the maximum installable photovoltaic capacity and the corresponding annual energy production for various public parking areas located in the Valdigne district.

HelioScope software was employed for the preliminary design of the photovoltaic systems: by inputting parameters such as shading of possible obstacles, orientation, tilt, and the physical layout of the available spaces, the tool directly provided the resulting installable capacity in kWp.

The sites analyzed include parking areas, grouped by the service area of the primary substations present in the Valdigne zone, and the roof of the Courmayeur ice rink (within the service area of the Entrèves substation). This subdivision provides a coherent and organized view of the installable photovoltaic capacity at the local level, with a focus on grid management and self-consumption. For each area, one or more parking lots with favorable geometric and technical characteristics for the installation of photovoltaic canopies were selected.

The specific details of each site (usable surface area, orientation, presence of obstacles, etc.) will be described in the following subsections.

Photovoltaic carports are elevated structures designed to cover parking areas while simultaneously supporting solar panels. This typology of installation optimizes land use by combining shading for vehicles with renewable energy generation, making it a practical solution where rooftop or ground-mounted options may be limited. As an example, in 2024 Dimensione Ingegnerie installed a photovoltaic carport at La Salle, showcasing the integration of such systems in real contexts.

Figure 18 . Carport Dimensione Ingegnerie – La salle

The sites analyzed in this study were selected as examples, with the purpose of establishing an initial photovoltaic energy base for the Energy Community (CER). The idea is to start the development of the CER from installations on municipal areas, highlighting their public value and accessibility. In particular, public parking lots were identified as suitable locations, as they provide ample surfaces for photovoltaic carports that combine energy production with practical benefits such as vehicle shading.

5.1. Modeling with HelioScope

5.1.1. Software Overview

HelioScope is an online photovoltaic simulation and design software, particularly well-suited for the preliminary study phases. It combines energy analysis with an intuitive CAD interface to create realistic system layouts and estimate annual electricity production.

Among its main features:

- Import of high-resolution satellite maps.
- Definition of customized modules and inverters.
- Insertion of shading objects (buildings, trees, lamp posts).
- Loss analysis (due to shading, mismatch, temperature, etc.).
- Calculation of energy production on a monthly and annual basis.
- Export of detailed data.

5.1.2. Procedure Used

For each parking lot, the following steps were carried out within HelioScope:

1. **Site geolocation** – via address search or GPS coordinates.
2. **Layout design** – tracing the usable installation area, taking into account physical constraints (lanes, lamp posts, trees). An example is reported in the image below.

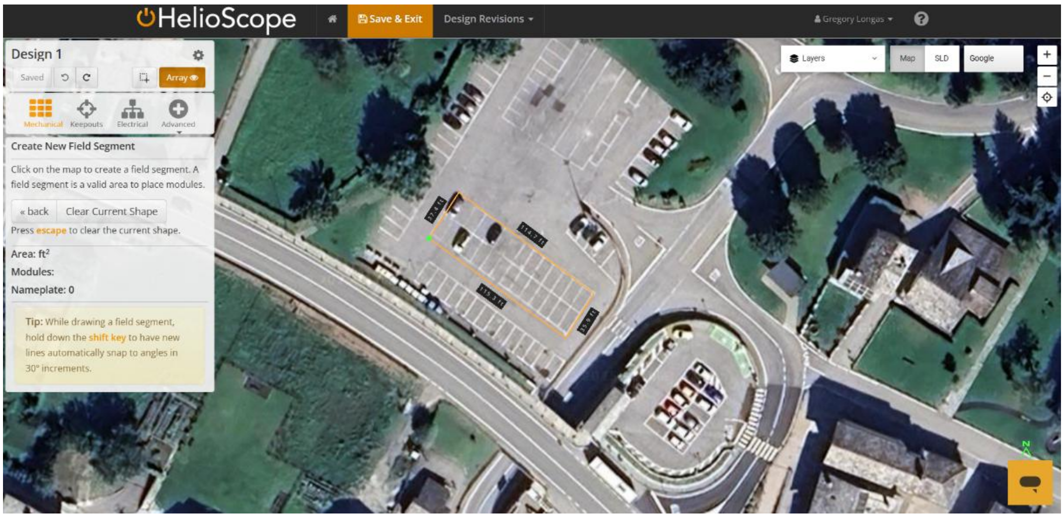

Figure 19 . tracing area in Helioscope (green line)

3. **System configuration**:
   - Selection of the PV module type (brand, power, dimensions); in this case study, Canadian Solar CS6-54TM-515 modules of 515 W were used.
   - Choice of configuration (type of structure: carport, tilt angle, row spacing).

- Setting up inverters and wiring (handled automatically by the software).

The orientation of the photovoltaic canopies was defined following the alignment of the individual parking spaces. In particular, the higher edge of the canopy was positioned on the access side of the parking bay, in order to ensure maximum usability and maneuverability for vehicles.

An example is reported in the image below.

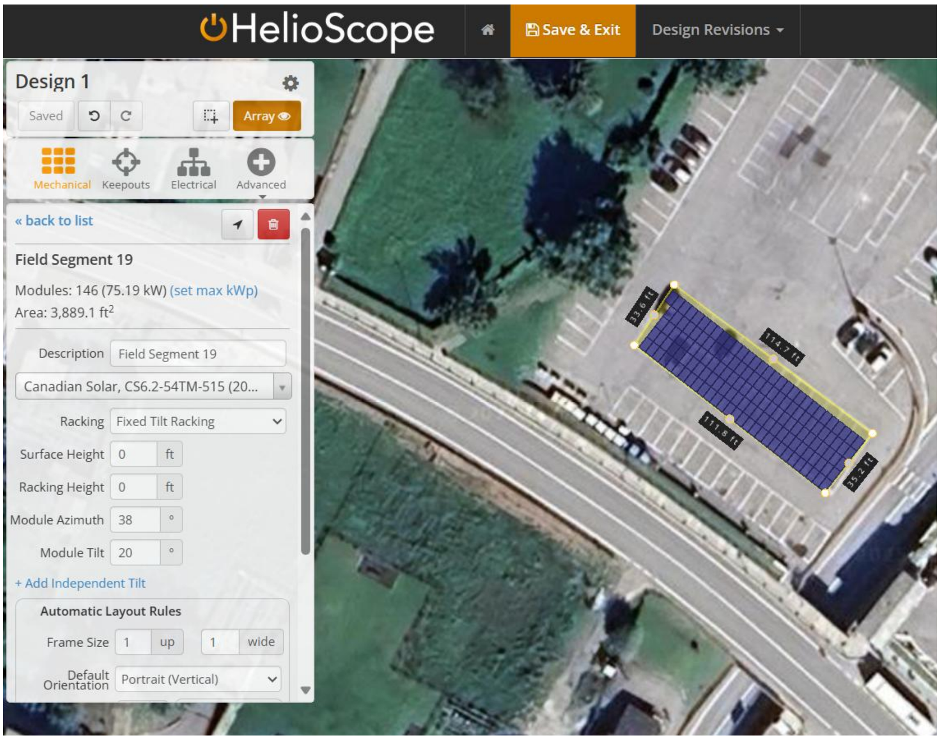

Figure 20 . Layout in Helioscope

4. **Shading analysis** – identifying and modeling in 3D the shadows cast by any obstacles in the surrounding area of each installation. The same example of the previous points is reported below.

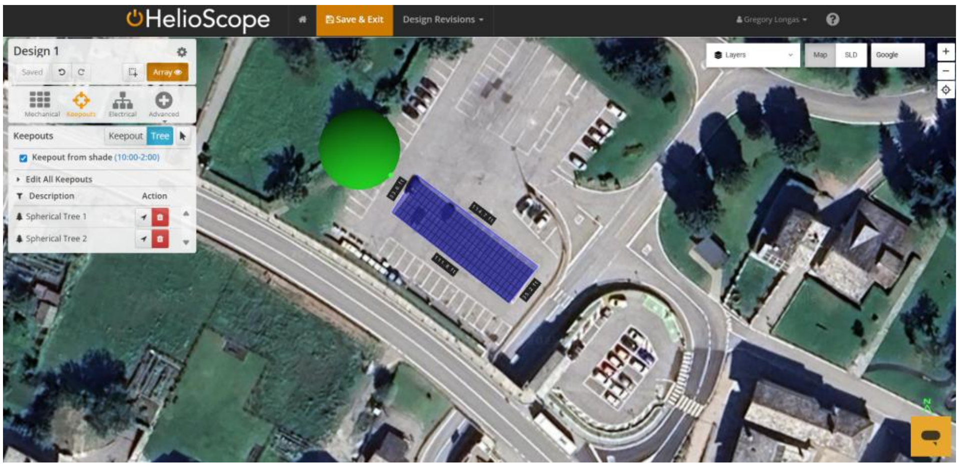

Figure 21 . Shading analysis in Helioscope

5. **Production simulation** – using the maximum installable capacity [kWp] and subsequently calculating energy production [kWh], and also the hourly production for each day of every month, using the same method previously described in this chapter.

5.2. Areas Identified for the Installation of Photovoltaic Carports

5.2.1. Entréves

In the service area of the Entrèves primary substation, six parking areas located in the northern part of Courmayeur were identified as suitable for the installation of photovoltaic carports. These areas lend themselves to the construction of structures that combine vehicle shelter with solar electricity generation.

In addition to the parking lots, the roof of the Courmayeur Ice Rink and of the middle school were also analyzed, representing a major opportunity for large-scale photovoltaic installation thanks to thier surface area and favorable exposure.

In the following image, all the selected parking lots can be seen.

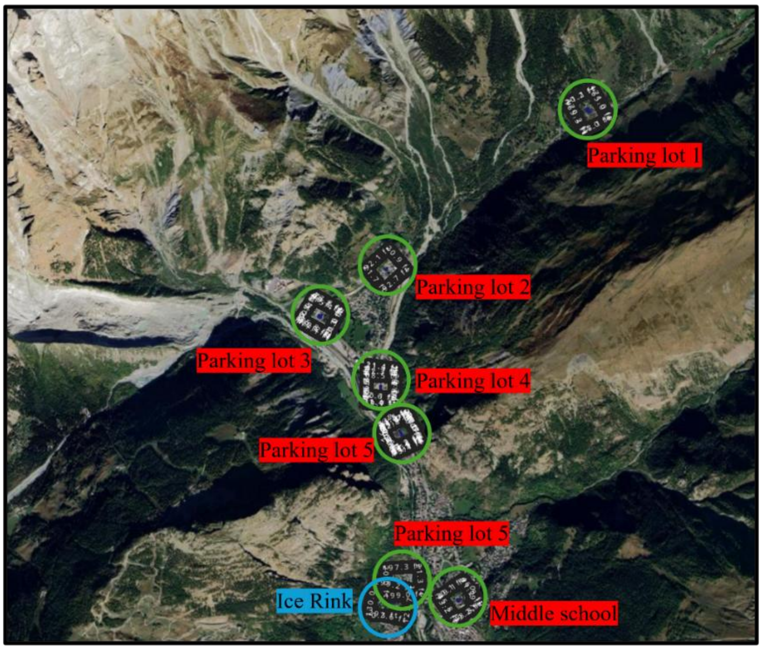

Figure 22 . Parking lots and municipality's roof Entrèves, Courmayeur

5.2.1.1. Parking Lot 1

Figure 23 . Parking Lot 1, Entrèves

The first site, called “Parcheggio Plampicieux”, is located along Strada della Val Ferret, north of Courmayeur. As shown in the reference image, the proposed photovoltaic system consists of two main canopies, oriented northeast (NE) and southwest (SW).

The proposed configuration achieves a total installed capacity of 135.97 kWp. The site benefits from good solar exposure and minimal shading, making it particularly suitable for energy production. The table below shows the estimated total production, the total power installed and the specific energy in one year.

Table 11 . Parking Lot 1, Entrèves

Total Power installed	135,97	kWp
Specific energy in one year	994,98	kWh/kWp
Total production [kWh]	135.287,7	kWh

5.2.1.2. Parking Lot 2

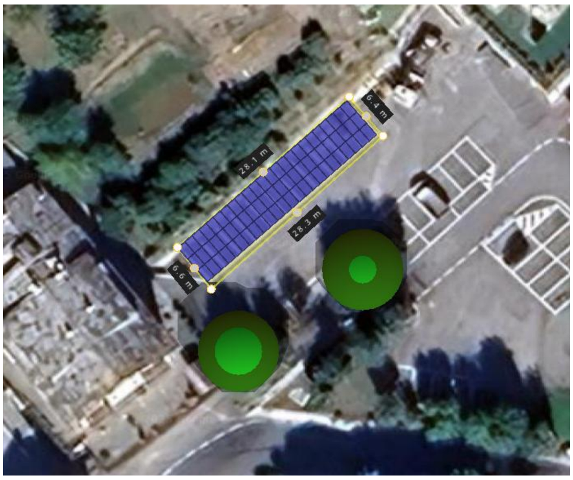

Figure 24 . Parking Lot 2, Entrèves

Located along Strada la Palud, northwest of the Skyway cable car station, this parking lot design includes a single canopy-oriented northwest (NW).

The installable capacity is 37 kWp, taking into account two trees visible from satellite images that may cause partial shading during certain hours. Despite this, the site shows good potential relative to its surface area.

Table 12 . Parking Lot 2, Entrèves

Total Power installed	37,08	kWp
Specific energy in one year	828,99	kWh/Kwp
Total production	30.738,95	kWh

5.2.1.3. Parking Lot 3

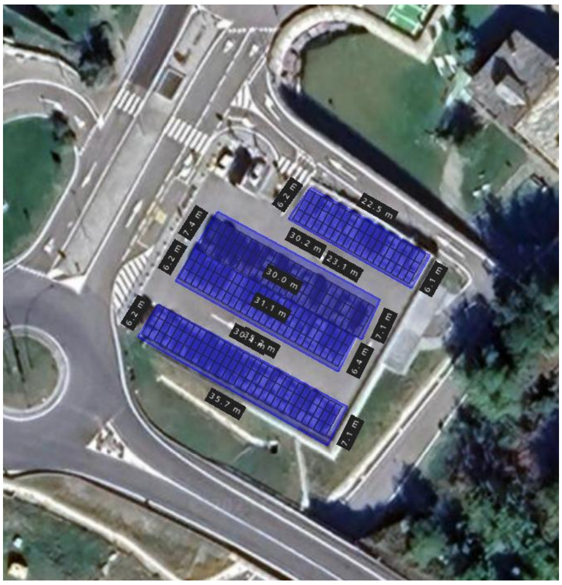

Figure 25 . Parking Lot 4, Entrèves

Located just below the Skyway cable car, this is one of the largest sites analyzed. It can accommodate three canopies: two single and one double, for a total capacity of 156.06 kWp.

Thanks to its shape and optimized NE and SW orientations, the site allows efficient solar capture throughout the day.

Table 13 . Parking lot 3, Entréves

Total Power installed	156,05	kWp
Specific energy in one year	1.017,90	kWh/kWp
Total production [kWh]	158.843,74	kWh

5.2.1.4. *Parking lot 4*

Figure 26 . Parking Lot 4, Entrèves

The fourth parking lot analyzed is located along Strada Larzey–Entrèves, immediately south of State Road SS26dir.
It is the largest parking area among those considered in the study and consists of a complex arrangement of four canopies: three single units oriented west, east, and south respectively, and one double canopy with a combined east–west orientation.

The estimated installable capacity is 173.04 kWp. The variety of orientations allows for well-distributed solar production over time.
The table below shows the estimated total production, the total power installed and the specific energy in one year.

Table 14 . Parking lot 4, Entréves

Total Power installed	173,04	kWp
Specific energy in one year	1.045,84	kWh/kWp
Total production [kWh]	180.972,25	kWh

5.2.1.5. Parking lot 5

Figure 27 . Parking Lot 5, Entrèves

Parking Lot 5 is located just south of the previous site (Parking Lot 4) and can accommodate a photovoltaic system consisting of three double canopies-oriented northwest/southeast (NW–SE) and one single canopy-oriented southeast (SE).

The total installable capacity is 122.08 kWp. The proposed configuration takes into account optimal spatial use of the area, ensuring good solar exposure on all available surfaces and achieving high overall energy efficiency.
The estimated total possible production, the total power installed and the specific energy in one year are shown in the following table.

Table 15 . Parking lot 5, Entréves

Total Power installed	122,08	kWp
Specific energy in one year	1.053,73	kWh/kWp
Total production [kWh]	128.639,49	kWh

5.2.1.6. Parking lot 6

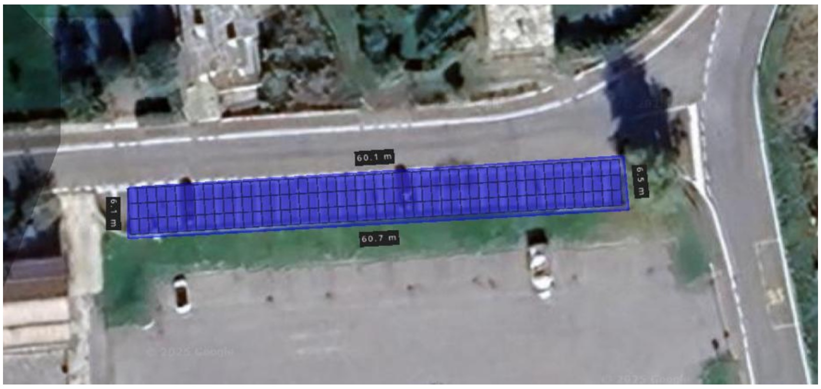

Figure 28 . Parking Lot 6, Entrèves

The sixth identified parking lot is located adjacent to the Courmayeur Ice Rink. In this case, the design foresees the installation of a single south-facing canopy, with a total installed capacity of 80.34 kWp.

The proximity to the sports facility and the absence of shading elements makes this site a strong candidate for photovoltaic integration.
The table below shows the estimated total production, the total power installed and the specific energy in one year

Table 16 . Parking lot 6, Entréves

Total Power installed	80,34	kWp
Specific energy in one year	1.257,06	kWh/kWp
Total production [kWh]	100.993,00	kWh

5.2.1.7. Focus Ice Rink

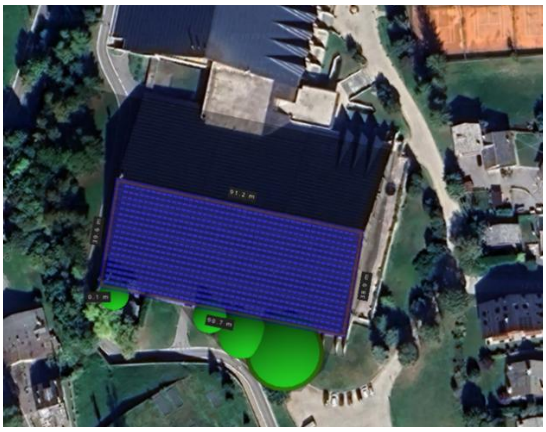

Figure 29 . Ice Rink, Entrèves

In parallel with the parking lot analysis, a dedicated study was carried out on the roof of the Courmayeur Ice Rink, with the aim of assessing its capacity to host a large-scale photovoltaic system. In this updated scenario, only the south-facing roof is considered for installation, with an estimated installed capacity of 500 kWp.

The favorable orientation and unobstructed exposure of this section make it a highly advantageous option in terms of energy yield and efficient use of the available surface.

The table below shows the estimated total production, the total power installed and the specific energy in one year

Table 17 . Ice Rink, Courmayeur, Entrevés

Total Power installed	500	kWp
Specific energy in one year	1.019,53	kWh/kWp
Total production [kWh]	509.765,00	kWh

5.2.1.8. Middle school

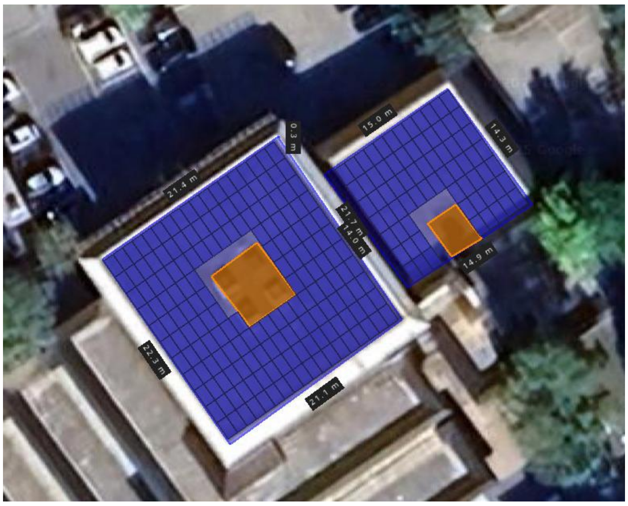

Figure 30 . Middle School , Entrèves

The middle school of Courmayeur was also analyzed. Thanks to its large roof and optimal exposure, it represents an excellent site for the installation of a photovoltaic system. The total power of the plant is 127.21 kWp.

Table 18 . Middle school production

Total Power installed	127,21	kWp
Specific energy in one year	1.118,14	kWh/kWp
Total production [kWh]	142.238,59	kWh

5.2.1.9. Total production

By summing up all the contributions from the previous subsections, the total production within the primary substation area (considering only the parking lots and the ice rink, but excluding other building rooftops) and the total power installed are obtained as follows:

Table 19 . Total power installed and energy produced

	Energy produced		**Power installed**	
Ice rink	509.765,00	kWh	500	kWp
Parking Lot 1	135.287,69	kWh	135,97	kWp
Parking Lot 2	30.738,95	kWh	37,08	kWp
Parking Lot 3	158.843,74	kWh	156,05	kWp
Parking Lot 4	180.972,25	kWh	173,04	kWp
Parking Lot 5	128.639,49	kWh	122,08	kWp
Parking Lot 6	100.993,00	kWh	80,34	kWp
Middle school	142.238,59	kWh	127,21	kWp
Total	**1.387.478,71**	**kWh**	**1.331,77**	**kWp**

5.2.1.10. Hourly production of Municipality-owned PV plants

Starting from the estimated installed capacity and annual production of each photovoltaic plant installed in Municipality-owned areas (carports in parking lots, roof of the ice rink building, roof of middle school building) within the service area of the Entrèves primary substation, a total hourly production profile was constructed for every month of the year. The procedure followed the same methodological steps described previously described in this chapter, namely the combination of monthly specific yields with normalized hourly irradiance distributions.

In this case, instead of considering roof categories, the contributions from all selected parking areas were aggregated. The individual hourly production curves of the carports were summed to obtain the overall monthly hourly profile representative of the entire Entrèves substation.

As an illustrative case, the following table reports the aggregated hourly production profile for the month of April.

Table 20 . Hourly production parking lots and municipality roofs – Entréves- April

Hour	Ice Rink	Parking Lot 1	Parking Lot 2	Parking Lot 3	Parking Lot 4	Parking Lot 5	Parking Lot 6	Middle School	Total
	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]
0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5	5,096	1,391	0,383	1,596	1,767	1,245	0,818	1,406	13,701
6	25,623	6,992	1,924	8,022	8,883	6,259	4,115	7,066	68,883
7	83,209	17,197	3,455	19,224	22,030	16,264	10,574	18,136	190,089

8	233,573	43,570	6,244	48,762	57,321	43,107	30,745	47,835	511,157
9	255,920	54,230	9,428	61,882	71,695	52,624	39,241	58,616	603,635
10	257,143	60,620	11,970	70,133	80,372	57,924	44,504	64,694	647,360
11	243,501	63,644	13,996	74,438	84,442	59,884	46,920	67,019	653,843
12	213,239	62,123	15,043	73,369	82,407	57,544	45,784	64,565	614,074
13	177,837	59,610	15,879	71,218	79,137	54,277	44,134	61,209	563,302
14	124,104	50,356	15,034	60,836	66,658	44,755	36,803	50,697	449,244
15	68,378	40,031	13,857	49,128	52,733	34,284	28,612	39,106	326,129
16	35,287	26,768	11,066	33,369	37,011	20,781	17,454	23,947	205,682
17	20,201	6,032	1,858	7,001	7,826	5,361	3,436	5,860	57,575
18	1,222	0,333	0,092	0,383	0,424	0,298	0,196	0,337	3,285
19	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
20	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
21	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
22	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
23	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

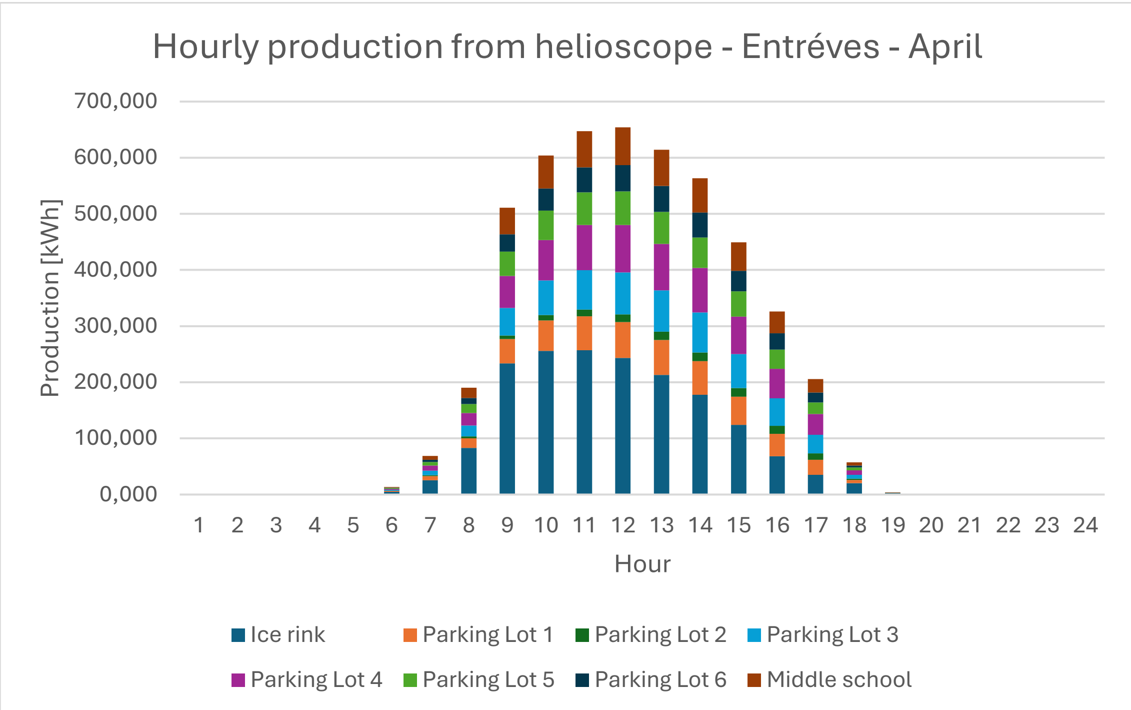

Figure 31 . Hourly production from helioscope - Entréves - April

5.2.2. Morgex

As part of the territorial analysis carried out within the service area of the Morgex primary substation, nine parking lot and the roof of “Istituzione scolastica Valdigne Mont Blanc” were identified as potentially suitable for the installation of photovoltaic carports, located in the municipalities of Morgex and La Salle.

The procedure used to calculate the potential total production is the same as that applied in the previous chapters.

As for Entréves the position of the chosen sites is shown in the image below.

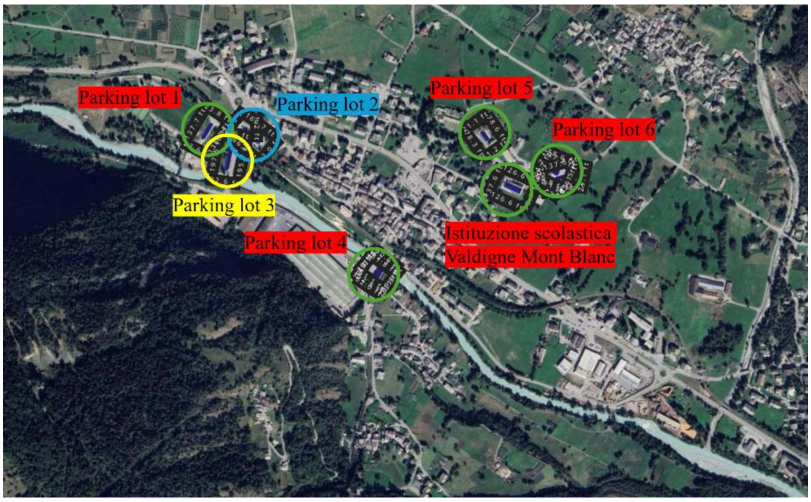

Figure 32 . Parking lots and municipality's roofs Morgex, Morgex

Figure 33 . Parking lots and municipality's roofs Morgex, La Salle

5.2.2.1. *Parking lot 1*

Figure 34 . Parking lot 1, Morgex, Morgex

The first site identified is located in the municipality of Morgex, near the sports field. The proposed system consists of a single canopy with a peak capacity of 55.62 kWp. The table below shows the estimated total production, the total power installed and the specific energy in one year

Table 21 . Parking lot 1, Morgex

Total Power installed	55,62	kWp
Specific energy in one year	828,98	kWh/kWp
Total production [kWh]	46.108,42	kWh

5.2.2.2. *Parking lot 2*

Figure 35 . Parking lot 2, Morgex, Morgex

Located near Parking Lot 1, this site is referred to as the "North Entrance Parking." A single canopy has been proposed, taking into account the presence of two trees identified via Google Maps.
The system's peak capacity is estimated at 58.20 kWp.

Table 22 . Parking lot 2, Morgex, Morgex

Total Power installed	58,20	kWp
Specific energy in one year	824,76	kWh/kWp
Total production [kWh]	48.001,61	kWh

5.2.2.3. Parking lot 3

Figure 36 . Parking lot 3, Morgex, Morgex

Located close to the previous two sites, this location is identified on maps as "Sports Field Parking."
The plan includes the installation of a single canopy with a peak capacity of 80.34 kWp. The table below shows the estimated total production, the total power installed and the specific energy in one year

Table 23 . Parking lot 3, Morgex, Morgex

Total Power installed	80,34	kWp
Specific energy in one year	990,64	kWh/kWp
Total production [kWh]	79.588,02	kWh

5.2.2.4. Parking lot 4

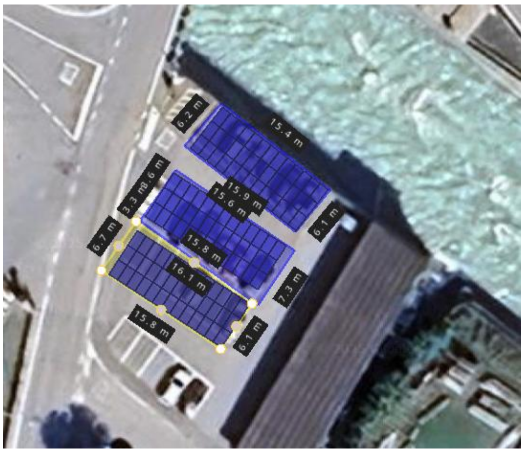

Figure 37 . Parking lot 4, Morgex, Morgex

As the fourth option, the parking lot shown in the figure was identified, located in the municipality of Morgex and referred to as "Pautex and Reading Park Parking." The proposed system consists of two canopies: one double (oriented NE–SW) with a peak capacity of 40.18 kWp, and one single (oriented NE) with a peak capacity of 20.09 kWp. The table below shows the estimated total production, the total power installed and the specific energy in one year.

Table 24 . Parking lot 4, Morgex, Morgex

Total Power installed	60,27	kWp
Specific energy in one year	940,88	kWh/Kwp
Total production [kWh]	56.707,04	kWh

5.2.2.5. Parking lot 5

Figure 38 . Parking lot 5, Morgex, Morgex

The fifth parking lot identified is located next to the Morgex outpatient clinic. The proposed system consists of a single canopy with a peak capacity of 30.90 kWp.

Table 25 . Parking lot 5, Morgex, Morgex

Total Power installed	30.9	kWp
Specific energy in one year	1.173,11	kWh/kWp
Total production [kWh]	36.249,10	kWh

5.2.2.6. Parking lot 6

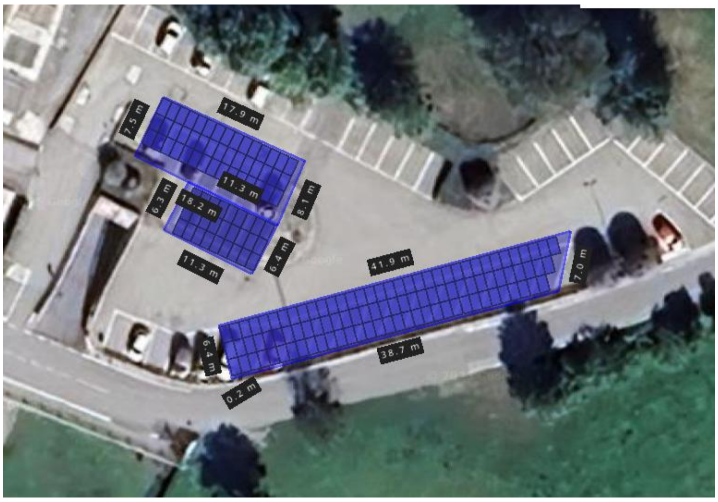

Figure 39 . Parking lot 6, Morgex, Morgex

Located along Strada del Berno, this site is planned to host three single canopies for a total installed capacity of 88.90 kWp. The table below shows the estimated total production, the total power installed and the specific energy in one year.

Table 26 . Parking lot 6, Morgex, Morgex

Total Power installed	88,9	kWp
Specific energy in one year	1.171,03	KWh/kWp
Total production [kWh]	104.105,29	kWh

5.2.2.7. *Parking lot 7*

Figure 40 . Parking lot 7, La Salle, Morgex

Parking Lot 7 is the site with the highest potential installable capacity within the La Salle primary substation area, at 100.96 kWp. It is located in the municipality of La Salle, below the town hall, on Via Col Serena. The proposed system consists of four canopies: one double (oriented E–W) and three single canopies (oriented E and NE).

Table 27 . Parking lot 7, La Salle, Morgex

Total Power installed	100,96	kWp
Specific energy in one year	931,09	kWh/kWp
Total production [kWh]	94.003,3	kWh

5.2.2.8. *Parking lot 8*

Figure 41 . Parking lot 8, La Salle, Morgex

The eighth option analyzed is located in the municipality of La Salle. The proposed system consists of a single west-facing canopy.

Table 28 . Parking lot 8, La Salle, Morgex

Total Power installed	27,81	kWp
Specific energy in one year	990,64	kWh/kWp
Total production [kWh]	27.549,70	kWp

5.2.2.9. Parking lot 9

Figure 42 . Parking lot 9, La Salle, Morgex

The last parking lot analyzed is located in the municipality of La Salle, near the water treatment plant. The system consists of a single north-east-facing canopy with a total capacity of 35.54 kWp.

Table 29 . Parking lot 9, La Salle Morgex

Total Power installed	35,54	kWp
Specific energy in one year	824,77	kWh/kWp
Total production [kWh]	29.312,33	kWh

5.2.2.10. *Istituzione scolastica Valdigne Mont Blanc*

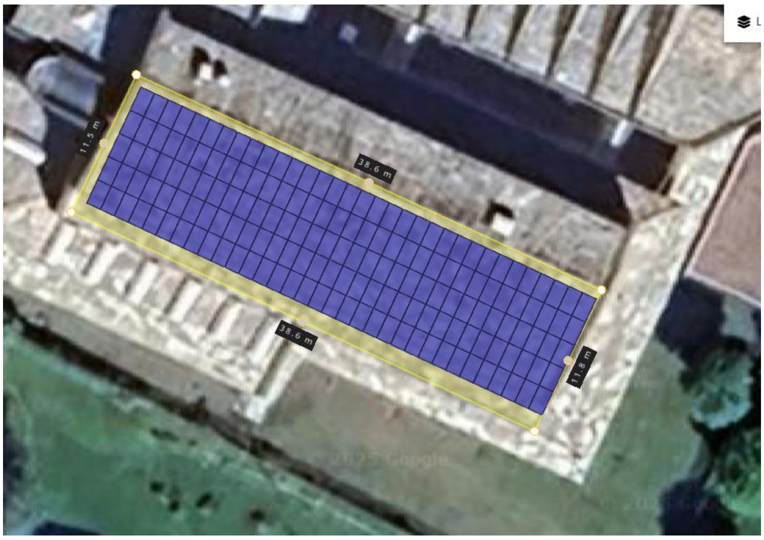

Figure 43 . Istituzione scolastica Valdigne Mont Blanc

The last option identified within the area served by the Morgex substation is the roof of the *Istituzione Scolastica Valdigne Mont Blanc*, located in the municipality of Morgex. The proposed system has a total installed capacity of 84.98 kWp.

Table 30 . Istituzione scolastica Valdigne Mont Blanc

Total Power installed	84,28	kWp
Specific energy in one year	1.182,85	kWh/kWp
Total production [kWh]	99.690,89	kWh

5.2.2.11. *Total production*

By summing up the contributions from all the identified parking lots, the following total potential production and total power installed are obtained within the Morgex primary substation area.

Table 31 . Total production

	Energy produced		**Power installed**	
Parking lot 1	46.108,42	kWh	55,62	kWp
Parking lot 2	48.001,61	kWh	58,2	kWp
Parking lot 3	79.588,02	kWh	80,34	kWp
Parking lot 4	56.707,04	kWh	60,27	kWp
Parking lot 5	36.249,10	kWh	30,9	kWp
Parking lot 6	104.105,29	kWh	88,9	kWp
Parking lot 7	94.003,30	kWh	100,96	kWp
Parking lot 8	27.549,70	kWh	27,81	kWp

Parking lot 9	29.312,32	kWh	35,54	kWp
Istituzione scolastica Valdigne Mont Blanc	99.690,89	kWh	84,28	kWp
Total	**621.315,69**	**kWh**	**622,82**	**kWp**

5.2.2.12. Hourly production of Municipality-owned PV plants

Starting from the estimated installed capacity and annual production of each photovoltaic carport within the service area of the Morgex primary substation, a total hourly production profile was constructed for every month of the year. The procedure followed the same methodological steps described in the previous chapter on rooftop producibility, namely the combination of monthly specific yields with normalized hourly irradiance distributions.

In this case, the contributions from all selected parking areas were aggregated. The individual hourly production curves of the carports were summed up to obtain the overall monthly hourly profile representative of the entire Morgex substation.

As an illustrative case, the following table and graph report the aggregated hourly production profile for the month of January.

Table 32 . Hourly production of Municipality-owned PV plants – Morgex -April

Hour	Parking Lot 1	Parking Lot 2	Parking Lot 3	Parking Lot 4	Parking Lot 5	Parking Lot 6	Parking Lot 7	Parking Lot 8	Parking Lot 9	Valdigne Mont Blanc Educational Institution	Total
	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]
0	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
5	0,574	0,597	0,823	0,617	0,315	0,907	1,032	0,285	0,364	0,867	6,381
6	2,886	2,999	4,136	3,101	1,585	4,559	5,190	1,432	1,832	4,359	32,079
7	5,182	8,779	6,815	8,089	3,120	11,244	14,985	2,359	5,361	8,580	74,514
8	9,366	22,092	13,604	20,446	7,989	31,102	39,187	4,709	13,491	21,971	183,957
9	14,142	24,199	22,783	24,363	11,776	39,975	44,295	7,886	14,777	32,385	236,580
10	17,954	24,394	30,326	26,359	14,639	45,609	45,854	10,498	14,897	40,261	270,792
11	20,994	23,377	36,269	26,938	16,611	48,437	44,937	12,555	14,275	45,683	290,075
12	22,564	20,853	39,487	25,648	17,306	47,644	40,977	13,669	12,734	47,594	288,476
13	23,818	17,747	42,372	23,866	17,863	46,279	36,076	14,667	10,837	49,126	282,652

14	22,551	13,125	40,144	19,546	16,127	39,136	27,563	13,896	8,015	44,353	244,455
15	20,785	8,314	36,951	14,841	13,998	31,093	18,569	12,791	5,077	38,498	200,916
16	16,598	4,123	29,092	9,451	10,159	19,967	11,192	10,070	2,517	27,938	141,107
17	2,787	2,365	4,115	2,602	1,491	3,901	4,240	1,424	1,444	4,101	28,471
18	0,138	0,143	0,197	0,148	0,076	0,217	0,247	0,068	0,087	0,208	1,530
19	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
20	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
21	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
22	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
23	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

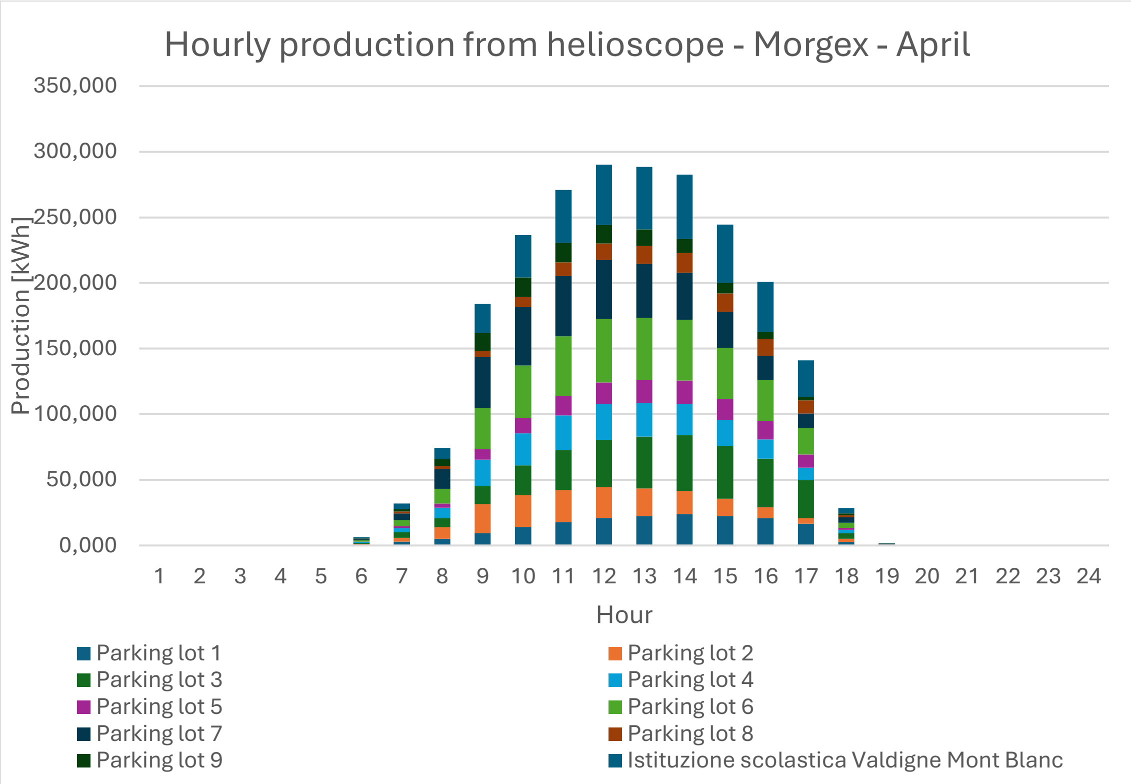

Figure 44 . Hourly production from helioscope - Morgex – April

5.2.3. P.S. Didier

In the area served by the P.S. Didier primary substation, five parking lots and a small adjacent roof have been identified as suitable for the installation of photovoltaic canopies (carports). The selection of these sites was carried out on the basis of a series of technical and environmental criteria, including favorable solar exposure for a high number of daily hours and the almost total absence of obstacles that could cause shading, such as buildings or dense tree cover. For each site, the same calculation methodology for potential photovoltaic energy production already used in the previous chapters was applied.

Figure 45 . Parking lots and Municipality's roofs P.S.Didier, Courmayeur & Pré-Saint Didier

Figure 46 . Parking lots and Municipality's roofs P.S.Didier, La Thuile

5.2.3.1. Parking lot 1

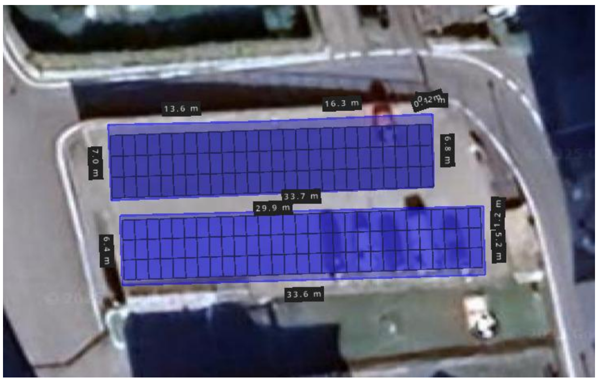

Figure 47 . Parking lot 1, Courmayeur, P.S. Didier

The first site selected is located in the southern part of the municipality of Courmayeur, specifically near Strada della Funivia. The proposed photovoltaic system for this parking lot consists of two canopies: one oriented north and the other south, for a total installed capacity of 84.98 kWp.

The estimated annual production, taking into account the site's exposure and technical characteristics, is as follows:

Table 33 . Parking lot 1, Courmayeur, P.S. Didier

Total Power installed	84,98	kWp
Specific energy in one year	1.021,036	kWh/kWp
Total production [kWh]	86.767,72	kWh

5.2.3.2. Parking lot 2

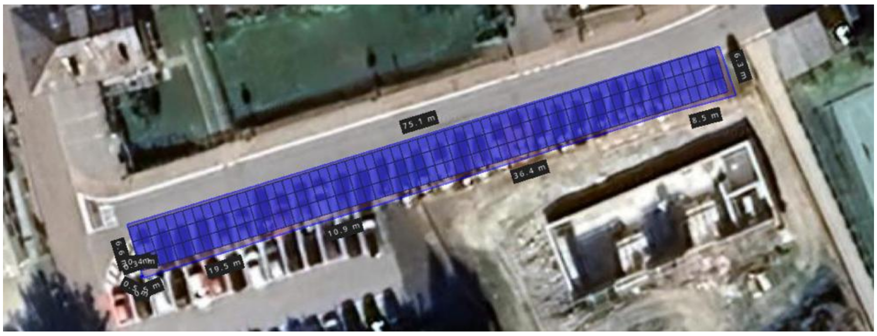

Figure 48 . Parking lot 2, Prés Saint Didier, P.S. Didier

The second parking lot is located in the municipality of Pré-Saint-Didier, on Via dell'Ancien Casino. In this case, the proposed design includes the installation of a long south-facing canopy, allowing optimal capture of solar radiation.
The total installed capacity is 100.43 kWp.

Table 34 . Parking lot 2, Prés Saint Didier, P.S. Didier

Total Power installed	100,43	kWp
Specific energy in one year	1.257,06	kWh/kWp
Total production [kWh]	126.247,54	kWh

5.2.3.3. Parking lot 3

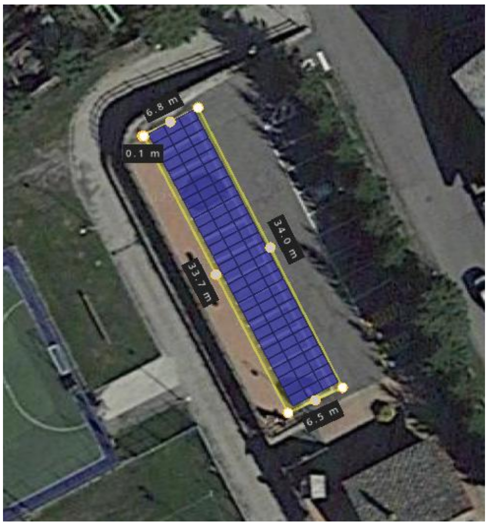

Figure 49 . Parking lot 3, La Thuile, P.S. Didier

The third site is located in the municipality of La Thuile, at the parking lot adjacent to the municipal sports field. The proposed photovoltaic system consists of a single southwest-facing canopy with an installed capacity of 44.81 kWp.

Table 35 . Parking lot 3, La Thuile, P.S. Didier

Total Power installed	44,81	kWp
Specific energy in one year	1.173,11	kWh/kWp
Total production [kWh]	52.567,06	kWh

5.2.3.4. Parking lot 4

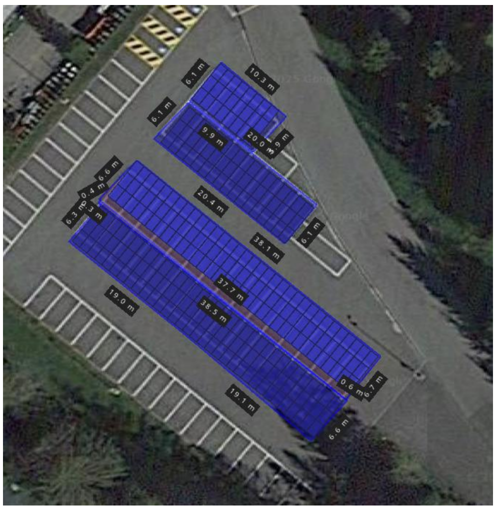

Figure 50 . Parking lot 4, La Thuile, P.S. Didier

The fourth site is also located in the municipality of La Thuile, in the municipal parking lot situated behind the Waste Collection Center.
In this area, a large photovoltaic system has been proposed, consisting of three canopies: two single and one double, for a total installed capacity of 140.61 kWp. This is the most powerful system proposed within the P.S. Didier primary substation area, and its isolated location, free from obstacles, makes it particularly suitable for maximizing production.
The table below shows the estimated total production, the total power installed and the specific energy in one year.

Table 36 . Parking lot 4, La Thuile, P.S. Didier

Total Power installed	140,61	kWp
Specific energy in one year	981,71	kWh/kWp
Total production [kWh]	138.038,25	kWh

5.2.3.5. *Parking Lot 5 + Adjacent Roof*

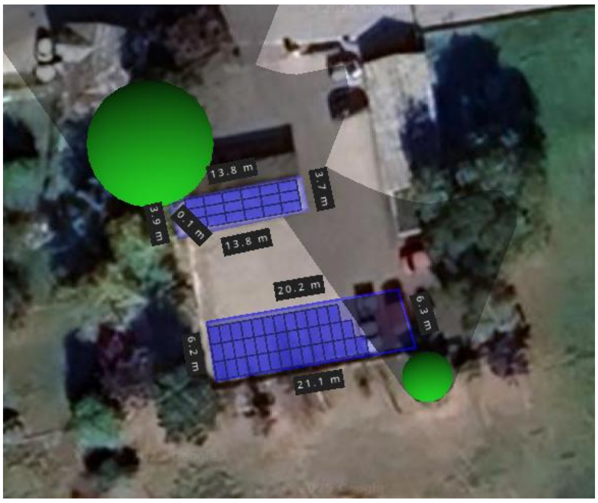

Figure 51 . Parking lot + adjacent roof, Courmayeur, P.S.Didier

The last site identified is located once again in the municipality of Courmayeur and includes both a parking lot and a small adjacent roof, both with a south-facing orientation. This configuration, which combines the use of carports and existing roof surfaces, is advantageous in terms of making the most of available space and optimizing production. The total planned capacity is 29.36 kWp.
In the design analysis, special attention was given to the presence of trees and their corresponding shadow projections, as shown in the reference figure.
The table below shows the estimated total production, the total power installed and the specific energy in one year.

Table 37 . Parking lot + adjacent roof, Courmayeur, P.S.Didier

Total Power installed	29,36	kWp
Specific energy in one year	1.257,07	kWh/kWp
Total production [kWh]	36.907,58	kWh

5.2.3.6. *Total production*

By summing up the contributions from all the identified parking lots, the following total potential production is obtained within the P.S. Didier primary substation area.

Table 38 . Total production

	Energy produced		**Power installed**	
Parking lot 1	86.767,72	kWh	84,98	kWp
Parking lot 2	126.247,54	kWh	100,43	kWp
Parking lot 3	52.567,06	kWh	44,81	kWp
Parking lot 4	138.038,25	kWh	140,61	kWp
Parking lot + adjacent roof	36.907,58	kWh	29,36	kWp
Total	**440.528,15**	**kWh**	**400,19**	**kWp**

5.2.3.7. *Hourly production of Municipality-owned PV plants*

Starting from the estimated installed capacity and annual production of each photovoltaic carport within the service area of the Pré-Saint-Didier primary substation, a total hourly production profile was constructed for every month of the year. The procedure followed the same methodological steps described in the previous chapter on rooftop producibility, namely the combination of monthly specific yields with normalized hourly irradiance distributions.

As with the other substations, the contributions from all selected parking areas were aggregated. The individual hourly production curves of the carports were summed to obtain the overall monthly hourly profile representative of the entire Pré-Saint-Didier substation.

As an illustrative case, the following table reports the aggregated hourly production profile for the month of April.

Table 39 . Aggregated hourly production profile – P.S. Didier - April

Hour	Parking lot 1	Parking lot 2	Parking lot 3	Parking lot 4	Parking lot and roof	Total
	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]	Production [kWh]
0	0,000	0,000	0,000	0,000	0,000	0,000
1	0,000	0,000	0,000	0,000	0,000	0,000
2	0,000	0,000	0,000	0,000	0,000	0,000
3	0,000	0,000	0,000	0,000	0,000	0,000
4	0,000	0,000	0,000	0,000	0,000	0,000
5	0,870	1,023	0,457	1,438	0,299	4,088
6	4,374	5,144	2,299	7,231	1,504	20,552

7	10,762	13,218	4,524	18,051	3,864	50,419
8	27,513	38,433	11,585	45,706	11,236	134,472
9	34,362	49,053	17,077	56,266	14,340	171,098
10	38,498	55,633	21,229	62,396	16,264	194,020
11	40,469	58,653	24,089	65,087	17,147	205,445
12	39,536	57,233	25,096	63,162	16,732	201,759
13	37,990	55,170	25,904	60,181	16,129	195,373
14	32,096	46,005	23,387	50,486	13,449	165,424
15	25,513	35,767	20,300	39,736	10,456	131,772
16	16,504	21,819	14,732	26,300	6,379	85,733
17	3,720	4,295	2,163	6,197	1,256	17,631
18	0,209	0,245	0,110	0,345	0,072	0,980
19	0,000	0,000	0,000	0,000	0,000	0,000
20	0,000	0,000	0,000	0,000	0,000	0,000
21	0,000	0,000	0,000	0,000	0,000	0,000
22	0,000	0,000	0,000	0,000	0,000	0,000
23	0,000	0,000	0,000	0,000	0,000	0,000

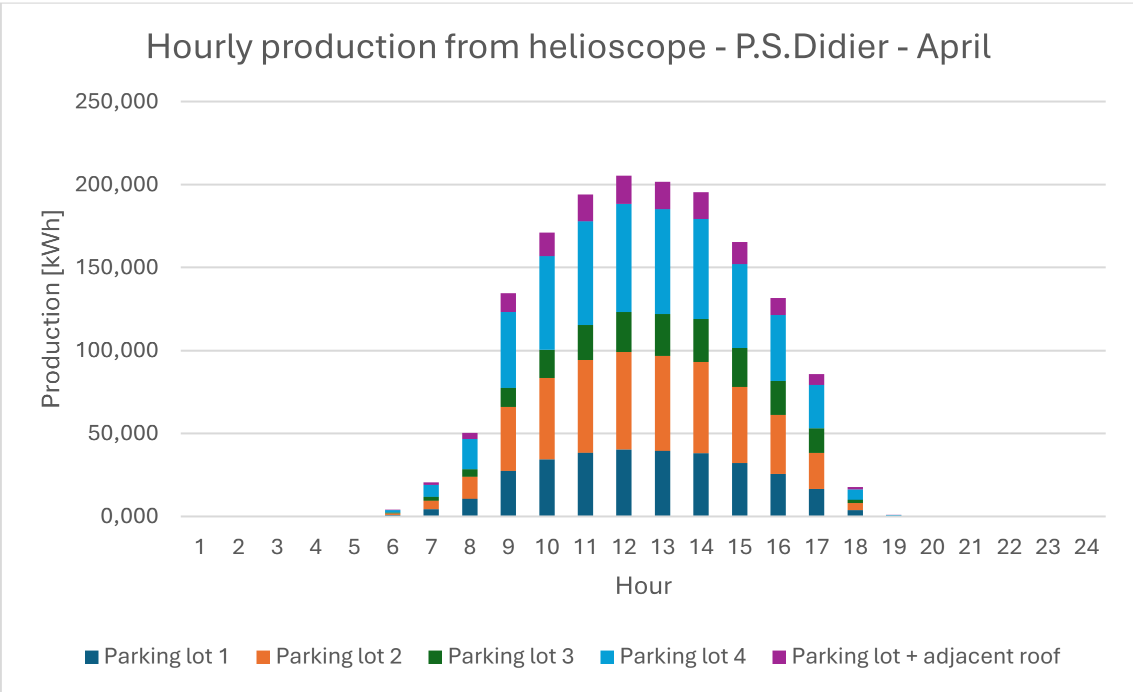

Figure 52 . Hourly production from helioscope - P.S.Didier – April

5.2.4. Total production and power installed for all Primary substations

In conclusion of this chapter, the aggregated values of installed power and expected production for each primary substation, considering both carports and rooftops, are reported in the table below.

Table 40 . Total production and power installed for all Primary substations

Entréves	Ice rink	509.765,00	kWh	500	kWp
	Parking Lot 1	135.287,69	kWh	135,97	kWp
	Parking Lot 2	30.738,95	kWh	37,08	kWp
	Parking Lot 3	158.843,74	kWh	156,05	kWp
	Parking Lot 4	180.972,25	kWh	173,04	kWp
	Parking Lot 5	128.639,49	kWh	122,08	kWp
	Parking Lot 6	100.993,00	kWh	80,34	kWp
	Middle school	142.238,59	kWh	127,21	kWp
	Total	1.387.478,71	kWh	1331,77	kWp
Morgex	Parking lot 1	46.108,42	kWh	55,62	kWp
	Parking lot 2	48.001,61	kWh	58,2	kWp
	Parking lot 3	79.588,02	kWh	80,34	kWp
	Parking lot 4	56.707,04	kWh	60,27	kWp
	Parking lot 5	36.249,10	kWh	30,9	kWp
	Parking lot 6	104.105,29	kWh	88,9	kWp
	Parking lot 7	94.003,30	kWh	100,96	kWp
	Parking lot 8	27.549,70	kWh	27,81	kWp
	Parking lot 9	29312,3258	kWh	35,54	kWp
	Istituzione scolastica Valdigne Mont Blanc	99.690,89	kWh	84,28	kWp
	Total	621.315,69	kWh	622,82	kWp
P.S.Didier	Parking lot 1	86.767,72	kWh	84,98	kWp
	Parking lot 2	126.247,54	kWh	100,43	kWp
	Parking lot 3	52.567,06	kWh	44,81	kWp
	Parking lot 4	138.038,25	kWh	140,61	kWp
	Parking lot + adjacent roof	36.907,58	kWh	29,36	kWp
	Total	440.528,15	kWh	400,19	kWp

6. Total Electricity Consumption in the Valdigne

This chapter estimates the total electricity consumption of the Valdigne, so it can be compared with the potential PV production quantified earlier. The objective is to test the real-world feasibility of a Renewable Energy Community (CER) in the Valdigne by checking whether, when, and where local demand can be matched by local generation.

Consistent with the producibility analyses, the territory is partitioned in the three primary substations (cabine primarie): Entrèves, Pré-Saint-Didier, and Morgex. This subdivision is essential for the next chapter, where production and consumption must be matched at the primary-substation level, according to the regulatory constraints about CERs normative framework.

For each building in the Valdigne, some parameters were elaborated:

- an indicative annual consumption based on the category of the building [kWh/year];
- a monthly seasonality vector (12 factors that reflect -month-by-month- tourism, climate, and business cycles).
- Thanks to these parameter, annual consumption is distributed over months: a representative intraday load profile (weekday/weekend).

Thanks to these parameter, monthly consumption values are distributed with hour granularity.

- Monthly factors that redistribute the annual kWh into months. For example, second homes and hospitality show peaks in December–March and July–August, while primary residences remain comparatively flatter.
- Daily/weekly profiles that differentiate weekdays vs. weekends and adjust for holiday periods.

Then, results are aggregated by substation.

6.1. Building categories and definitions

The analysis distinguishes the following building categories, selected to reflect the Valdigne's residential mix, tourism intensity and the presence of winter sports infrastructure:

- Primary residences: dwellings where occupants are habitually resident (registered domicile).
- Second homes: owned dwellings not used as the main residence, like holiday homes or investment properties (including those occasionally rented). Considering the touristic significance of the Valdigne area and the consequent prevalence of second homes, it was essential to distinguish between primary residences and secondary dwellings.
- Commercial and industrial activities with low energy intensity: shops, offices, workshops and small productive sites with typical annual consumption around 10,000 kWh.
- Commercial and industrial activities with high energy intensity: larger or more energy-intensive activities with typical annual consumption around 100,000 kWh.
- Hotels and B&Bs: accommodation serving visitors and tourists. In this analysis, consumption is parameterized by star rating (with B&Bs grouped with 2-stars hotels) to reflect service level, amenities (kitchens, spas, laundries), and occupancy.
- Domain skiable: Ski lifts, cableways, and related mountain facilities.

As stated in the introduction, the Italian regulatory framework does not allow very large energy-intensive users, defined in practice as consumers with contracted power above 1 MW or annual consumption exceeding several gigawatt-hours, to participate as members within the sharing perimeter of a Renewable Energy Community. Such users (for example, heavy industry facilities or the Mont-Blanc Tunnel infrastructure) fall outside CER eligibility or practicality constraints and are therefore excluded from the analysis.

6.2. Allocation by primary substation

Every building is tagged to Entrèves, Pré-Saint-Didier, or Morgex primary electric substation using geospatial assignment.

In the end the chapter delivers, for each substation and for the whole Valdigne:

- Total annual consumption and its split by category,
- Monthly demand profiles highlighting winter/summer peaks,
- Representative hourly/daily load profiles for weekday/weekend and seasonal archetypes.

This structure is necessary for CER design because energy sharing and incentives are constrained within the same primary substation perimeter. These outputs are used in the next chapter to compare against potential PV production (rooftops, carports, and any ground-mount considered) and to compute:

- Simultaneity between generation and load;
- Self-consumption;
- Residual demand (to be met from the grid) and exported surplus (eligible for CER valorization).

6.3. Entréves

The first area examined corresponds to the territory served by the Entrèves primary substation. Within this perimeter, the analysis considers the categories of buildings previously defined for the study, applying a consistent methodological framework so that results are comparable across categories and with the other areas assessed in the thesis.

6.3.1. Primary Residences

The number of primary residences within the catchment of the Entrèves primary substation was obtained from the official ISTAT housing database, which provides the census of dwelling units for all Italian municipalities [22]. Only the portion of the municipality of Courmayeur that lies inside the substation's service area is included in the present analysis. Consistently with the spatial delimitation adopted for this study, the 80% of the Courmayeur municipality's total stock of primary dwelling units was retained to reflect the share effectively supplied by the Entrèves substation (the remaining 20% is connected to the Pre-St-Didier primary substation).

Dwelling units, rather than buildings, are counted, since a single building may contain multiple independent households and the objective is to estimate energy load at the unit level. On this basis, the number of primary residences within the study area is 1.082.

To quantify electricity demand, an average annual consumption of 3,000 kWh per primary dwelling unit, representative of a typical three-person household, was assumed [23]. Applying this intensity to the stock yields an aggregate annual consumption of 3,244,800 kWh for primary residences in the Entrèves service area.

The annual total energy load value was then allocated across months using seasonal weighting factors designed to produce a rational intra-annual profile for primary residences. Because these are first homes, occupancy is relatively stable over the year, whit a limited seasonality. In particular, higher consumption is expected in winter due to increased lighting needs and occasional use of heat pumps; and a moderate increase is foreseen in summer due to air-conditioning. Autumn is taken to be slightly higher than spring, primarily because of shorter daylight hours.

The seasonal weights are normalized to sum to unity, and monthly consumption values are obtained by multiplying the annual total by the respective monthly weight. The adopted weights and the resulting monthly consumption figures are presented below.

Table 41 . Seasonal weights and the resulting monthly consumption of all primary residences - Entrèves

Month	Seasonal weights [%]	Monthly consumption [kWh]
January	10%	335.296,00
February	9%	302.848,00
March	6%	196.804,17
April	6%	190.455,65
May	6%	196.804,17
June	10%	317.426,09
July	10%	328.006,96
August	10%	328.006,96
September	7%	235.337,14
October	7%	243.181,71
November	7%	235.337,14
December	10%	335.296,00

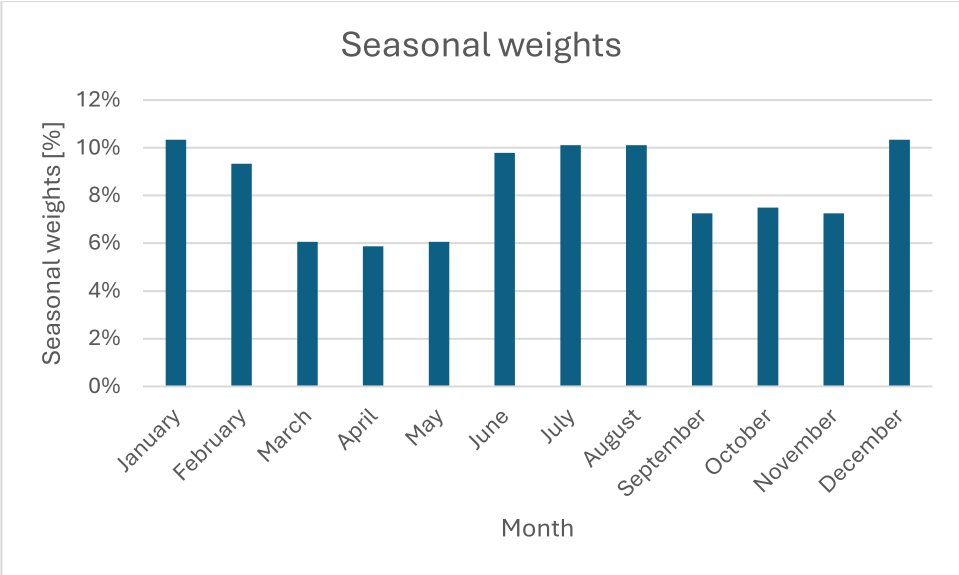

Figure 53 . Seasonal Weights of Primary Residences

Table 42 . Seasonal weights, monthly consumption for all primary residences and one primary residence - Entréves

Month	Seasonal weights [%]	Monthly consumption [kWh]	Monthly consumption For one house [kWh]
January	10%	335.296,00	310,00
February	9%	302.848,00	280,00
March	6%	196.804,17	181,96
April	6%	190.455,65	176,09
May	6%	196.804,17	181,96
June	10%	317.426,09	293,48
July	10%	328.006,96	303,26
August	10%	328.006,96	303,26
September	7%	235.337,14	217,58
October	7%	243.181,71	224,84
November	7%	235.337,14	217,58
December	10%	335.296,00	310,00
Total		3.244.800,00	3.000,00

Subsequently, the monthly energy consumption was also disaggregated to the hourly level for each day, producing an hourly daily load estimate. The procedure first divides the monthly total by the number of days in the month under analysis to obtain an average daily consumption [kWh/day], for each month. This daily value is then distributed across the 24 hours using a normalized daily percentage profile (i.e., a vector of hourly shares that sums to 100%), thereby preserving the monthly energy balance. The hourly profile was defined to reflect typical residential usage patterns for primary homes and incorporates two characteristic demand peaks:

- a lower, mid-morning peak between 10:00 and 11:00 [24];
- a higher, early-evening peak around 18:00, when most residents return from work and engage in cooking, lighting, and other household activities [24].

Lower consumption is assumed during night-time and the early morning hours, when occupancy-driven demand and appliance use are minimal. The same daily profile is applied uniformly to each day of the month, so that the sum of hourly allocations over all days exactly matches the monthly total previously derived. The resulting set of hourly percentage weights, together with an illustrative application for the month of January, is reported below.

Table 42 . Hourly percentage, Hourly consumption for all primary residences and one primary residence - Entréves

Hour	Hourly Percentage weights	Hourly consumption [kWh]	Hourly consumption for one house [kWh]
0	2,37%	256,32	0,24
1	2,17%	234,35	0,22
2	2,08%	225,31	0,21
3	2,10%	227,59	0,21
4	2,37%	256,66	0,24
5	3,12%	337,76	0,31
6	3,95%	427,38	0,40
7	4,40%	475,98	0,44
8	4,56%	493,56	0,46
9	4,62%	499,75	0,46
10	5,33%	576,80	0,53
11	5,49%	593,93	0,55
12	4,92%	532,62	0,49
13	4,49%	485,37	0,45
14	4,27%	462,30	0,43
15	4,43%	479,36	0,44
16	5,11%	552,55	0,51
17	6,04%	652,84	0,60
18	6,47%	699,98	0,65

19	6,01%	649,86	0,60
20	5,22%	564,28	0,52
21	4,29%	463,71	0,43
22	3,40%	367,30	0,34
23	2,78%	300,46	0,28

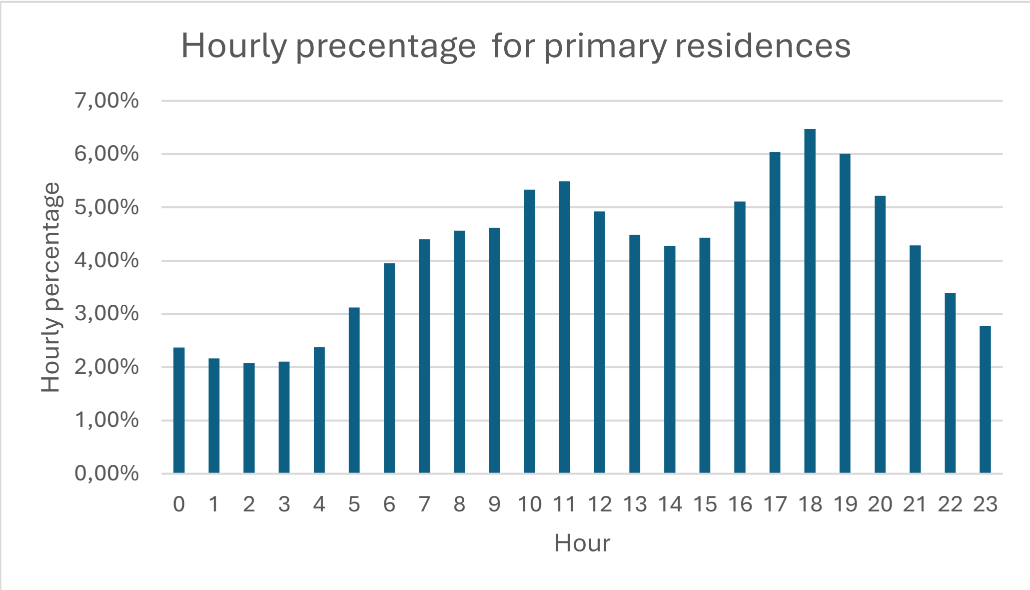

Figure 54 . Hourly percentage for primary residences

6.3.2. Second homes

The same methodology described in previous chapter for the main residence was applied to the analysis of second homes located within the service area of the Entrèves primary substation. Also in this case, using as source the ISTAT data and adopting the unit-based approach, the total stock of secondary dwelling units in the study area amounts to 4,289 [22].

Also for the secondary homes, seasonal weighting factors vector was defined to allocate annual consumption across the months. In this case, the profile explicitly reflects the pronounced occupancy-driven peaks typical of second homes: higher demand in winter and summer due to holiday periods, ski and outdoor sporting activities, and summer vacations. By contrast, consumption during the shoulder seasons (spring and fall) was assumed to be markedly lower, reflecting the reduced presence of tourists and the infrequent use of second homes by their owners. The seasonal weighting factors adopted for this category are reported below.

Table 43 . Seasonal weights and monthly consumption for all second homes and one second home - Entrèves

Month	Seasonal weights	Monthly consumption [kWh]	Monthly consumption one house [kWh]
January	19%	814.872,00	190,00
February	17%	729.096,00	170,00

March	1%	49.750,08	11,60
April	1%	49.750,08	11,60
May	1%	49.750,08	11,60
June	8%	343.104,00	80,00
July	15%	643.320,00	150,00
August	15%	643.320,00	150,00
September	1%	49.750,08	11,60
October	1%	49.750,08	11,60
November	1%	49.750,08	11,60
December	19%	814.872,00	190,00
Total		4.287.084,48	999,60

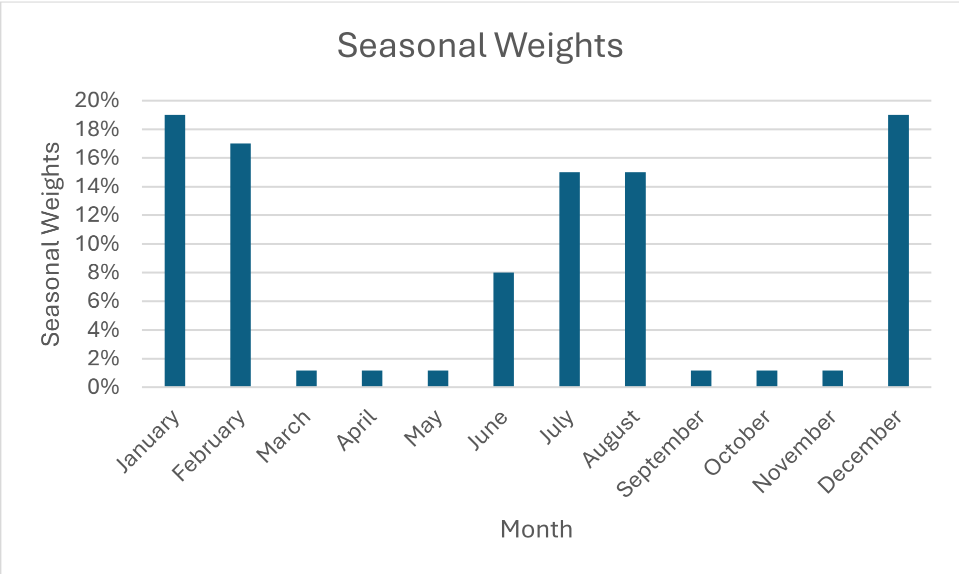

Figure 55 . Seasonal Weights Second homes

Finally, the hourly consumption percentages were estimated, adopting a daily load profile consistent with that was used for primary residences. For each month, the monthly total assigned to second homes was first divided by the number of days in the month to obtain an average daily energy value. This daily figure was then distributed across the 24 hours using a normalized hourly percentage vector that preserves the key residential features already described for primary homes: a modest mid-morning rise (around 10:00–11:00, a more pronounced early-evening peak (around 18:00, coinciding with typical returns home and meal preparation), and subdued demand during night-time and the early morning hours [24]. To maintain methodological coherence and ensure that the aggregation across hours reproduces the monthly energy exactly, the same hourly profile was applied uniformly to all days within each month. The set of hourly percentage weights used, together with a worked example for the month of January, is reported below.

Table 44 . Hourly percentage weights, hourly consumption and hourly consumption fro one second home - Entréves

Hour	Hourly Percentage weights	Hourly consumption [kWh]	Hourly consumption for one house[kWh]
0	2,37%	622,95	0,15
1	2,17%	569,55	0,13
2	2,08%	547,58	0,13
3	2,10%	553,10	0,13
4	2,37%	623,75	0,15
5	3,12%	820,87	0,19
6	3,95%	1.038,67	0,24
7	4,40%	1.156,77	0,27
8	4,56%	1.199,51	0,28
9	4,62%	1.214,54	0,28
10	5,33%	1.401,80	0,33
11	5,49%	1.443,42	0,34
12	4,92%	1.294,43	0,30
13	4,49%	1.179,59	0,28
14	4,27%	1.123,54	0,26
15	4,43%	1.164,98	0,27
16	5,11%	1.342,87	0,31
17	6,04%	1.586,60	0,37
18	6,47%	1.701,17	0,40
19	6,01%	1.579,35	0,37
20	5,22%	1.371,36	0,32
21	4,29%	1.126,96	0,26
22	3,40%	892,65	0,21
23	2,78%	730,20	0,17

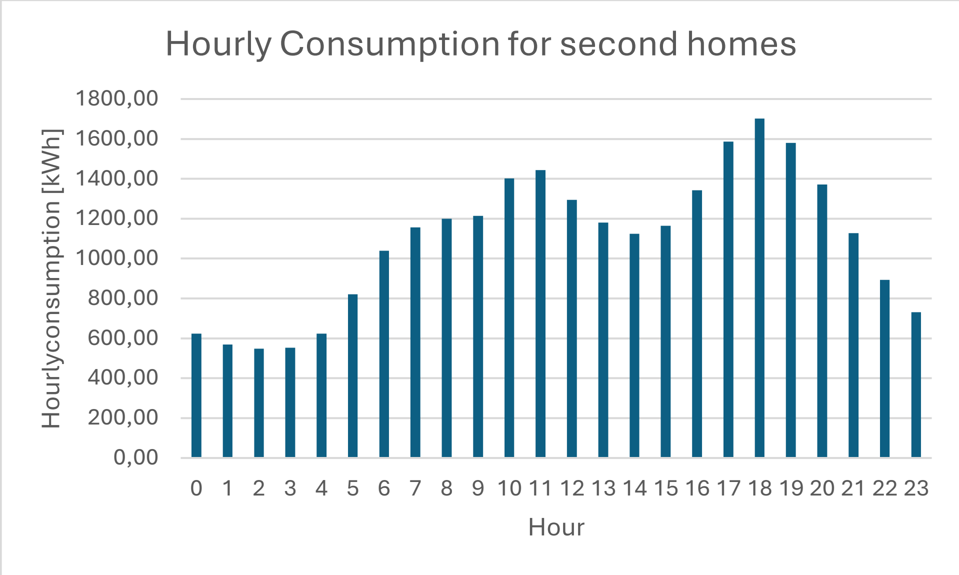

Figure 56 . Hourly consumption for all second homes - Entréves

6.3.3. Commercial and industrial activities

For the commercial and industrial activities located within the service area of the Entrèves primary substation, data were compiled for firms registered under the national ATECO 2007 industry classification, using the official ISTAT Data platform. The ATECO 2007 code is the Italian classification system of economic activities, developed by the Italian National Institute of Statistics (ISTAT). It is based on the European NACE Rev. 2 classification but adapted to the Italian context. Each business or professional activity in Italy is assigned an ATECO code, which is used for statistical, fiscal, and administrative purposes, for example, when registering a company, issuing invoices, or applying specific tax regimes [22]. This procedure made it possible to determine not only the number of establishments operating within the municipality of Courmayeur (considering as filter in the municipality "Courmayeur"), but also to verify whether each establishment falls within the catchment of the Entrèves primary substation or that of Pré-Saint-Didier, and to assign each to an energy-intensity class. In keeping with the dimensional characteristics of small Alpine municipalities without large industrial plants, two representative consumption classes were adopted: activities classified as low energy intensity, with an average annual electricity use of approximately 10,000 kWh per year, and activities classified as high energy intensity, with an average annual electricity use of approximately 100,000 kWh per year. The table reproduced below is taken directly from the ISTAT Data portal and reports the distribution of enterprises by location and energy-intensity category for the municipality of Courmayeur.

Hotels will not be considered within this section due to their high and distinct consumption patterns. Their hourly load distribution differs substantially from that of other members, and therefore they are analyzed separately in a dedicated paragraph.

Table 45 . Number of activities from ISTATdata portal - Entréves

	Indicatore	[LU] Numero di unità locali delle imprese attive	Type of activites
	Attività economica (ATECO 2007)		
[0010] TOTAL	[0010] TOTALE	642	

[B] Estrazione di minerali da cave e miniere	[B] Mining and quarrying	1	High energy intensity
[C] Attività manifatturiere	• [C] Manufacturing	23	High energy intensity
[D] Fornitura di energia elettrica, gas, vapore e aria condizionata	• [D] Electricity, gas, steam and air-conditioning supply	2	High energy intensity
[E] Fornitura di acqua reti fognarie, attività di gestione dei rifiuti e risanamento	• [E] Water supply; sewerage, waste management and remediation activities	1	Low energy density
[F] Costruzioni	• [F] Construction	79	Low energy density
[G] Commercio all'ingrosso e al dettaglio, riparazione di autoveicoli e motocicli	[G] Wholesale and retail trade; repair of motor vehicles and motorcycles	79	High energy intensity
[H] Trasporto e magazzinaggio	• [H] Transportation and storage	14	Low energy density
[I] Attività dei servizi di alloggio e di ristorazione	• [I] Accommodation and food service activities	149	High energy intensity
[J] Servizi di informazione e comunicazione	[J] Information and communication services	6	Low energy density
[K] Attività finanziarie e assicurative	• [K] Financial and insurance activities	10	High energy intensity
[L] Attività immobiliari	• [L] Real estate activities	53	Low energy density
[M] Attività professionali, scientifiche e tecniche	• [M] Professional, scientific and technical activities	79	Low energy density
[N] Noleggio, agenzie di viaggio, servizi di supporto alle imprese	• [N] Administrative and support service activities (including rental services and travel agencies)	55	High energy intensity
[P] Istruzione	[P] Education	21	Low energy density
[Q] Sanità e assistenza sociale	• [Q] Human health and social work activities	17	Low energy density
[R] Attività artistiche, sportive, di intrattenimento e divertimento	• [R] Arts, entertainment and recreation	29	High energy intensity
[S] Altre attività di servizi	• [S] Other service activities	24	Low energy density

On the basis of this classification, the area served by the Entrèves primary substation hosts 238 low-energy-intensity establishments and 276 high-energy-intensity establishments. The total annual electricity demand for the commercial and productive sector was then obtained by multiplying the number of establishments in each group by a representative specific consumption (10,000 kWh/year for low-energy-intensity activities and 100,000 kWh/year for high-energy-intensity activities) and summing the two contributions. This yields an aggregate annual consumption of 29,976,000 kWh.

As for primary and secondary residences, the annual total for businesses was distributed over the months using seasonal weighting factors. The profile reflects higher consumption in spring, summer, and autumn (with August treated as an exception due to widespread holiday closures) so as to reproduce observed local operating patterns, particularly in productive activities. The adopted seasonal weights and the corresponding monthly consumption values are reported below.

Table 46 . Seasonal weights and total consumption for all activities and one activity - Entrèves

Month	Seasonal weights	Total consumption [kWh]	Total consumption for one activity [kWh]
January	7%	2.098.320,00	2.588,60
February	7%	2.098.320,00	2.588,60
March	8%	2.398.080,00	2.958,40
April	9%	2.697.840,00	3.328,20
May	9%	2.697.840,00	3.328,20
June	10%	2.997.600,00	3.698,00
July	10%	2.997.600,00	3.698,00
August	6%	1.798.560,00	2.218,80
September	9%	2.697.840,00	3.328,20
October	8%	2.398.080,00	2.958,40
November	8%	2.398.080,00	2.958,40
December	9%	2.697.840,00	3.328,20
Total		29.976.000,00	36.980,01

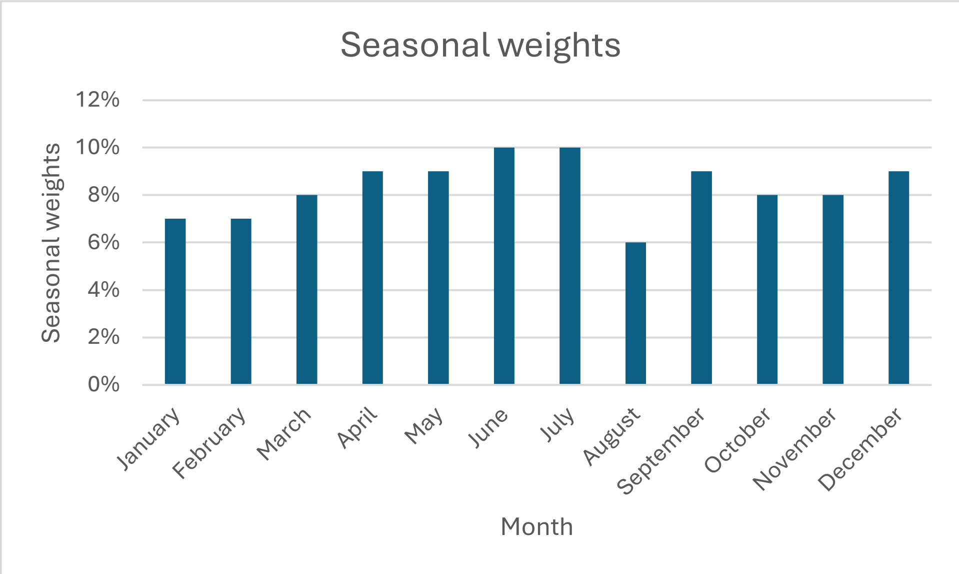

Figure 57 . Seasonal weights for Activities

Finally, the monthly consumption for each month was further disaggregated to a daily profile by applying a set of estimated daily percentage weights (like it was done before for the primary and the second houses). In this way, the allocation preserves the monthly energy balance while enabling a consistent breakdown of consumption at the daily scale for all months in the series.

The daily profile split for commercial and productive activities is characterized by two salient peaks that reflect typical operating patterns:

- the first occurs between 09:00 and 10:00, coinciding with the opening of retail businesses and the morning ramp-up of production activities;
- the second emerges between 15:00 and 16:00, corresponding to post-lunch reopening in the commercial sector and the afternoon production peak in the productive sector. Outside these intervals (namely in the early morning hours, during mid-day closure periods, and in the late evening when operations taper off) consumption is comparatively subdued.

The complete set of daily percentage weights adopted in the analysis, together with an illustrative application for the month of January, is reported below.

Table 47 . Hourly percentage and hourly consumption for all activities and one activity - Entréves

Hour	Hourly percentage	Hourly consumption [kWh]	Hourly consumption for one activity[kWh]
0	67687,74	947,63	1,85
1	67687,74	879,94	1,71
2	67687,74	812,25	1,58
3	67687,74	812,25	1,58
4	67687,74	947,63	1,85
5	67687,74	1.286,07	2,50
6	67687,74	2.233,70	4,35

7	67687,74	3.249,01	6,33
8	67687,74	3.858,20	7,51
9	67687,74	4.535,08	8,83
10	67687,74	5.482,71	10,68
11	67687,74	5.482,71	10,68
12	67687,74	4.805,83	9,36
13	67687,74	4.535,08	8,83
14	67687,74	4.535,08	8,83
15	67687,74	5.144,27	10,02
16	67687,74	5.144,27	10,02
17	67687,74	4.535,08	8,83
18	67687,74	3.249,01	6,33
19	67687,74	1.962,94	3,82
20	67687,74	1.286,07	2,50
21	67687,74	947,63	1,85
22	67687,74	676,88	1,32
23	67687,74	473,81	0,92

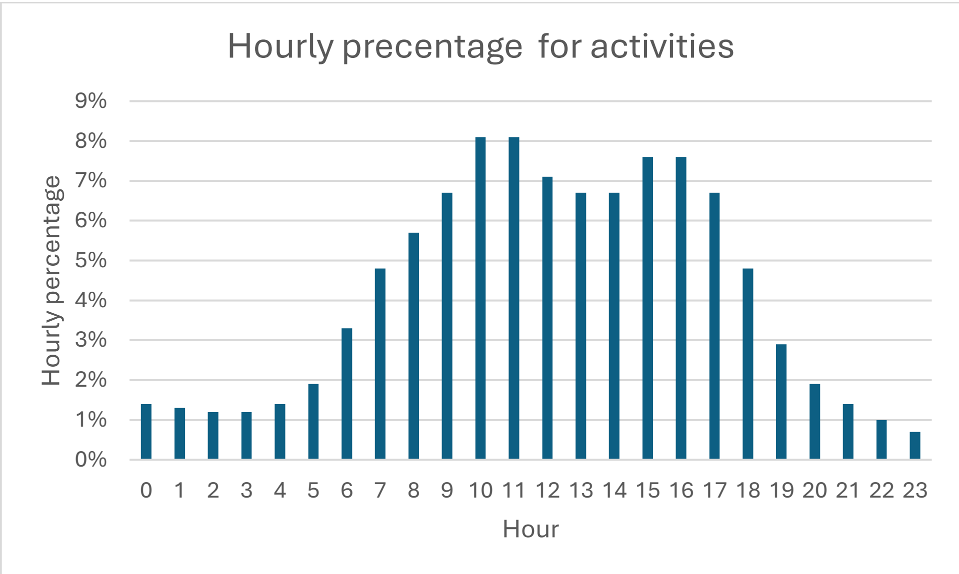

Figure 58 . Hourly percentage for activites

6.3.4. Hotels and B&Bs

For accommodation facilities, this category was disaggregated into sub-groups according to each structure's star rating within the Valdigne area. Electricity demand was then estimated on a per-room basis, adopting average annual specific consumptions by star class derived from the ENEA study *Caratterizzazione energetica del settore alberghiero in Italia* (Ente per le Nuove tecnologie, l'Energia e l'Ambiente) [25]. This star-based segmentation captures the differentiated service levels and amenity sets typical of higher-rated hotels and, at the same time, normalizes consumption to capacity by expressing it per room. For each facility, the total annual demand is obtained by multiplying the number of rooms by the class-specific per-room intensity and summing across all establishments in the corresponding subcategory.

The subdivision and reference intensities adopted are as follows:

- 2-star hotels and B&Bs: average annual consumption of 5 MWh per room per year;
- 3-star hotels: average annual consumption of 7 MWh per room per year;
- 4-star hotels: average annual consumption of 9 MWh per room per year;
- 5-star hotels: average annual consumption of 11 MWh per room per year.

The number of accommodation facilities was determined through the official Courmayeur tourism website, retaining only establishments located within the service area of the Entrèves primary substation [26]. Each hotel identified online was geolocated using Google Maps and imported into the QGIS project containing the boundaries of the primary substations. A spatial overlay was then performed to assign each establishment to the appropriate catchment area; only those falling within the Entrèves polygon were retained.

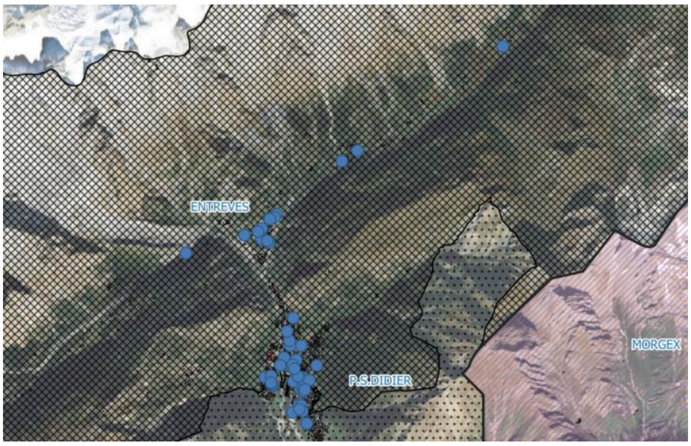

Figure 59 . Position of hotels Entréves Imported in Qgis

For each facility, the number of rooms was identified by searching the website of each hotel, so as to compile a star-based distribution of total rooms across the relevant subcategories. The resulting room counts are as follows:

- 2-star hotels and B&Bs: 76 rooms;
- 3-star hotels: 361 rooms;
- 4-star hotels: 272 rooms;
- 5-star hotels: 191 rooms.

Having established the total number of rooms by category, the aggregate electricity consumption for each subcategory was calculated by multiplying the average annual per-room consumption associated with its star rating by the corresponding number of rooms. This procedure yields the following annual demands:

- 2-star and B&B facilities: 380,000 kWh;

- 3-star facilities: 2,527,000 kWh;
- 4-star facilities: 2,448,000 kWh;
- 5-star facilities: 2,101,000 kWh.

Subsequently, the annual consumption estimated for each accommodation subcategory was apportioned across the twelve months of the year, differentiating monthly loads in line with typical demand patterns for the area. A vector of seasonal weighting coefficients was defined to reflect the strong concentration of touristic activity during the winter and summer tourist seasons (driven by the Christmas–New Year period, the ski season, and the July-August holiday peak) while assigning very low shares to the shoulder months, when tourist inflows are limited and occupancy rates are subdued. The seasonal coefficients were then applied consistently to each star-rating class to disaggregate annual energy use into monthly values. The adopted coefficients, together with the resulting monthly consumption values for each accommodation category, are reported below.

Table 48 . Seasonal weight, consumption for each category hotel and total consumption of all hotels - Entréves

Month	Seasonal Weights	Consumption 2 star hotels [kWh]	Consumption 3 star hotels [kWh]	Consumption 4 star hotels [kWh]	Consumption 5 star hotels [kWh]	Total
January	19%	72.200	480.130	465.120	399.190	1.416.640
February	17%	64.600	429.590	416.160	357.170	1.267.520
March	1%	4.408	29.313,2	28.397	24.371,6	86.490
April	1%	4.408	29.313,2	28.397	24.371,6	86.490
May	1%	4.408	29.313,2	28.397	24.371,6	86.490
June	8%	30.400	202.160	195.840	168.080	596.480
July	15%	57.000	379.050	367.200	315.150	1.118.400
August	15%	57.000	379.050	367.200	315.150	1.118.400
September	1%	4.408	29.313,2	28.397	24.371,6	86.490
October	1%	4.408	29.313,2	28.397	24.371,6	86.490
November	1%	4.408	29.313,2	28.397	24.371,6	86.490
December	19%	72.200	480.130	465.120	399.190	1.416.640

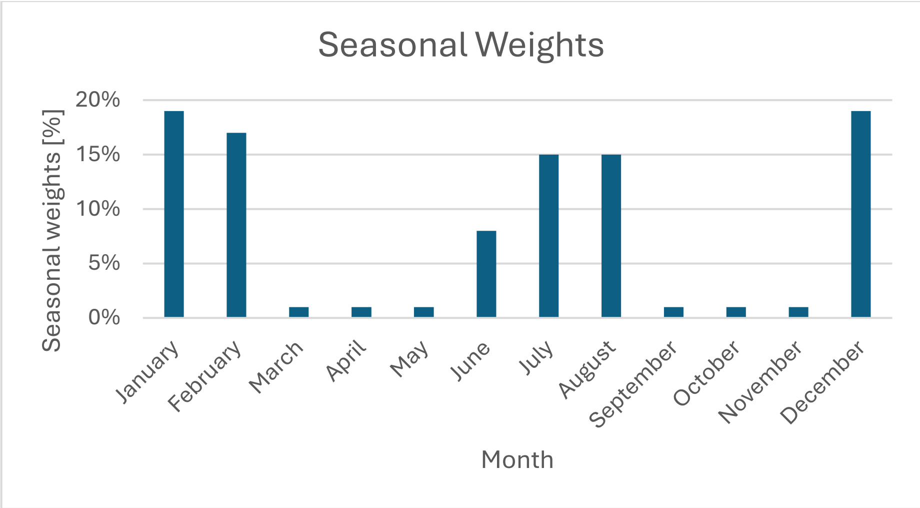

Figure 60 . Seasonal weights for hotels

Finally, for each month of the year, the daily consumption percentages were determined by specifying a normalized hourly profile for the accommodation sector, consistent with the profiles already adopted for secondary dwellings. The curve exhibits two characteristic peaks, one between 11AM and 12AM, and another at 7PM, with comparatively lower levels across the remaining hours. The percentage vectors, normalized to 100%, were applied uniformly to all days of the month and, unless otherwise noted, were used identically across all hotel star categories. The complete set of daily percentage weights adopted in the analysis, together with an illustrative application for the month of January for the 2-star category, is reported below.

Table 49 . Hourly percentage and hourly consumption for all 2 stars hotels and one 2 star hotel - Entréves

Hour	Hourly percentage	Hourly consumption [kWh]	Hourly consumption for one hotel 2-star [kWh]
0	2%	55,19	0,73
1	2%	50,46	0,66
2	2%	48,52	0,64
3	2%	49,01	0,64
4	2%	55,27	0,73
5	3%	72,73	0,96
6	4%	92,03	1,21
7	4%	102,49	1,35
8	5%	106,28	1,40
9	5%	107,61	1,42
10	5%	124,20	1,63
11	5%	127,89	1,68
12	5%	114,69	1,51

13	4%	104,51	1,38
14	4%	99,55	1,31
15	4%	103,22	1,36
16	5%	118,98	1,57
17	6%	140,58	1,85
18	6%	150,73	1,98
19	6%	139,93	1,84
20	5%	121,51	1,60
21	4%	99,85	1,31
22	3%	79,09	1,04
23	3%	64,70	0,85

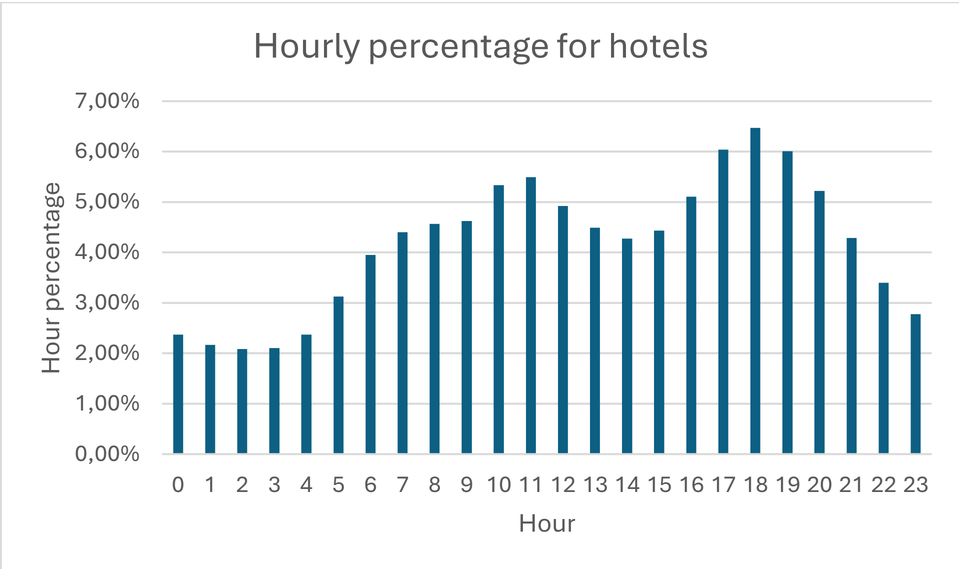

Figure 61 . Hourly percentage for hotels

6.3.5. Domains skiable

Both the Courmayeur ski resort (Courmayeur Mont Blanc Funivie, CMBF) and the Skyway Monte Bianco (Funivia Monte Bianco) fall within the service area of the Entrèves primary substation. For this analysis, annual electricity consumption was retrieved for both systems from their respective FY 2023–2024 financial statements [27]. The Courmayeur ski resort reported monthly electricity withdrawals for the calendar year 2024, whereas Skyway provided only an annual total [28]. Consequently, monthly percentage shares were derived from the Courmayeur series by normalizing the 2024 monthly values to obtain a 12-month distribution vector, which was then applied to Skyway's annual figure to generate a consistent monthly breakdown. The adopted annual totals are 2,845,000 kWh for the Skyway Monte Bianco and 6,008,002 kWh for the Courmayeur Mont Blanc Funivie. The table below reports, for both the Courmayeur ski area and the Skyway Monte Bianco, the monthly consumption in kWh together with the corresponding percentage shares.

Table 50. SkyWay consumption

Month	Consumption [kWh]	Seasonal weights
October	54.409,66	2%
November	615.011,80	22%
Dicember	601.672,31	21%
January	489.924,65	17%
February	367.017,19	13%
March	312.650,62	11%
April	128.079,89	5%
May	57.042,99	2%
June	49.263,75	2%
July	64.837,85	2%
August	63.426,72	2%
September	41.662,57	1%

Table 51. Courmayeur Ski Area consumption

Month	Consumption [kWh]	Seasonal weights
October	114.901,00	2%
November	1.298.767,00	22%
Dicember	1.270.597,00	21%
January	1.034.611,00	17%
February	775.058,00	13%
March	660.248,00	11%
April	270.476,00	5%
May	120.462,00	2%
June	104.034,00	2%
July	136.923,00	2%
August	133.943,00	2%
September	87.982,00	1%

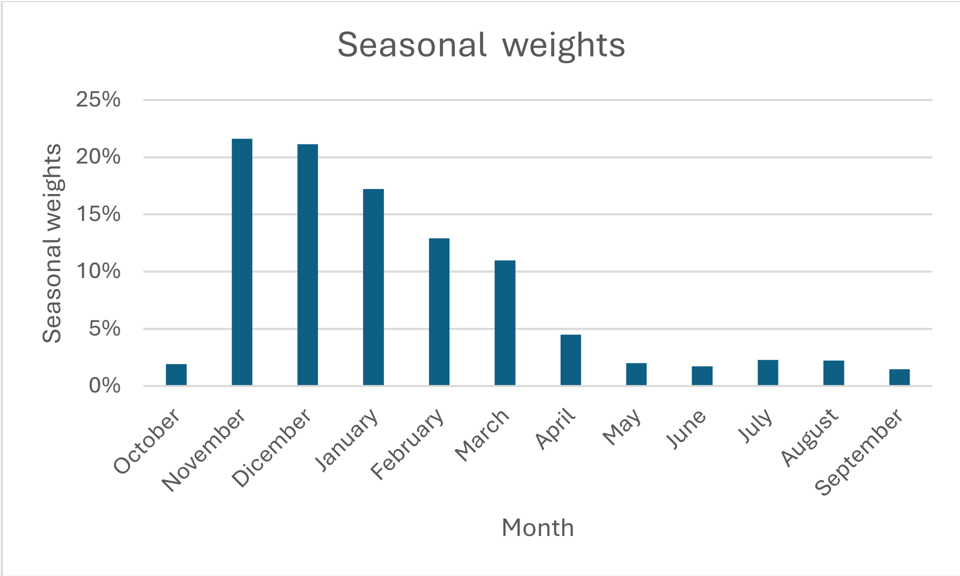

Figure 62 . Seasonal Weights for ski areas

Consistently with the approach adopted for the other consumer categories, hourly consumption shares were estimated to derive a daily distribution for each month for both the Courmayeur ski area and the Skyway Monte Bianco. For the Courmayeur domain skiable, two distinct operating regimes were considered in November, December, and January:

- snowmaking, modelled as an approximately constant load between 18:00 and 08:00 (evening and night)
- cable car systems (also applied to the Skyway), defined over the operating window, 09:00–17:00, with two characteristic peaks: a higher peak around 11:00 and a lower peak around 14:00.

In November, 90% of the monthly energy demand was allocated to the snowmaking profile, while the remaining 10% was assigned to the uplift profile. In December and January, this distribution was inverted, with 90% of the demand attributed to cable car systems and 10% to snowmaking. For the subsequent months in the Courmayeur dataset, as well as for all twelve months of the Skyway, exclusively the cable car system's daily profile was adopted.

Daily profiles were constructed as percentage distributions across predefined time sectors of the day. These distributions were normalized to ensure a total of 100% and subsequently applied uniformly across all days within each month. The adopted profiles, along with an illustrative application for the Courmayeur lifts in January, are reported below.

Table 52 . Hourly percentage – Cable car systems

Hour	Hourly percentage
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	7,5%
10	12,0%
11	15,0%
12	11,0%
13	12,0%
14	13,0%
15	12,0%
16	10,0%
17	7,5%
18	0
19	0
20	0
21	0
22	0
23	0

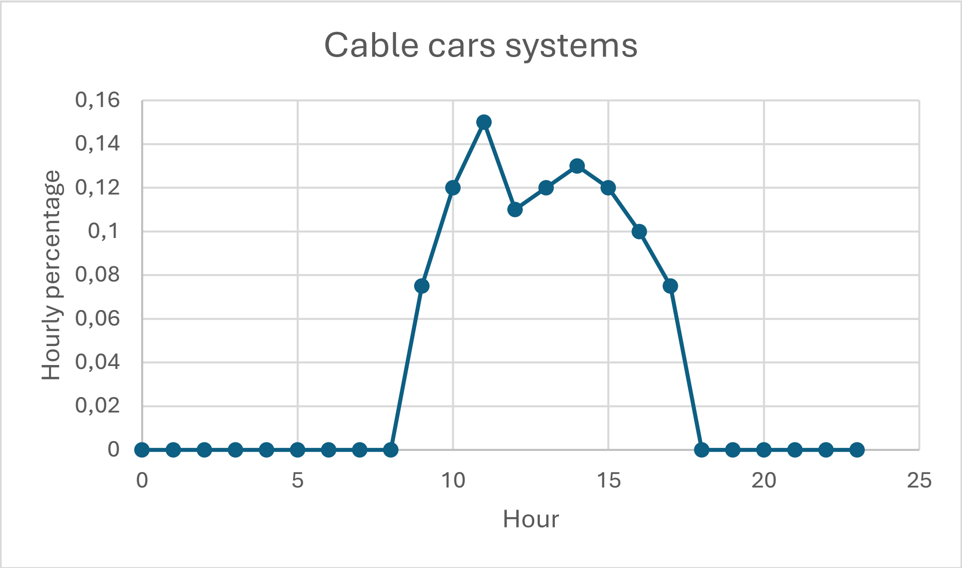

Figure 62. Hourly percentage - Cable car systems

Table 53. Hourly percentage - Snowmaking

Hour	Hourly percentage
0	6,66%
1	6,66%
2	6,66%
3	6,66%
4	6,66%
5	6,66%
6	6,66%
7	6,66%
8	6,66%
9	0,0%
10	0,0%
11	0,0%
12	0,0%
13	0,0%
14	0,0%
15	0,0%
16	0,0%
17	0,0%
18	6,66%
19	6,66%
20	6,66%
21	6,66%
22	6,66%
23	6,66%

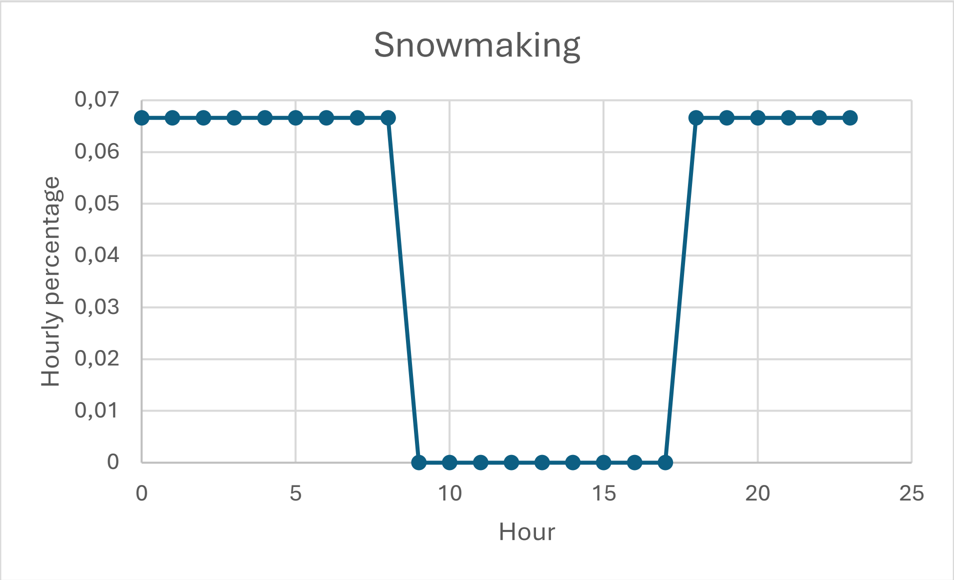

Figure 63. Hourly percentage - Snowmaking

Table 54 . Total consumption and subdivision of car cable system – snowmaking consumption - Courmayeur Ski Area

Hour	Total consumption [kWh]	Car cable systems[kWh]	Snowmaking [kWh]
0	222,27	-	222,27
1	222,27	-	222,27
2	222,27	-	222,27
3	222,27	-	222,27
4	222,27	-	222,27
5	222,27	-	222,27
6	222,27	-	222,27
7	222,27	-	222,27
8	222,27	-	222,27
9	2.252,78	2.252,78	-
10	3.604,45	3.604,45	-
11	4.505,56	4.505,56	-
12	3.304,08	3.304,08	-
13	3.604,45	3.604,45	-
14	3.904,82	3.904,82	-
15	3.604,45	3.604,45	-
16	3.003,71	3.003,71	-
17	2.252,78	2.252,78	-
18	222,27	-	222,27
19	222,27	-	222,27
20	222,27	-	222,27
21	222,27	-	222,27
22	222,27	-	222,27
23	222,27	-	222,27

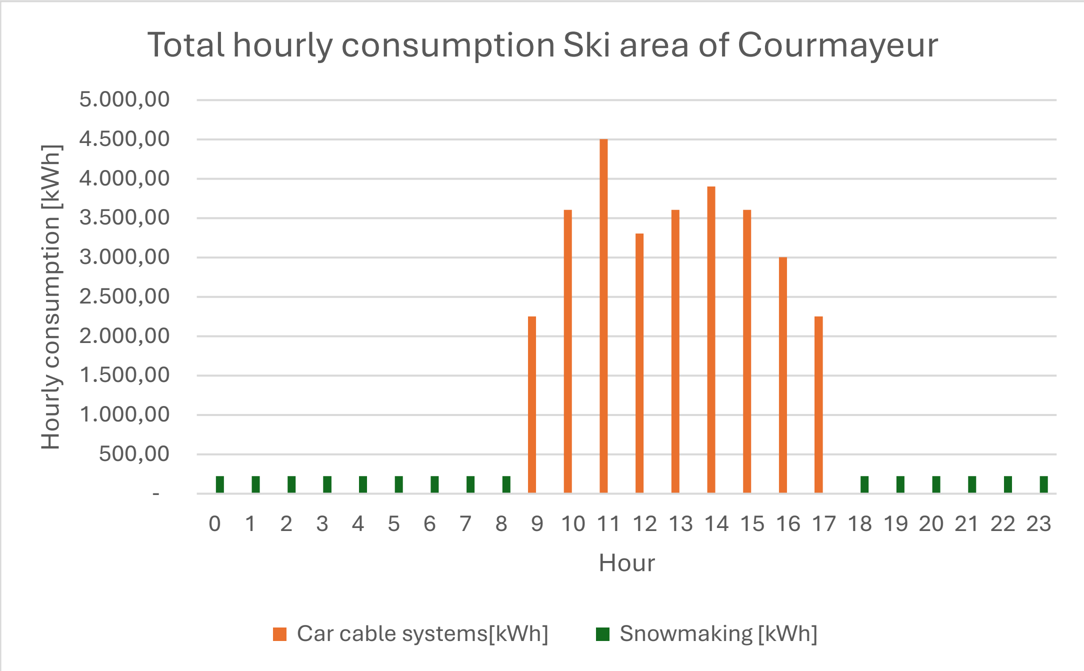

Figure 63 . Total hourly consumption Ski area of Courmayeur

An example for Skyway consumption during the month of January is always reported in the table below.

Table 55 . Hourly consumption Skyway

Hour	Hourly percentage	Hourly consumption [kWh]
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	7,5%	1.185,30
10	12,0%	1.896,48
11	15,0%	2.370,60
12	11,0%	1.738,44
13	12,0%	1.896,48
14	13,0%	2.054,52

15	12,0%	1.896,48
16	10,0%	1.580,40
17	7,5%	1.185,30
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0

6.3.6. Municipal electricity consumption

The Municipality of Courmayeur did not provide any information on municipal electricity consumption; consequently, municipal loads were excluded from the load calculation.

6.4. Morgex

The same analytical framework developed for the Entrèves primary substation and described in the previous chapter was applied to the service area of the Morgex primary substation.

6.4.1. Primary residences

Using ISTAT Data as the source, the stock of primary dwelling units was identified by summing those located in the municipalities of Morgex and La Salle [22].

fully encompassing the Morgex substation, whose boundaries coincide with those of the municipalities of Morgex and La Salle.

The resulting total amounts to 1,989 primary units. Applying the same average annual consumption per primary dwelling adopted for the Entrèves analysis (3,000 kWh per unit per year), the aggregate annual demand for this category is 5,967,000 kWh.

For the temporal disaggregation, the same seasonal (monthly and hourly) weighting coefficients and the same normalized daily hourly profile previously defined were used, so as to preserve methodological consistency and ensure direct comparability with the Entrèves results. The resulting monthly consumptions, together with an illustrative hourly distribution for a January day, are reported below.

Table 56 . Hourly consumption of all primary residences and of one primary residence - Morgex

Month	Monthly consumption [kWh]	Monthly consumption of one house[kWh]
January	616.590,00	310,00
February	556.920,00	280,00
March	361.911,52	181,96
April	350.236,96	176,09
May	361.911,52	181,96
June	583.728,26	293,48
July	603.185,87	303,26
August	603.185,87	303,26
September	432.771,43	217,58
October	447.197,14	224,84
November	432.771,43	217,58
December	616.590,00	310,00
Total	5.967.000,00	3000

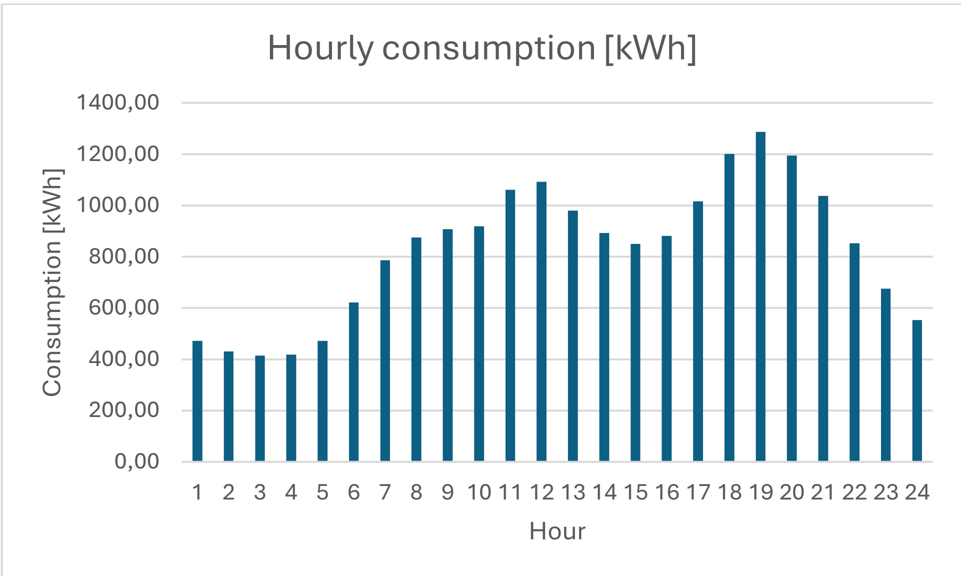

Figure 64 . Hourly consumption of all Primary residences - Morgex

Table 57 . Hourly Consumption Morgex

Hour	Hourly Consumption [kWh]
0	471,36
1	430,96
2	414,34
3	418,52
4	471,97
5	621,12
6	785,93
7	875,30
8	907,64
9	919,01
10	1.060,70
11	1.092,19
12	979,46
13	892,56
14	850,15
15	881,51
16	1.016,11
17	1.200,54
18	1.287,23
19	1.195,05
20	1.037,67
21	852,74
22	675,44
23	552,52

6.4.2. Second homes

Using the same ISTAT Data platform employed for primary residences, the total number of secondary dwelling units within the Morgex primary substation's service area was identified as 4,935 [22]. Assuming an average annual electricity use of 1,000 kWh per unit, the resulting aggregate annual demand for this category is 4,935,000 kWh. For the temporal disaggregation, the same seasonal (monthly and hourly) coefficients and the same normalized daily hourly profiles previously adopted were applied, ensuring methodological consistency and direct comparability with earlier results. The corresponding monthly allocations and the derived daily distributions are reported in the following tables.

Table 58 . Monthly consumption and monthly consumption for one second home - Morgex

Month	Monthly consumption [kWh]	Monthly consumption of one house[kWh]
January	937.650,00	190
February	838.950,00	170
March	57.246,00	11,6
April	57.246,00	11,6
May	57.246,00	11,6
June	394.800,00	80
July	740.250,00	150
August	740.250,00	150
September	57.246,00	11,6
October	57.246,00	11,6
November	57.246,00	11,6
December	937.650,00	190
Total	4.933.026,00	999,6

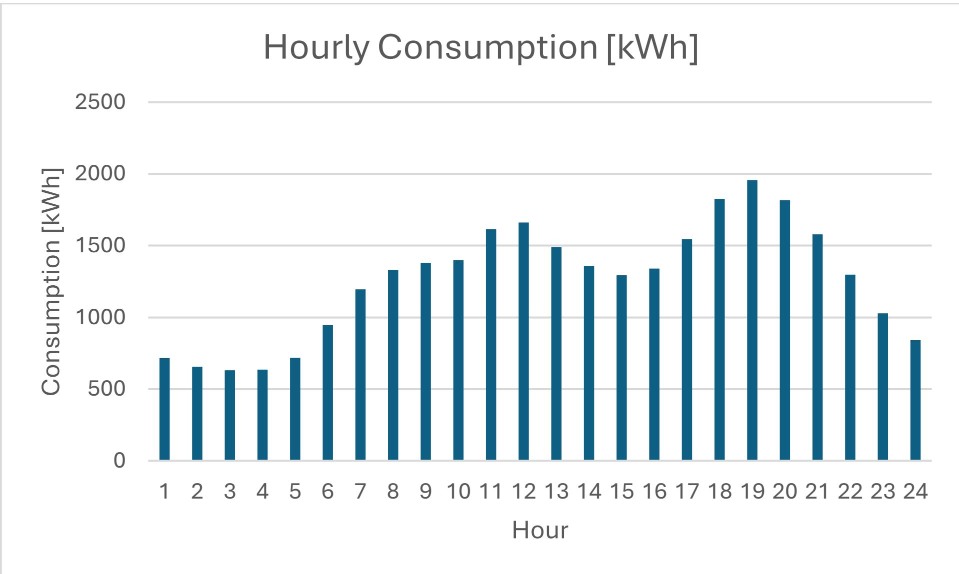

Figure 65 . Hourly consumption of all second homes - Morgex

Table 59. Hourly Consumption - Morgex

Hour	Hourly Consumption [kWh]
0	716,81
1	655,37
2	630,08
3	636,44
4	717,73
5	944,55
6	1.195,16
7	1.331,06
8	1.380,24
9	1.397,53
10	1.613,01
11	1.660,90
12	1.489,46
13	1.357,32
14	1.292,82
15	1.340,51
16	1.545,20
17	1.825,66
18	1.957,49
19	1.817,31
20	1.577,99
21	1.296,76
22	1.027,14
23	840,22

6.4.3. Commercial and industrial activities

For the commercial and productive sector, the same classification adopted for the Entrèves primary substation was applied, together with the same assumptions on average annual consumption and the same seasonal and daily coefficients [22]. The two tables below report the number of establishments located within the two municipalities served by the Morgex primary substation.

Table 60 . Number of activities Morgex and La Salle from ISTATdata

Indicator	Indicatore	[LU] Numero di unità locali delle imprese attive -La Salle	[LU] Numero di unità locali delle imprese attive-Morgex
	Attività economica (ATECO 2007)		
[0010] TOTAL	[0010] TOTALE	187	257
[B] Mining and quarrying	[B] Estrazione di minerali da cave e miniere		1
[C] Manufacturing	[C] Attività manifatturiere	17	25
[D] Electricity, gas, steam and air-conditioning supply	[D] Fornitura di energia elettrica, gas, vapore e aria condizionata	2	3
[E] Water supply; sewerage, waste management and remediation activities	[E] Fornitura di acqua reti fognarie, attività di gestione dei rifiuti e risanamento	1	1
[F] Construction	[F] Costruzioni	50	42
Wholesale and retail trade; repair of motor vehicles and motorcycles	[G] Commercio all'ingrosso e al dettaglio, riparazione di autoveicoli e motocicli	18	34
Transportation and storage	[H] Trasporto e magazzinaggio	3	5
Accommodation and food service activities	[I] Attività dei servizi di alloggio e di ristorazione	24	30
Information and communication services	[J] Servizi di informazione e comunicazione	1	3
Financial and insurance activities	[K] Attività finanziarie e assicurative	3	7
Real estate activities	[L] Attività immobiliari	4	18
Professional, scientific and technical activities	[M] Attività professionali, scientifiche e tecniche	24	36
Administrative and support service activities (including rental services and travel agencies)	[N] Noleggio, agenzie di viaggio, servizi di supporto alle imprese	18	16
[P] Education	[P] Istruzione	2	2
	[Q] Sanità e assistenza sociale	6	12
	[R] Attività artistiche, sportive, di intrattenimento e divertimento	11	7
	[S] Altre attività di servizi	3	15

On this basis, the total annual electricity demand for commercial and productive activities amounts to 27,570,000 kWh. The resulting monthly average consumptions and an illustrative January daily profile are presented below.

Table 61. Monthly consumption of all activities and of one activity - Morgex

Month	Monthly consumption [kWh]	Monthly consumption for one activity [kWh]
January	1.929.900,00	4.346,62
February	1.929.900,00	4.346,62
March	2.205.600,00	4.967,57
April	2.481.300,00	5.588,51
May	2.481.300,00	5.588,51
June	2.757.000,00	6.209,46
July	2.757.000,00	6.209,46
August	1.654.200,00	3.725,68
September	2.481.300,00	5.588,51
October	2.205.600,00	4.967,57
November	2.205.600,00	4.967,57
December	2.481.300,00	5.588,51
Total	27.570.000,00	62.094,59

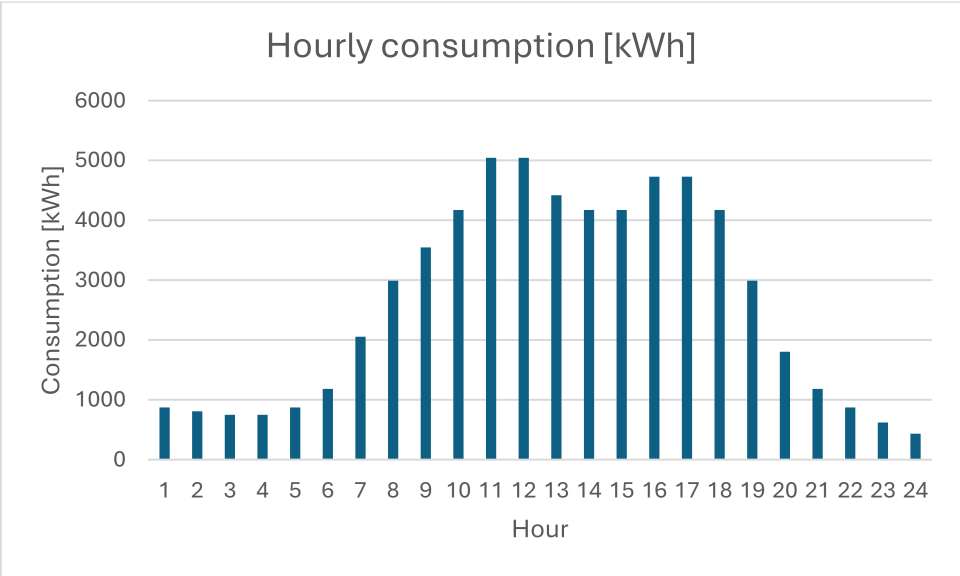

Figure 66 . Hourly consumption of all the activities - Morgex

Table 62 . Hourly Consumption of all activities - Morgex

Hour	Hourly Consumption [kWh]
0	871,57
1	809,31
2	747,06
3	747,06
4	871,57
5	1.182,84
6	2.054,41
7	2.988,23
8	3.548,53
9	4.171,07
10	5.042,64
11	5.042,64
12	4.420,09
13	4.171,07
14	4.171,07
15	4.731,37
16	4.731,37
17	4.171,07
18	2.988,23
19	1.805,39
20	1.182,84
21	871,57
22	622,55
23	435,78

6.4.4. Hotel and B&Bs

Using the same seasonal and daily coefficients, as well as the same per-room consumption assumptions adopted for the Entrèves primary substation, the accommodation inventory for the Morgex service area was compiled with the same star-based methodology [29][30]. Based on the geospatial screening (see QGIS figure), the resulting room counts are:

- 67 rooms in 2-star hotels and B&Bs;
- 33 rooms in 3-star hotels [29][30];
- 0 rooms in 4-star hotels [29][30];
- 55 rooms in 5-star hotels [29][30].

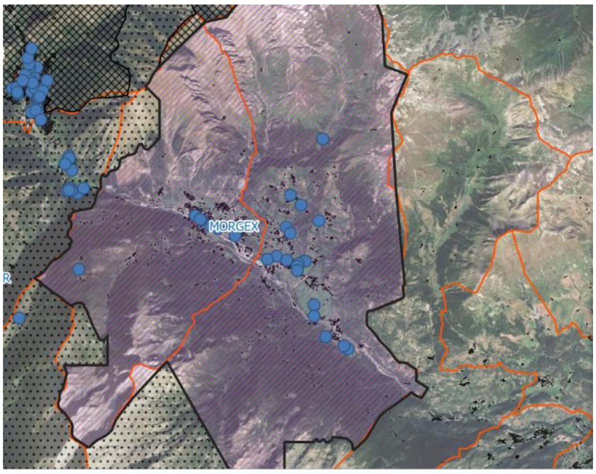

Figure 67 . Hotels in Morgex importend in Qgis

Applying the category specific benchmarks yields the following annual electricity demands:

- 335,000 kWh for 2-star/B&B facilities;
- 231,000 kWh for 3-star facilities;
- 0 kWh for 4-star facilities;
- 605,000 kWh for 5-star facilities.

The corresponding monthly consumptions and an illustrative hourly distribution for a January day of a 2 stars hotel are reported below.

Table 63 . Seasonal weights and total consumption for 2 stars hotels - Morgex

Month	Seasonal weights	Total consumption [kWh]
January	19,0%	222.490
February	17,0%	199.070
March	1,2%	13.583,6
April	1,2%	13.583,6
May	1,2%	13.583,6
June	8,0%	93.680
July	15,0%	175.650
August	15,0%	175.650
September	1,2%	13.583,6
October	1,2%	13.583,6

November	1,2%	13.583,6
December	19,0%	222.490

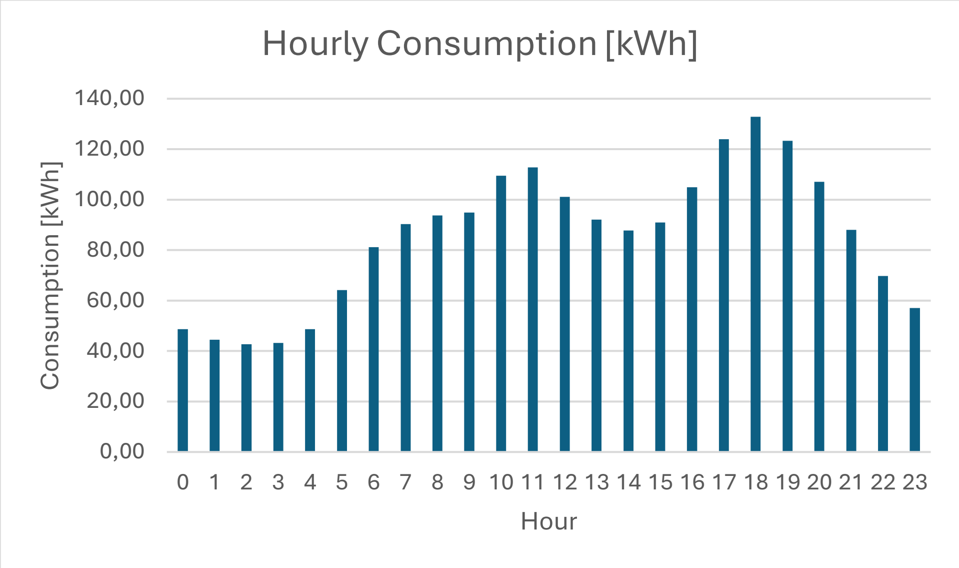

Figure 68 . Hourly consumption hotels 2-star - Morgex

Table 64 . Hourly Consumption of all 2 stars hotels - Morgex

Hour	Hourly Consumption [kWh]
0	48,66
1	44,49
2	42,77
3	43,20
4	48,72
5	64,12
6	81,13
7	90,36
8	93,69
9	94,87
10	109,49
11	112,75
12	101,11
13	92,14
14	87,76

15	91,00
16	104,89
17	123,93
18	132,88
19	123,36
20	107,12
21	88,03
22	69,72
23	57,04

6.4.5. Municipal electricity consumption

While we have not received any data about the load of the Municipality of Morgex-owned meters, the Municipality of La Salle provided consumption data; consequently, only these values were included in the totals. Despite the Municipality of Morgex did not report any figures; given the limited size of those loads, their omission does not materially affect the validity of the results.

For La Salle Municipality, all electricity bills were collected for every municipal POD (Point of Delivery) twelve bills per POD (point of delivery, id est meter), one per month. The total PODs that were analyzed were 24. A bill-level analysis was then performed to allocate each POD's monthly energy across the three Italian time-of-use bands:

- F1 (peak): Monday–Friday 08:00–19:00 (excluding public holidays);
- F2 (mid-peak): Monday–Friday 07:00–08:00 and 19:00–23:00; Saturday 07:00–23:00 (excluding public holidays);
- F3 (off-peak): Monday–Saturday 23:00–07:00; all day on Sundays and public holidays.

This procedure yields, for every month, not only total consumption per POD but also its distribution across the main daily time windows.

To reconstruct hourly demand for each day of each month, the energy values measured in bands F1, F2, and F3 were kept separate. For a given month, each band's monthly total was divided by the number of days in that month and then uniformly distributed over the hours belonging to that band's definition on each day. In the absence of higher-resolution metering from the DSO, this approach produces a continuous, flat profile within each band while preserving the monthly and band-specific energy balances.

The monthly consumptions for all municipal PODs in La Salle and an illustrative hourly breakdown for January are reported below.

Table 65 . F1 – F2 – F3 consumptions for all months of all municipality's PODs of La Salle

Municipality of La Salle				
Month	F1	F2	F3	Total
January	10.137,00	5.351,00	11.321,00	26.809,00
February	8.507,00	5.131,00	9.339,00	22.977,00

March	7.172,00	4.521,00	8.609,00	20.302,00
April	5.995,00	3.300,00	6.721,00	16.016,00
May	5.440,00	2.692,00	4.949,00	13.081,00
June	2.742,00	1.874,00	3.186,00	7.802,00
July	2.358,00	1.661,00	2.682,00	6.701,00
Augost	3.184,00	2.436,00	3.540,00	9.160,00
September	4.232,00	1.913,00	3.449,00	9.594,00
October	6.877,00	2.961,00	4.974,00	14.812,00
November	7.469,00	4.151,00	5.957,00	17.577,00
Dicember	8.537,00	5.132,00	11.431,00	25.100,00
Total	72.650,00	41.123,00	76.158,00	189.931,00

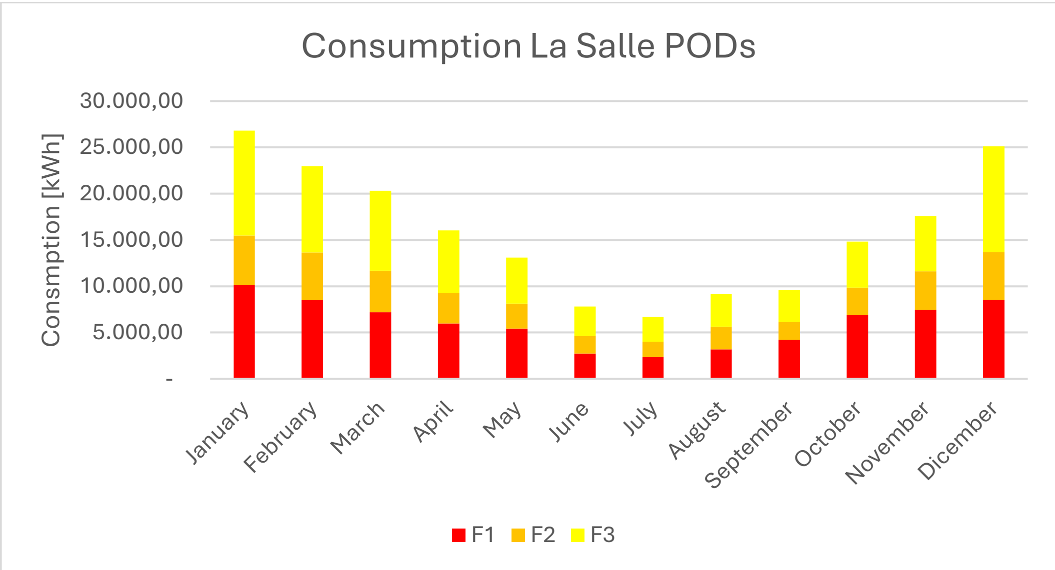

Figure 69 . Consumption Municipality Pods

Table 66 . Example of one day of January

January		
F3	0	45,65
	1	45,65
	2	45,65
	3	45,65
	4	45,65

	5	45,65
	6	45,65
F2	7	34,52
F1	8	29,73
	9	29,73
	10	29,73
	11	29,73
	12	29,73
	13	29,73
	14	29,73
	15	29,73
	16	29,73
	17	29,73
	18	29,73
F2	19	34,52
	20	34,52
	21	34,52
	22	34,52
F3	23	45,65

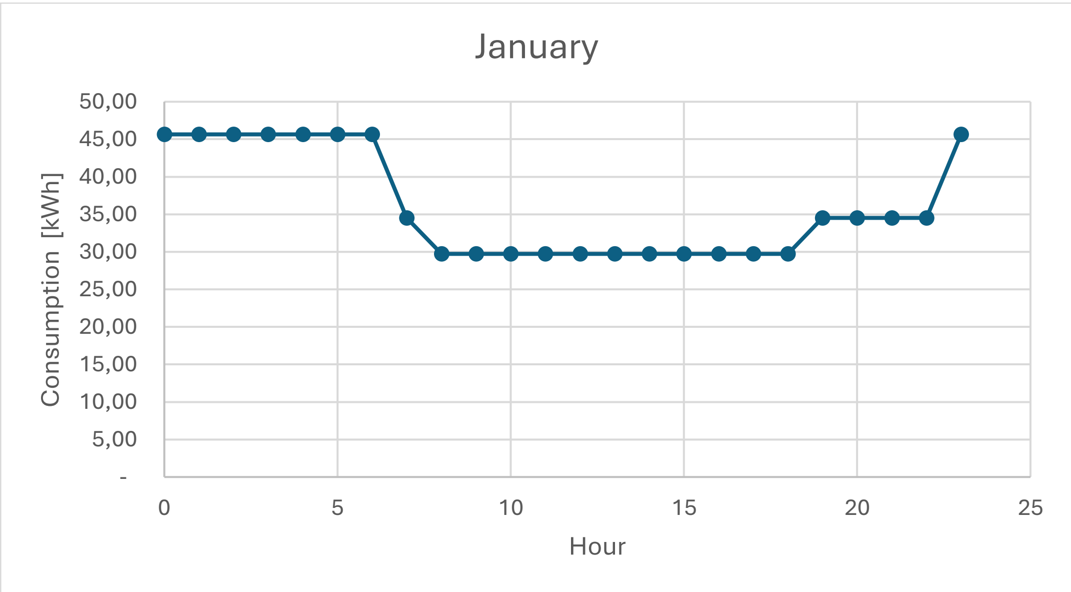

Figure 70 . Hourly consumption for Municipality Pods La Salle, Morgex - January

6.5. P.S.Didier

6.5.1. Primary residences

Using the ISTAT Data platform, the stock of primary dwelling units was compiled by aggregating those located in the municipalities intersecting the service area of the P.S. Didier primary substation, that includes the municipalities of Pré-Saint-Didier, La Thuile and the 20% of Courmayeur [22].

The resulting total amounts to 1.183 primary units. The same average annual per-unit consumption adopted for the Entrèves and the Morgex analysis was applied to derive the aggregate annual demand, that is 3.550.200 kWh.

For temporal disaggregation, the previously defined seasonal (monthly) weighting coefficients and the normalized daily hourly profile were used unchanged, ensuring full methodological consistency and direct comparability with the other substations' results. The resulting monthly allocations and an illustrative hourly distribution for a January day are reported below.

Table 67 . Seasonal wieghts and total consumption of all Primary residences – P.S. Didier

Month	Seasonal weights	Total consumption [kWh]
January	0,10	366.854,00
February	0,09	331.352,00
March	0,06	215.327,35
April	0,06	208.381,30
May	0,06	215.327,35
June	0,10	347.302,17
July	0,10	358.878,91
August	0,10	358.878,91
September	0,07	257.487,03
October	0,07	266.069,93
November	0,07	257.487,03
December	0,10	366.854,00

Table 68 . Monthly consumption af all primary residences and monthly consumption for one primary residence – P.SDidier

Month	Monthly consumption [kWh]	Monthly consumption for one house [kWh]
January	366.854,00	310,00
February	331.352,00	280,00

March	215.327,35	181,96
April	208.381,30	176,09
May	215.327,35	181,96
June	347.302,17	293,48
July	358.878,91	303,26
August	358.878,91	303,26
September	257.487,03	217,58
October	266.069,93	224,84
November	257.487,03	217,58
December	366.854,00	310,00
Total	3.550.200,00	3.000,00

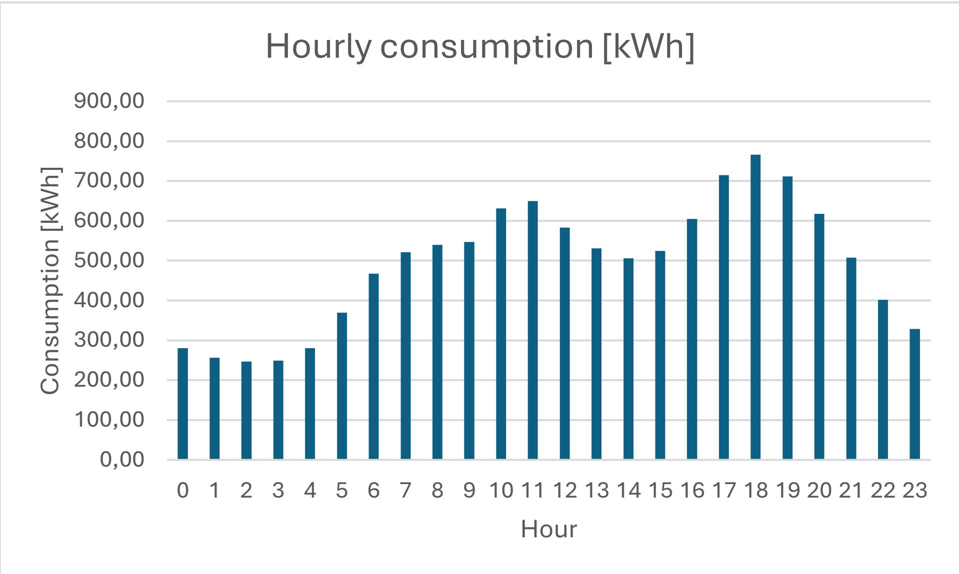

Figure 71 . Hourly consumption Primary residences P.S.Didier - January

Table 69 . Hourly Consumption of all primary residences – P.S.Didier

Hour	Hourly Consumption [kWh]
0	280,45
1	256,41
2	246,52
3	249,01
4	280,81

5	369,55
6	467,61
7	520,78
8	540,02
9	546,78
10	631,09
11	649,83
12	582,75
13	531,05
14	505,81
15	524,47
16	604,56
17	714,29
18	765,87
19	711,02
20	617,38
21	507,36
22	401,87
23	328,74

6.5.2. Second homes

Using the same ISTAT Data source and geospatial filtering procedure, the stock of secondary dwellings within the P.S. Didier substation's service area was identified and it is 6168 [22]. The annual electricity demand was estimated by applying the same per-unit benchmark employed for second homes in the Entrèves and Morgex analysis, resulting in 6.168.200 kWh.

Monthly values were then obtained with the same seasonal coefficients, and daily hourly profiles were assigned using the normalized vectors previously adopted. The corresponding monthly breakdowns and and example of daily distributions of January are presented in the following tables.

Table 70 . Monthly consumption of all Second homes and for one second home – P.S.Didier

Month	Monthly consumption [kWh]	Monthly consumption for one house[kWh]
January	1.171.958,00	190,00
February	1.048.594,00	170,00
March	71.551,12	11,60

April	71.551,12	11,60
May	71.551,12	11,60
June	493.456,00	80,00
July	925.230,00	150,00
August	925.230,00	150,00
September	71.551,12	11,60
October	71.551,12	11,60
November	71.551,12	11,60
December	1.171.958,00	190,00
Total	6.165.732,72	1.000

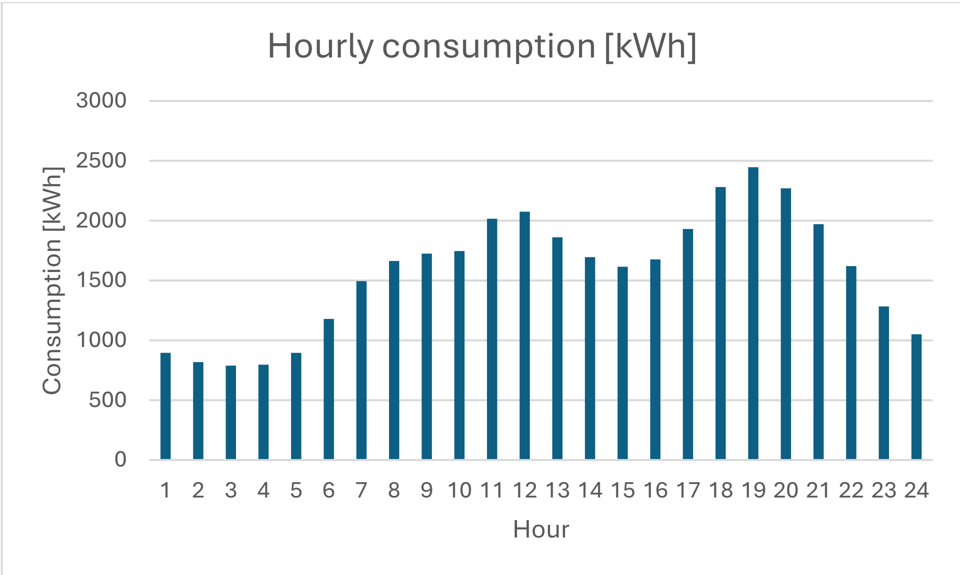

Figure 72 . Hourly consumption Second Homes - January

Table 71. Hourly Consumption of all second homes – P.S.Didier

Hour	Hourly Consumption [kWh]
0	895,93
1	819,14
2	787,53
3	795,48
4	897,09
5	1.180,58

6	1.493,82
7	1.663,68
8	1.725,15
9	1.746,76
10	2.016,08
11	2.075,94
12	1.861,66
13	1.696,50
14	1..615,88
15	1.675,49
16	1.931,32
17	2.281,87
18	2.446,65
19	2.271,43
20	1.972,31
21	1.620,81
22	1.283,81
23	1.050,18

6.5.3. Commercial and industrial activities

For the commercial and productive sector, the classification framework used for Entrèves and Morgex was replicated for the P.S. Didier service area, together with the same assumptions on average annual consumption by energy-intensity class and the same seasonal and daily coefficients [22].

The ISTATdata table of the commercial and industrial activities for the municipalities of Entréves and Morgex are reported below (20% of the total activity of Courmayeur were also considered.

Table 72 . Number of activites of Pré Saint Didier and La Thuile from ISTATdata

Indicator	Indicatore	[LU] Numero di unità locali delle imprese attive-Pré Saint Didier	[LU] Numero di unità locali delle imprese attive- La Thuile
	Attività economica (ATECO 2007)		
[0010] TOTAL	[0010] TOTALE	134	175
[C] Manufactu ring	[C] Attività manifatturiere	4	6

[D] Electricity, gas, steam and air-conditioning supply	[D] Fornitura di energia elettrica, gas, vapore e aria condizionata	4	3
[F] Construction	[F] Costruzioni	23	1
Wholesale and retail trade; repair of motor vehicles and motorcycles	[G] Commercio all'ingrosso e al dettaglio, riparazione di autoveicoli e motocicli	10	31
Transportation and storage	[H] Trasporto e magazzinaggio	3	16
Accommodation and food service activities	[I] Attività dei servizi di alloggio e di ristorazione	20	3
Information and communication services	[J] Servizi di informazione e comunicazione	1	56
Financial and insurance activities	[K] Attività finanziarie e assicurative	1	2
Real estate activities	[L] Attività immobiliari	5	11
Professional, scientific and technical activities	[M] Attività professionali, scientifiche e tecniche	17	13
Administrative and support service activities (including rental services and travel agencies)	[N] Noleggio, agenzie di viaggio, servizi di supporto alle imprese	13	21
[P] Education	[P] Istruzione	9	5
[Q] Human health and	[Q] Sanità e assistenza sociale	6	3

social work activities			
[R] Arts, entertainment and recreation	[R] Attività artistiche, sportive, di intrattenimento e divertimento	10	2
[S] Other service activities	[S] Altre attività di servizi	8	2

Establishments were inventoried and georeferenced to confirm inclusion within the substation's boundaries and then the total consumption was calculated, and it is of 26.690.000 kWh.

On this basis, the aggregate annual demand was computed and subsequently distributed across months and hours according to the established methodology. The resulting monthly averages and an illustrative January daily profile are shown below.

Table 73 . Monthly consumption for all second homes and one second home – P.S.Didier

Month	Monthly consumption [kWh]	Monthly consumption for one house [kWh
January	1.868.300,00	4.275,29
February	1.868.300,00	4.275,29
March	2.135.200,00	4.886,04
April	2.402.100,00	5.496,80
May	2.402.100,00	5.496,80
June	2.669.000,00	6.107,55
July	2.669.000,00	6.107,55
August	1.601.400,00	3.664,53
September	2.402.100,00	5.496,80
October	2.135.200,00	4.886,04
November	2.135.200,00	4.886,04
December	2.402.100,00	5.496,80
Totale	26.690.000,00	61.075,51

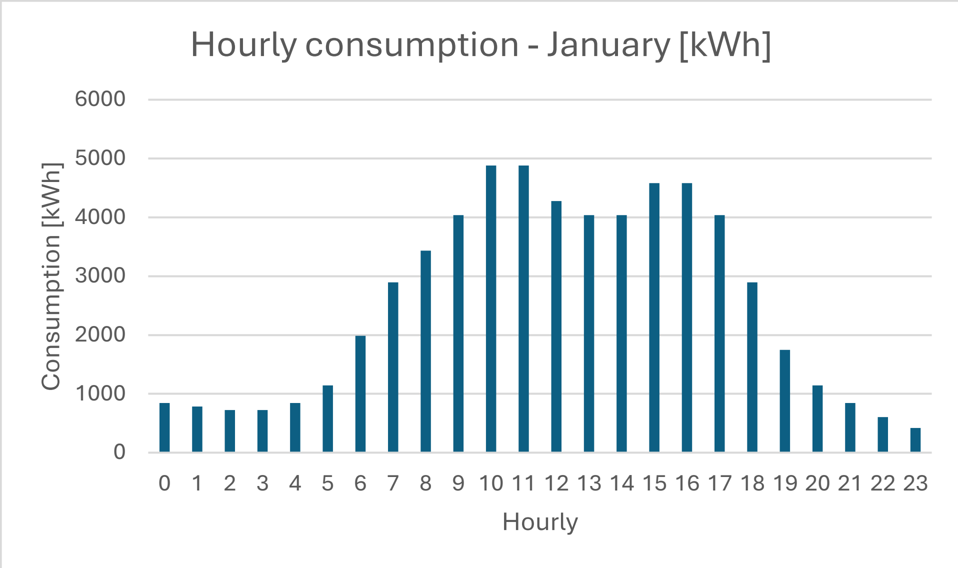

Figure 73 . Hourly consumption Activites - January

Table 74 . Hourly Consumption of all second homes- P.S.Didier

Hour	Hourly Consumption [kWh]
0	843,75
1	783,48
2	723,21
3	723,21
4	843,75
5	1.145,09
6	1.988,84
7	2.892,85
8	3.435,26
9	4.037,94
10	4.881,69
11	4.881,69
12	4.279,01
13	4.037,94
14	4.037,94
15	4.580,35

16	4.580,35
17	4.037,94
18	2.892,85
19	1.747,76
20	1.145,09
21	843,75
22	602,68
23	421,87

6.5.4. Hotel and B&Bs

The hospitality inventory for the P.S. Didier catchment was compiled with the same star-based approach used for Entrèves and Morgex. Each facility identified through web and official tourism sources was geolocated (see QGIS figure) and retained only within the substation's service perimeter [26][31][32].

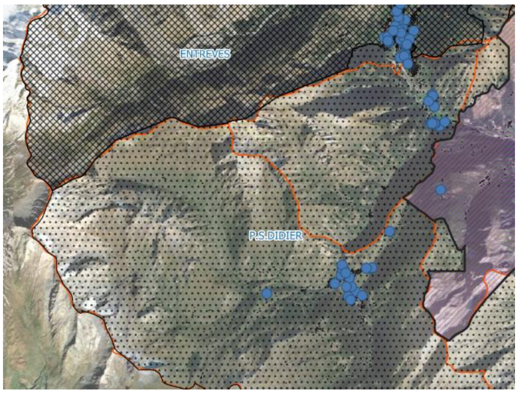

Figure 74 . Hotels in P.S.Didier imported in Qgis

Room counts were then aggregated by star category

- 199 rooms in 2-star hotels and B&BS [26][31][32];
- 383 rooms in 3-star hotels [26][31][32];
- 660 rooms in 4-star hotels [26][31][32];
- 135 rooms in 5-star hotels[26][31][32].

Applying the category specific benchmarks yields the following annual electricity demands:

- 995.000 kWh for 2-star/B&B facilities;
- 2.681,000 kWh for 3-star facilities;
- 5.940.000 kWh for 4-star facilities;
- 1.485.000 kWh for 5-star facilities.

As with the other categories, monthly consumptions were derived using the established seasonal coefficients, and an illustrative hourly distribution for a January day for the 2 star hotels is provided below.

Table 75 . Monthly consumption 2 stars hotels – P.S.Didier

Month	Monthly consumption [kWh]
January	2.109.190,00
February	1.887.170,00
March	128.771,60
April	128.771,60
May	128.771,60
June	888.080,00
July	1.665.150,00
August	1.665.150,00
September	128.771,60
October	128.771,60
November	128.771,60
December	2.109.190,00

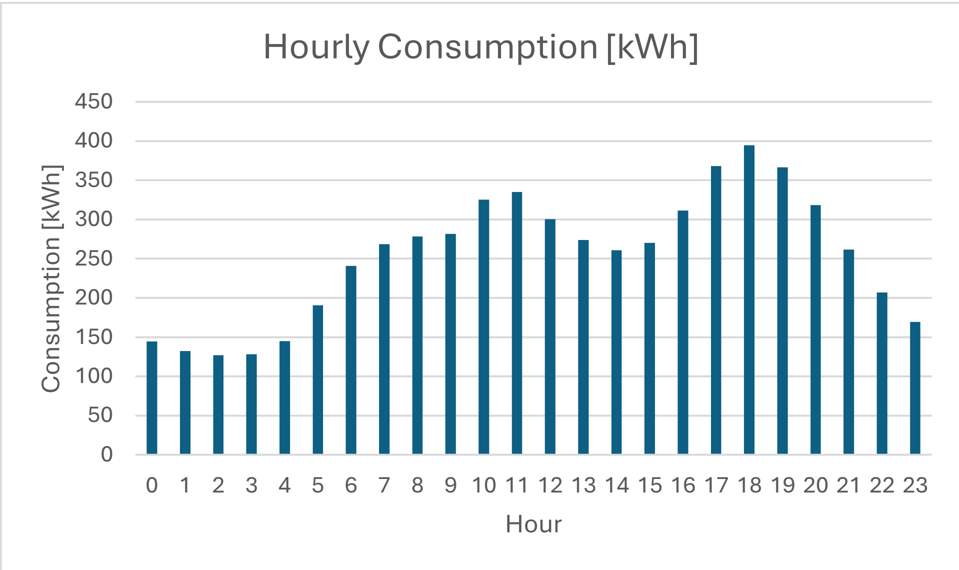

Figure 75 . Hourly consumption Hotels P.S.Didier - January

Table 76 . Hourly Consumption of all 2 stars hotels in January – P.S. Didier

Hour	Hourly Consumption [kWh]
0	144,52
1	132,14
2	127,04
3	128,32
4	144,71
5	190,44
6	240,97
7	268,37
8	278,29
9	281,77
10	325,22
11	334,87
12	300,31
13	273,66
14	260,66
15	270,28
16	311,54
17	368,09
18	394,67
19	366,41
20	318,16
21	261,45
22	207,09
23	169,41

6.5.5. Ski lifts, cableways, and related mountain facilities

Within the primary substation's service area lies the La Thuile ski area, whose annual electricity consumption was obtained from its 2023–2024 financial statements. The total annual demand amounts to 5,357,869.00 kWh [33].

For the monthly allocation, the same seasonal (monthly) weighting scheme adopted for the Courmayeur lifts was applied. Likewise, the same snowmaking shares and mixed uplift–snowmaking daily profiles used for November, December, and January were retained. The resulting monthly consumptions, together with an illustrative hourly distribution for a January day, are reported below.

Table 77. La Thuile ski area's monthly consumption and percentage

Month	Monthly Consumption [kWh]	Monthly Percentage
October	102.467,43	2%
November	1.158.225,89	22%
Dicember	1.133.104,20	21%
January	922.654,52	17%
February	691.188,06	13%
March	588.801,78	11%
April	241.207,47	5%
May	107.426,66	2%
June	92.776,36	2%
July	122.106,40	2%
Augost	119.448,87	2%
September	78.461,36	1%

Table 78 . Hourly consumption La Thuile sky area in January

Hour	Hourly Consumption [kWh]
0	198,22
1	198,22
2	198,22
3	198,22
4	198,22
5	198,22
6	198,22
7	198,22
8	198,22
9	2.009,01

10	3.214,41
11	4.018,01
12	2.946,54
13	3.214,41
14	3.482,28
15	3.214,41
16	2.678,67
17	2.009,01
18	198,22
19	198,22
20	198,22
21	198,22
22	198,22
23	198,22

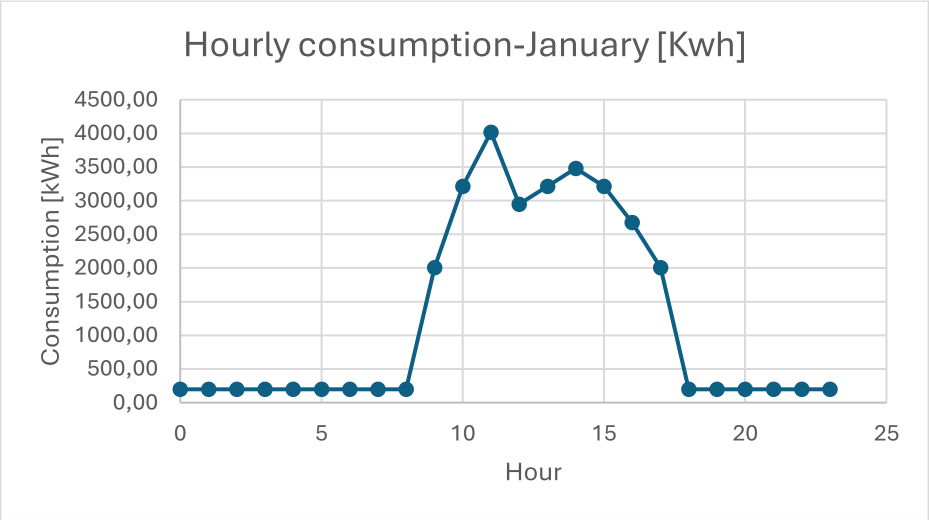

Figure 76 . Hourly consumption Ski area La Thuile - January

6.5.6. Municipal electricity consumption

The same analytical procedure described previously for the primary substation of Morgex, was replicated here. Regarding data availability:

- the Municipality of Pré-Saint-Didier supplied complete bills for every POD;
- La Thuile provided bills only for public-lighting PODs;
- Courmayeur did not provide any data.

The results, monthly distributions and an illustrative January daily profile for the municipalities of Pré-Saint-Didier

Table 79 . F1 -F2- F3 subdivision of all municipalities PODs of Pré Saint Didier

Prés Saint Didier				
Month	F1	F2	F3	Total
January	5.700,00	3.218,00	6.296,00	15.214,00
February	4.621,00	2.977,00	4.571,00	12.169,00
March	3.965,00	2.860,00	4.699,00	11.524,00
April	3.380,00	2.071,00	3.975,00	9.426,00
May	3.344,00	1.735,00	3.257,00	8.336,00
June	2.526,00	1.714,00	3.115,00	7.355,00
July	3.181,00	2.016,00	3.131,00	8.328,00
Augost	3.359,00	2.431,00	3.610,00	9.400,00
September	3.548,00	2.176,00	3.858,00	9.582,00
October	4.358,00	2.246,00	3.670,00	10.274,00
November	4.750,00	2.946,00	4.725,00	12.421,00
Dicember	5.802,00	3.800,00	7.750,00	17.352,00
Total	48.534,00	30.190,00	52.657,00	131.381,00

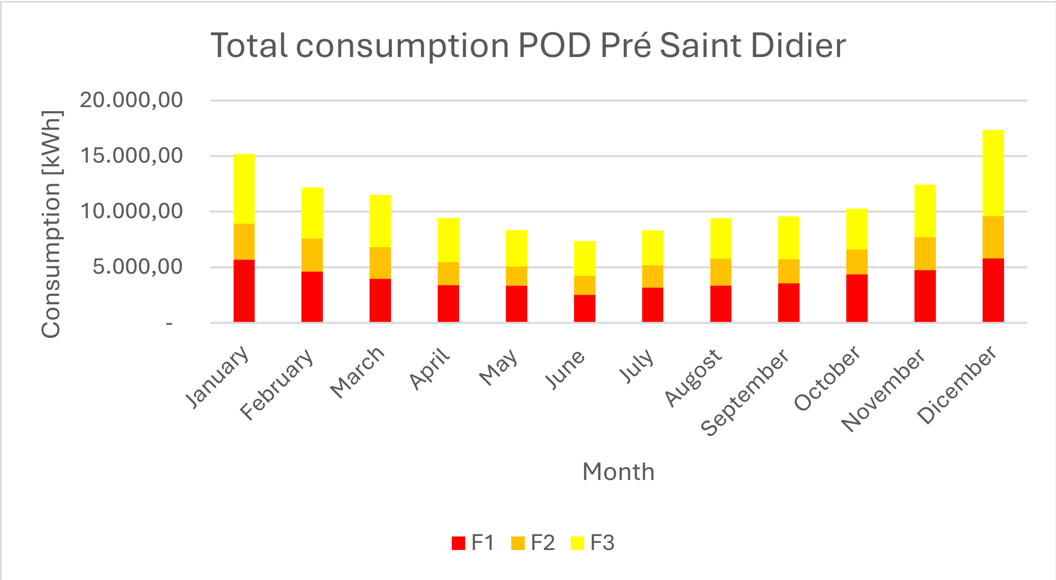

Figure 77 . Total consumption POD Pré Saint Didier

Table 80 . Hourly consumption of all municipality of prè Saint Didier PODs

January		
F3	0	25,39
	1	25,39
	2	25,39
	3	25,39
	4	25,39
	5	25,39
	6	25,39
F2	7	20,76
F1	8	16,72
	9	16,72
	10	16,72
	11	16,72
	12	16,72
	13	16,72
	14	16,72
	15	16,72
	16	16,72
	17	16,72
	18	16,72
F2	19	20,76
	20	20,76
	21	20,76
	22	20,76
F3	23	25,39

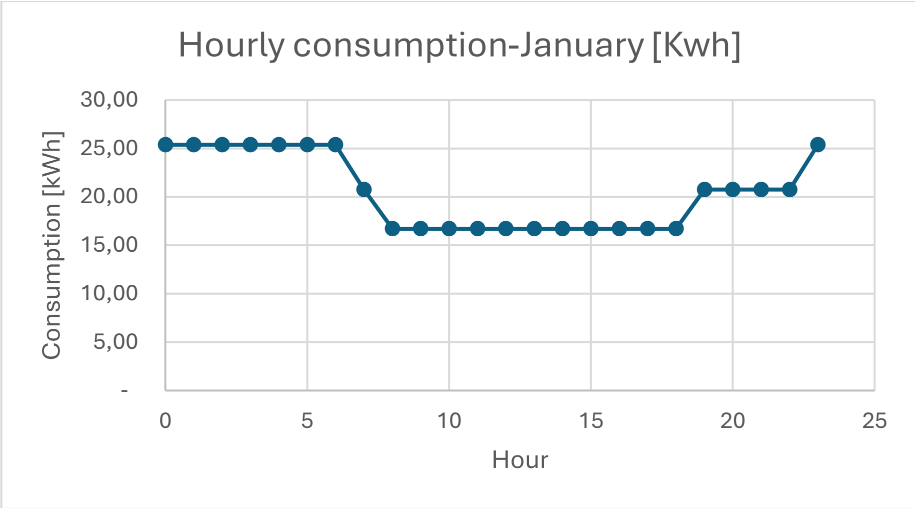

Figure 78 . Hourly Consumption Municipality PODs - January

6.6. Total results

It is important to present the overall results of this section, providing a comprehensive summary of the calculations carried out in this chapter.

The following tables report, for each primary substation:

- The number of buildings by category
- The total annual load for each building category, as well as the overall annual load for each primary substation.

Table 81. Number of buildings - Entréves

Entréves	
Category of building	Number
Primary residences	1.082,00
Second homes	4.289,00
High energy activites	345,00
Low energy activites	297,00
Hotels	37,00

Table 82 . Annual consumption for each category of building - Entréves

Entréves	
Category of building	Consumption [kWh]
Primary residences	3.244.800,00
Second homes	4.288.800,00
Activites	29.976.000,00
Hotels	7.456.000,00
Courmayer ski area	6.008.002,00
Skywat-y	2.845.000,00
Total	53.818.602,00

Table 83 . Number of buildings - Morgex

Morgex	
Category of building	Number
Primary residences	1.989,00
Second homes	4.935,00
High energy activites	257,00
Low energy activites	187,00
Hotels	27,00

Table 84 . Annual consumption for each category of building - Morgex

Morgex	
Category	Consumption [kWh]
Primary residences	5.967.000,00
Second homes	4.935.000,00
Activites	27.570.000,00
Hotels	1.171.000,00
Municipality Pods	189.931,00
Total	39.643.000,00

Table 85 . Number of buildings - P.S.Didier

P.S.Didier	
Category of building	Number
Primary residences	1.183,00
Second homes	6.168,00
High energy activites	248,00
Low energy activites	189,00
Hotels	27,00

Table 86 . Annual consumption for each category of building – P.S.Didier

P.S.Didier	
Category	Consumption [kWh]
Primary residences	3.550.200,00
Second homes	6.168.200,00
Activites	26.694.000,00
Hotels	11.101.000,00
Municipality Pods	131.381,00
Sky area La Thuile	5.357.869,00
Total	47.644.781,00

7. Comparison of Production and Consumption per Primary Substation

In this chapter, all contributions of potential electricity generation and estimated consumption are aggregated for each primary substation, based on the calculations developed in the preceding chapters. This step is essential to evaluate the overall technical feasibility of the project, by determining whether the total available rooftop and parking surfaces are sufficient to cover the demand within each substation perimeter.

In this chapter, the total load of all meters served by the same substation is compared with the potential PV output, id est, the energy that could be generated by photovoltaic systems installed on all suitable rooftops and in the selected parking areas.

Although in practice only a subset of buildings and households will eventually participate in the Renewable Energy Community (either as prosumers or as consumers), this aggregated balance provides a comprehensive upper-bound assessment of the local potential. It allows to verify whether, at the territorial scale, the Valdigne has enough distributed photovoltaic capacity to sustain its own demand.

The analysis therefore serves as a bridge between the technical dimension and the subsequent economic evaluation. By establishing whether local renewable resources can theoretically meet the load profiles reconstructed for Entrèves, Pré-Saint-Didier, and Morgex, the study clarifies the margins of self-sufficiency achievable under optimal deployment. In the following economic chapter, a more selective scenario will be introduced, focusing on the actual subset of surfaces and members expected to join the REC.

The match between generation and demand is evaluated on an hourly basis and summarized monthly. Hourly resolution is essential because it captures intraday variability and the frequent mismatch between solar production and demand, revealing hours of surplus or deficit.

Furthermore, the comparison highlights critical issues such as seasonal mismatches between photovoltaic production and tourism-driven demand peaks, the potential role of storage in balancing evening loads, and the importance of designing communities within regulatory substation boundaries. These elements are crucial in translating the physical availability of resources into a realistic and resilient REC configuration for the Valdigne.

7.1. Entréves

As illustrated by the monthly daily profiles, the Entrèves substation area shows a marked seasonal asymmetry between photovoltaic generation and local energy demand. During the winter months, particularly November, December, January, and February, production is insufficient to cover the pronounced electricity needs, even at midday when solar output peaks. This reflects both the natural reduction of solar irradiation in alpine valleys during winter and the sharp increase in demand associated with tourism, accommodation facilities, and ski infrastructure.

By contrast, in spring, summer, and early autumn, photovoltaic generation frequently exceeds local demand during the central hours of the day. The strong alignment between summer production peaks and the higher occupancy of second homes and hospitality facilities further improves the share of electricity that can be absorbed locally.

The total consumption and production are shown in the graph and table below.

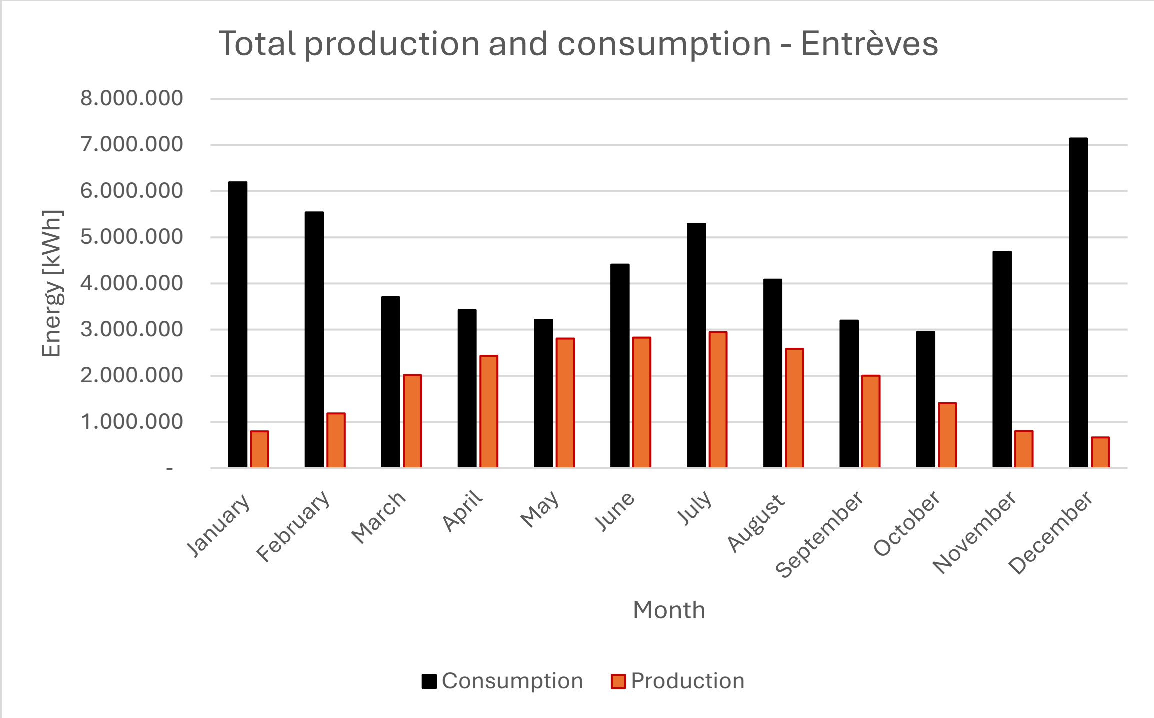

Figure 79 . Total production and consumption entire year - Entréves

Table 87 . Consumption, Production, and energy requested - Entréves

Month	Consumption [kWh]	Production [kWh]	Production/Consumption	Energy requested [kWh]
January	6.189.664	798.234	13%	5.391.430
February	5.539.859	1.185.969	21%	4.353.890
March	3.704.022	2.019.940	55%	1.684.082
April	3.423.091	2.434.669	71%	988.423
May	3.208.389	2.808.471	88%	399.918
June	4.407.908	2.828.960	64%	1.578.947
July	5.289.088	2.947.976	56%	2.341.112
August	4.085.657	2.589.293	63%	1.496.364
September	3.199.061	2.003.323	63%	1.195.738
October	2.946.812	1.410.332	48%	1.536.480
November	4.683.436	807.248	17%	3.876.188
December	7.136.917	669.162	9%	6.467.756

As the graphs indicate, the influence of the ski areas means that, at the monthly scale, consumption remains higher than production.

The seasonal variability does not constitute a weakness but rather a structural feature that can be leveraged by the community. In periods of surplus, excess electricity strengthens the pool of shared energy and ensures tangible economic returns for all members. In periods of scarcity, the cooperative structure enables a transparent and equitable allocation of resources, while also reinforcing members' awareness of their collective progress toward energy independence.

In addition, the composition of the local load (combining residential users with a high concentration of accommodation facilities and ski-related infrastructure) creates a diversified demand profile that enhances the value of local generation. Households tend to absorb energy in the evening hours, while hotels and services sustain steady daytime demand, ensuring that a substantial fraction of solar production is immediately consumed within the substation perimeter.

Taken together, these elements indicate that the Entrèves substation area, despite its winter deficits, offers a solid technical and economic foundation for the establishment of a Renewable Energy Community. Seasonal surpluses, diversified demand, and the visibility of production sites such as public roofs, hotels, and ski facilities make it an ideal candidate for mobilizing local participation and building long-term confidence in the REC model.

In the following graphs total hourly production and total hourly consumption are compared for every month for the substation of Entréves. The monthly profile of hourly production versus consumption at the Entrèves substation indicates that, during peak hours from March through November, generation frequently surpasses load. This supports the feasibility of establishing an energy community (CER).

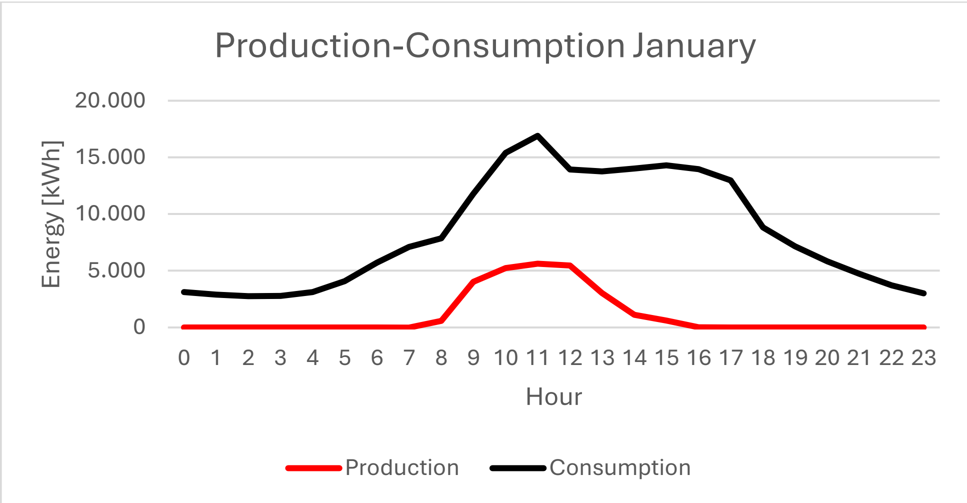

Figure 80 . Hourly production-consumption January - Entréves

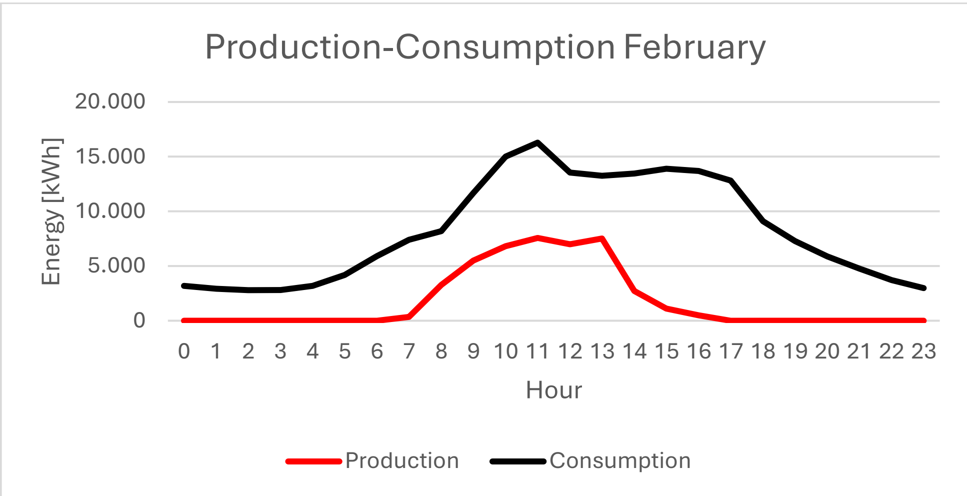

Figure 81 . Hourly production-consumption February - Entréves

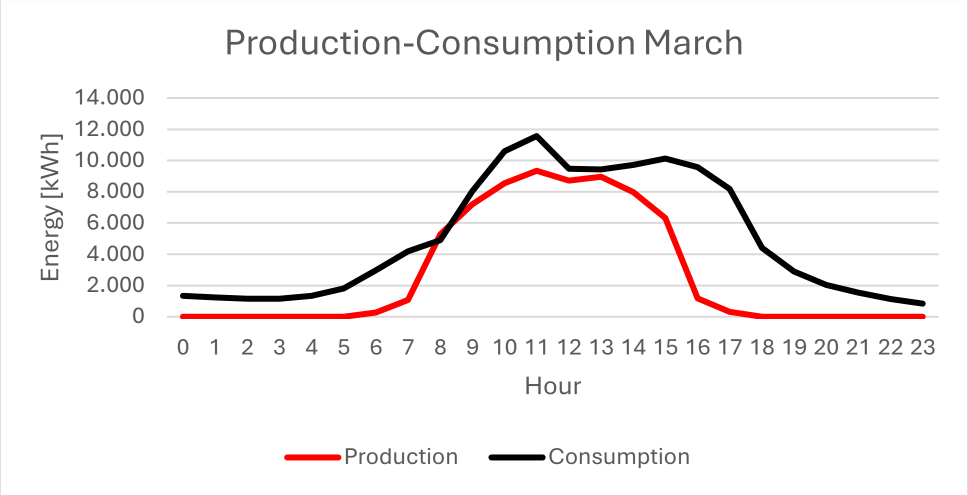

Figure 82 . Hourly production-consumption March - Entréves

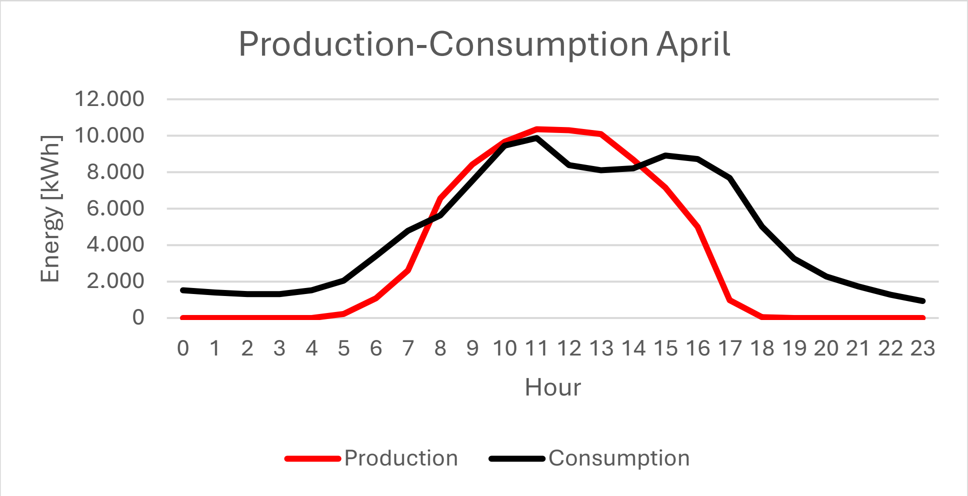

Figure 83 .Hourly production-consumption April - Entréves

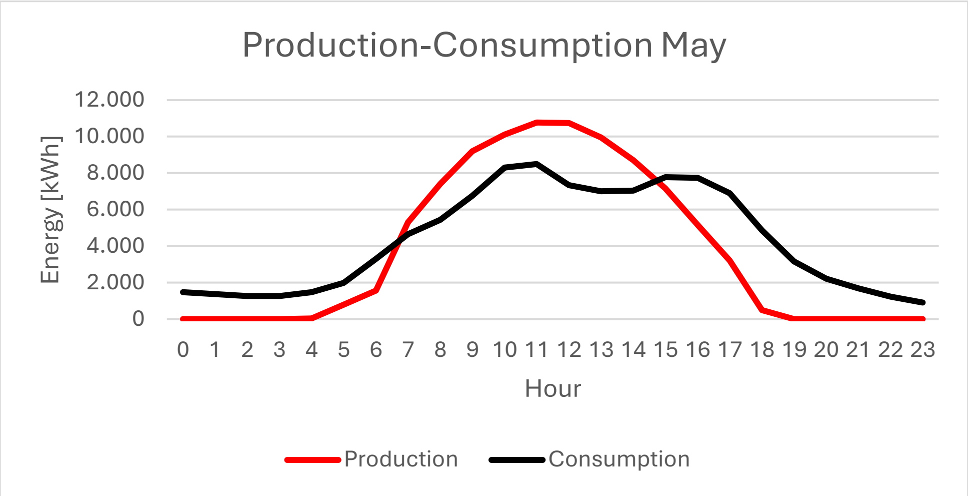

Figure 84 . Hourly production-consumption May - Entréves

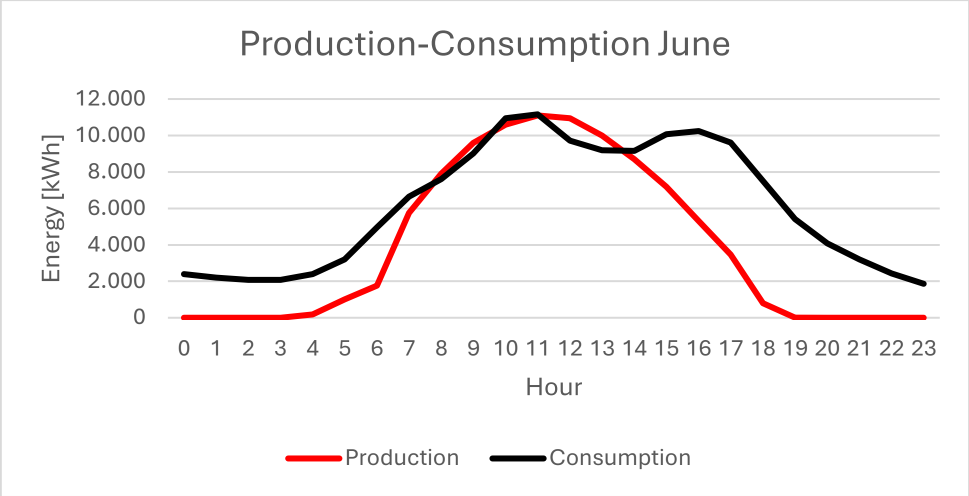

Figure 85 . Hourly production-consumption June - Entréves

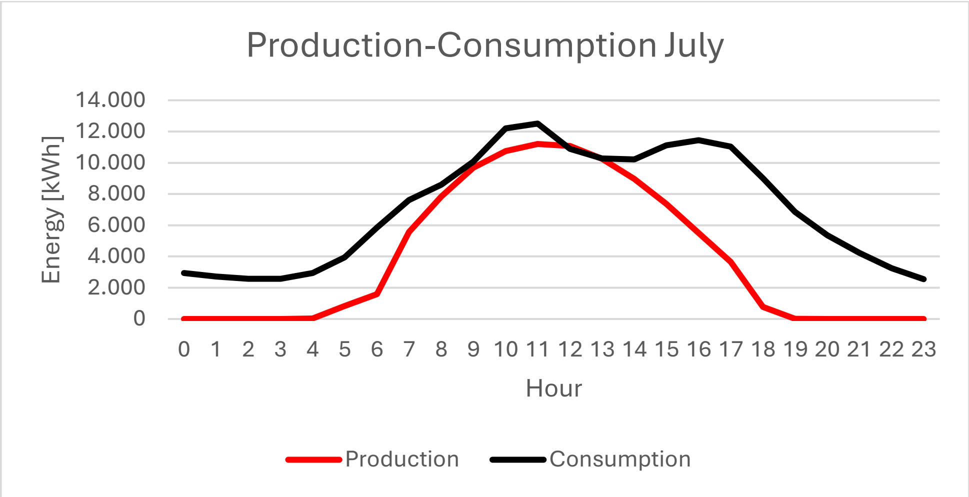

Figure 86 . Hourly production-consumption July - Entréves

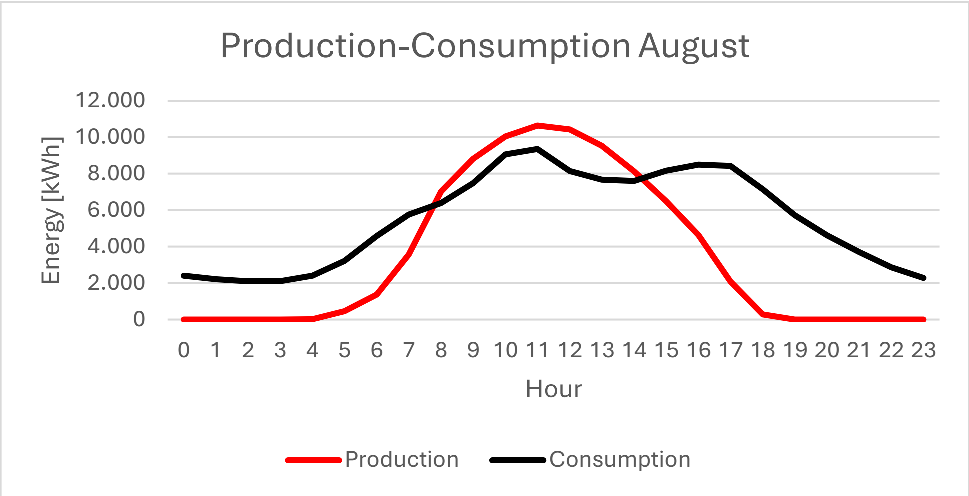

Figure 87 . Hourly production-consumption August - Entréves

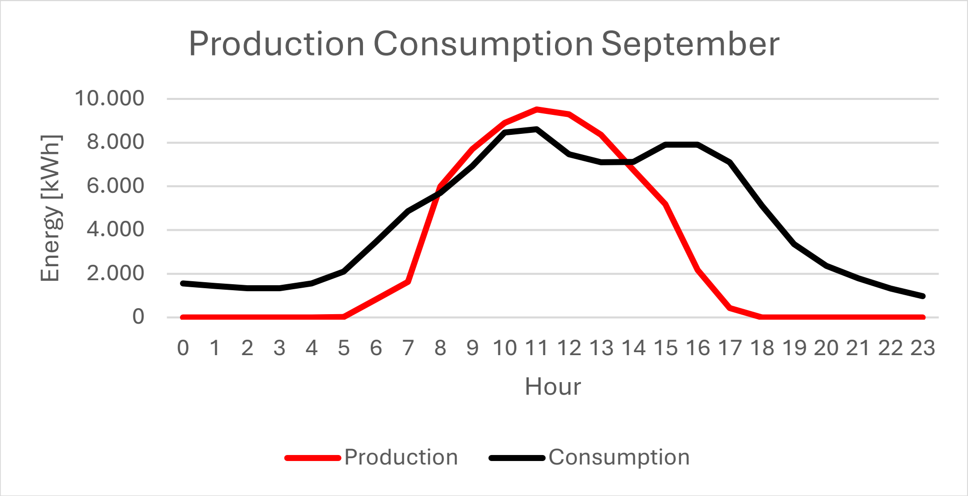

Figure 88 . Hourly production-consumption September - Entréves

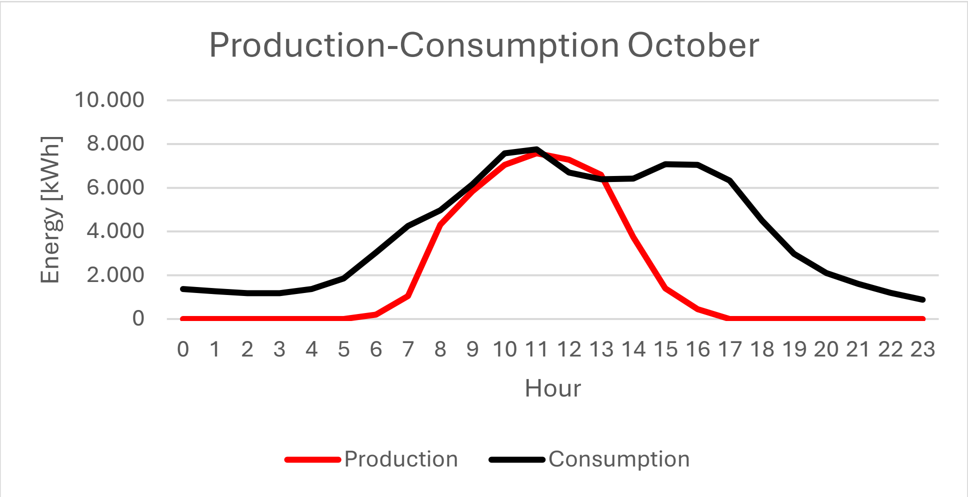

Figure 89 . Hourly production-consumption October - Entréves

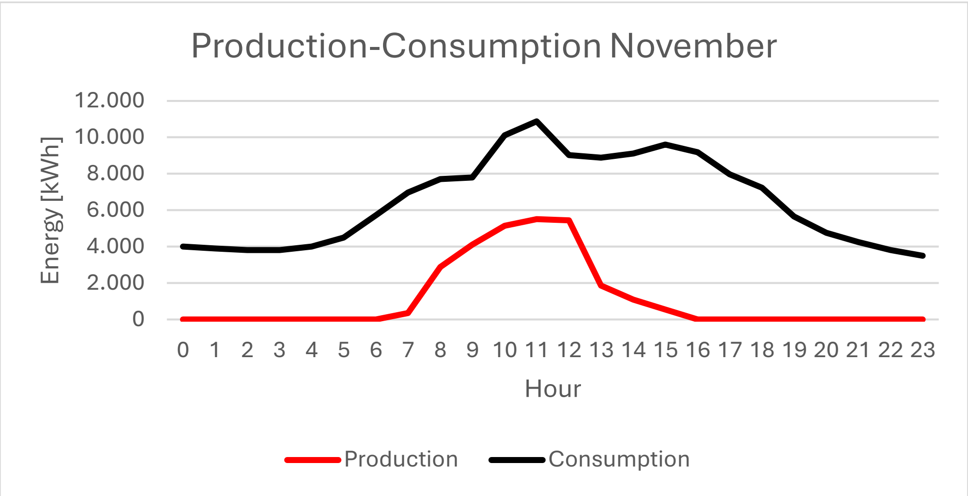

Figure 90 . Hourly production-consumption November - Entréves

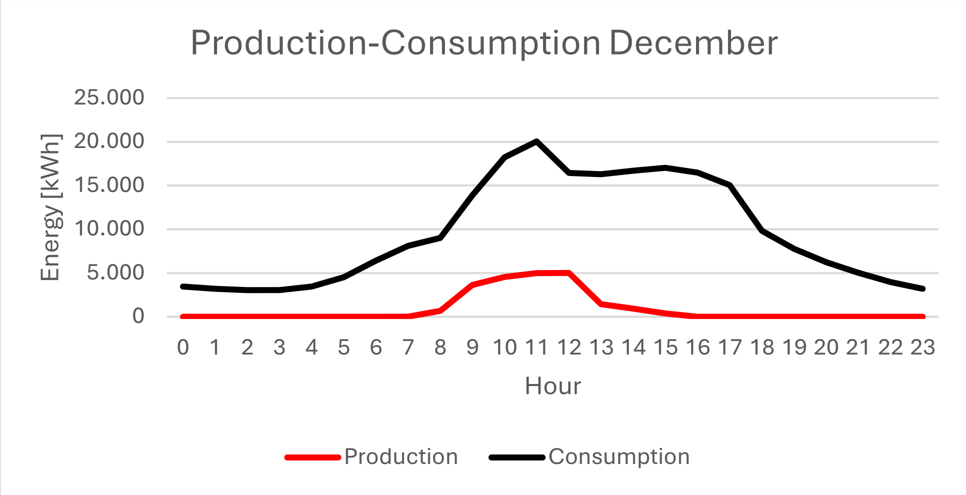

Figure 91 . Hourly production-consumption December - Entréves

7.2. Morgex

The Morgex substation area exhibits the most favorable balance between photovoltaic generation and local demand among the three substations considered. The absence of ski domains and large-scale tourism infrastructures keeps electricity consumption comparatively modest, while the prevalence of primary residences provides a stable, year-round load. Commercial activities are less and generally less energy-intensive, which further reduces seasonal volatility in the demand curve.

From a production perspective, Morgex substation area benefits from a wider availability of usable rooftop surfaces, enabling a photovoltaic potential higher than both Entrèves and P.S. Didier ones. This abundant capacity, when compared with the moderate demand, results in a strong alignment between generation and consumption.

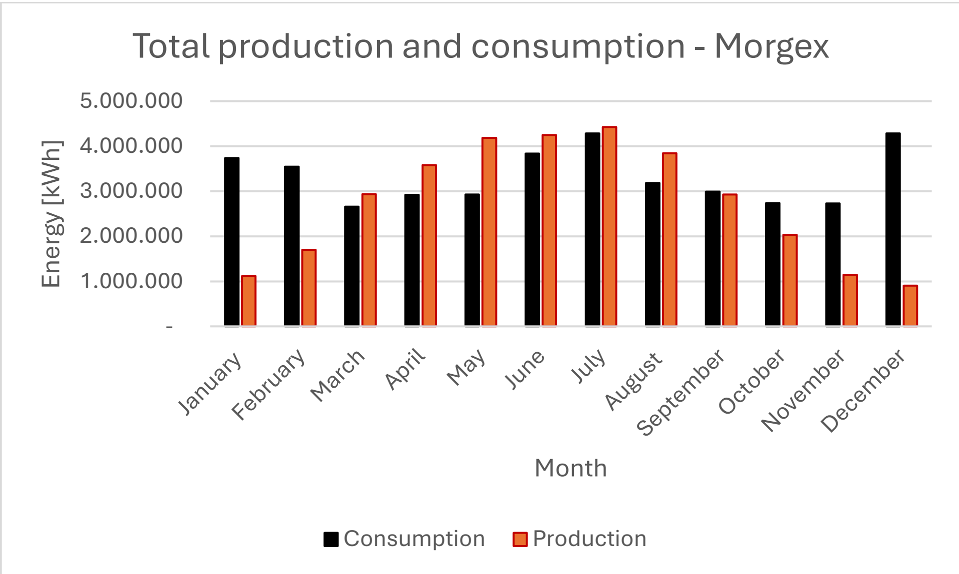

Figure 92 . Total production and consumption - Morgex

Table 88 . Total consumption, production and energy requested - Morgex

Month	Consumption [kWh]	Production [kWh]	Production/Consumption	Energy requested [kWh]
January	3.733.439	1.116.632	30%	2.616.807
February	3.547.817	1.699.118	48%	1.848.699
March	2.658.643	2.934.544	110%	- 275.901
April	2.918.383	3.581.625	123%	- 663.242
May	2.927.122	4.185.332	143%	- 1.258.210
June	3.837.010	4.245.414	111%	- 408.404
July	4.282.787	4.422.018	103%	- 139.231
August	3.182.446	3.842.578	121%	- 660.132
September	2.994.495	2.927.307	98%	67.188
October	2.738.439	2.030.225	74%	708.213
November	2.726.778	1.144.478	42%	1.582.300
December	4.283.130	905.308	21%	3.377.822

As can be seen, n contrary of what happen in entréves substation, the absebce of ski area consent to have higher total production on monthly basis in the months from march to august.

Only in December, the potential photovoltaic output fails to match the peak daily total energy demand, leaving part of the load uncovered even at midday. In January and November, the peak production hours are just sufficient to meet consumption, but the balance remains tight. In all other months, however, generation comfortably exceeds demand throughout most of the day.

Surpluses become particularly abundant from April through August, when solar irradiation is strongest: in these months, production is roughly double the local consumption, creating a significant pool of excess energy that a Renewable Energy Community could valorize. This condition ensures very high levels of self-consumption, complemented by substantial volumes of shared energy that translate into economic benefits under the incentive framework.

Altogether, Morgex combines a relatively low and stable demand profile with the highest production potential in the Valdigne. Its ability to cover nearly all local needs across the year, except for the most demanding winter month, and to generate large seasonal surpluses positions it as the most technically self-sufficient substation and a key asset for the feasibility of a Renewable Energy Community in the valley.

In the following graphs total hourly production and total hourly consumption are compared for every month for the substation of Morgex. The monthly profile of hourly production versus consumption at the Entrèves substation indicates that, during peak hours from February through November, generation frequently surpasses load (it doubles it from March to September). This highly supports the feasibility of establishing an energy community (CER).

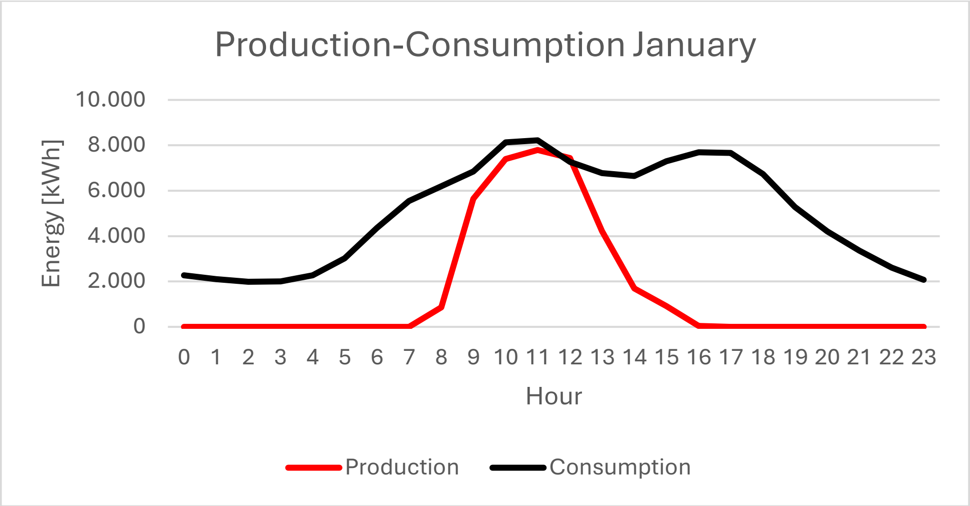

Figure 89 . Hourly production-consumption Januray - Morgex

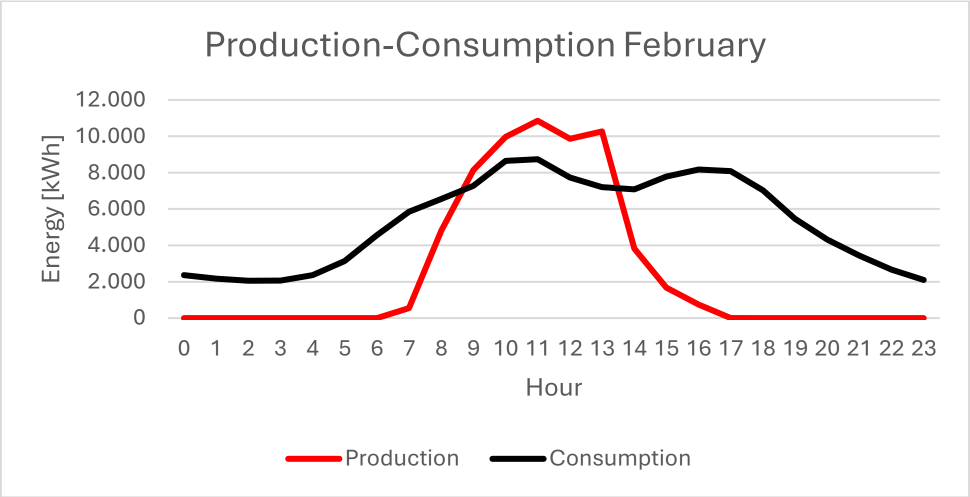

Figure 90 . Hourly production-consumption February - Morgex

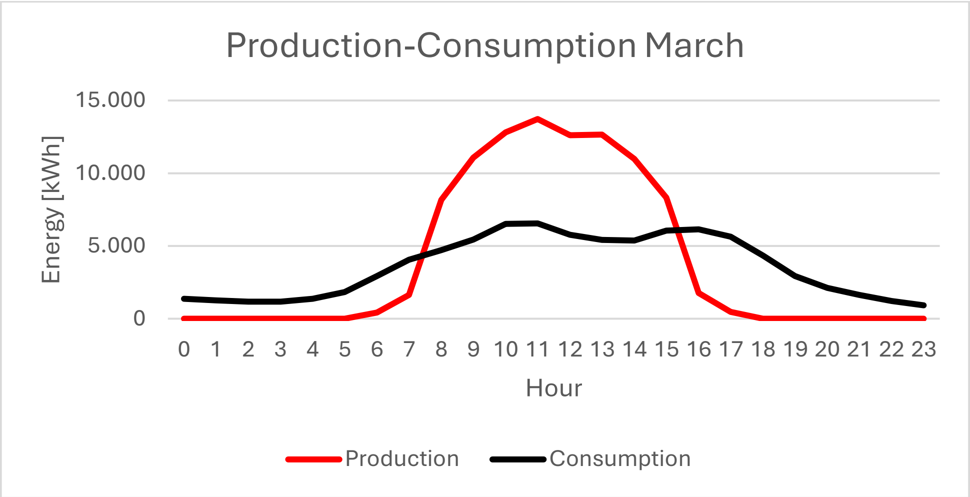

Figure 91 . Hourly production-consumption March - Morgex

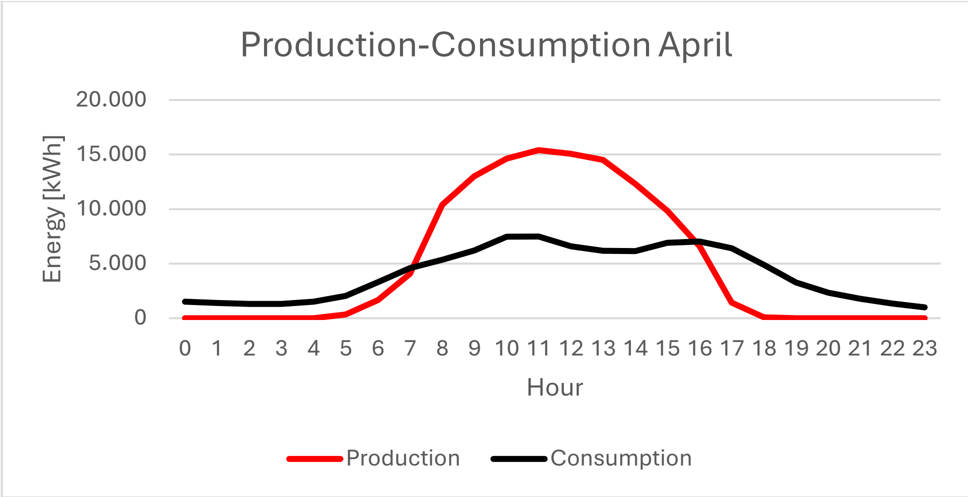

Figure 92 . . Hourly production-consumption April - Morgex

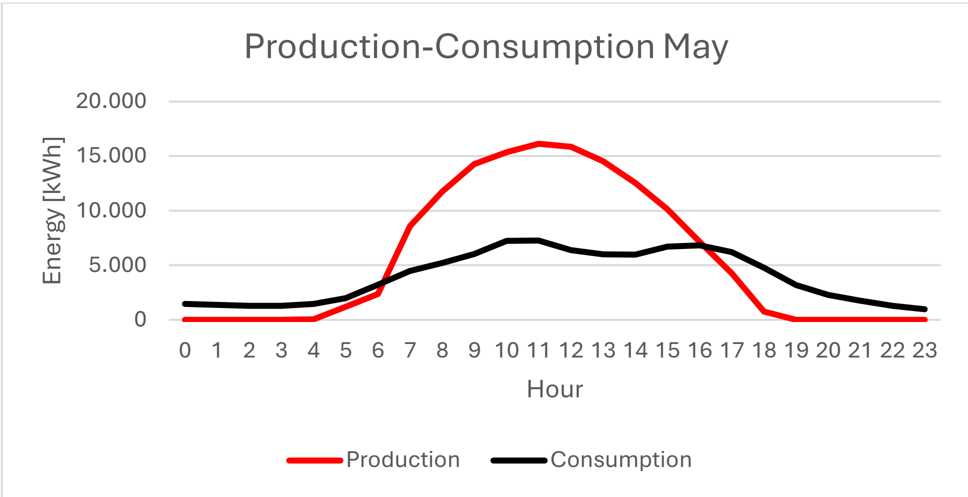

Figure 93 . Hourly production-consumption May - Morgex

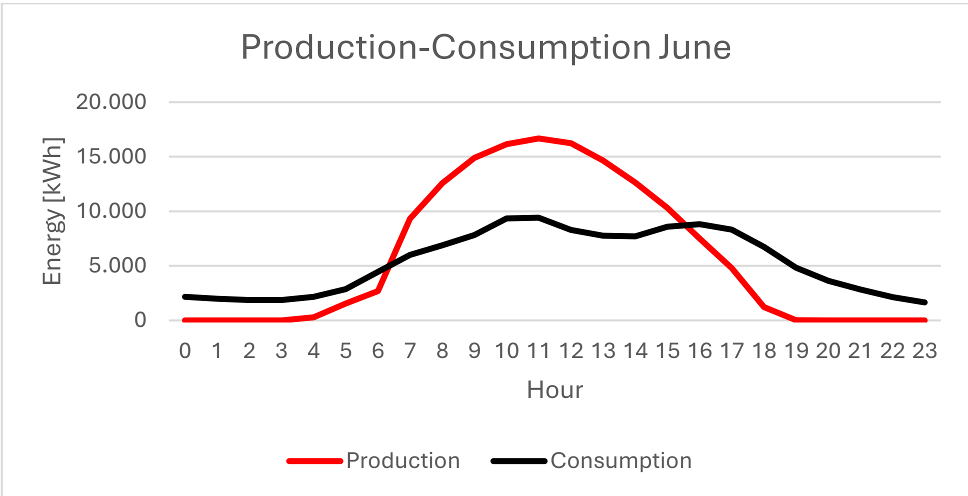

Figure 94 . Hourly production-consumption June - Morgex

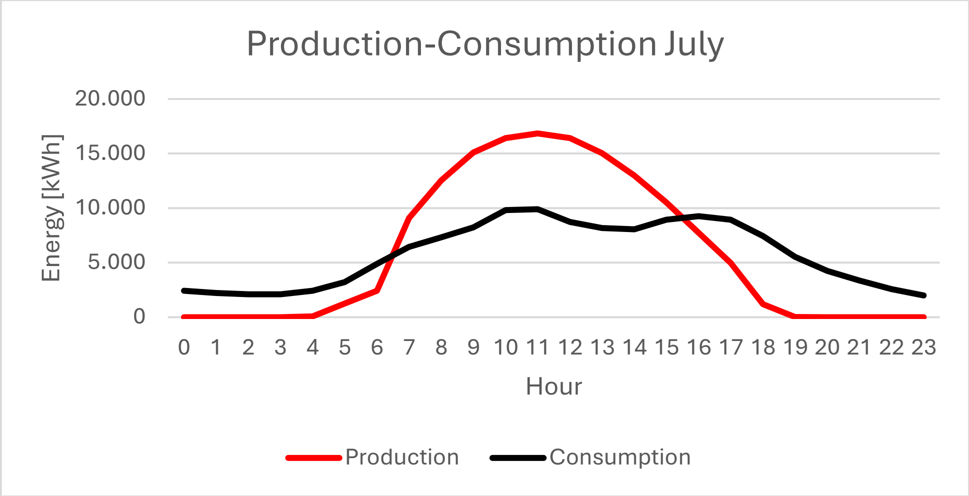

Figure 95 . Hourly production-consumption July - Morgex

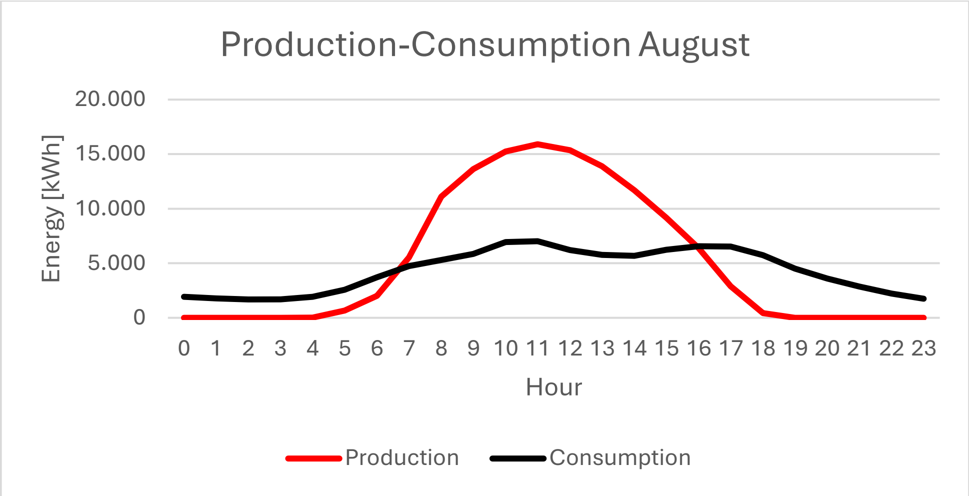

Figure 96 . Hourly production-consumption August - Morgex

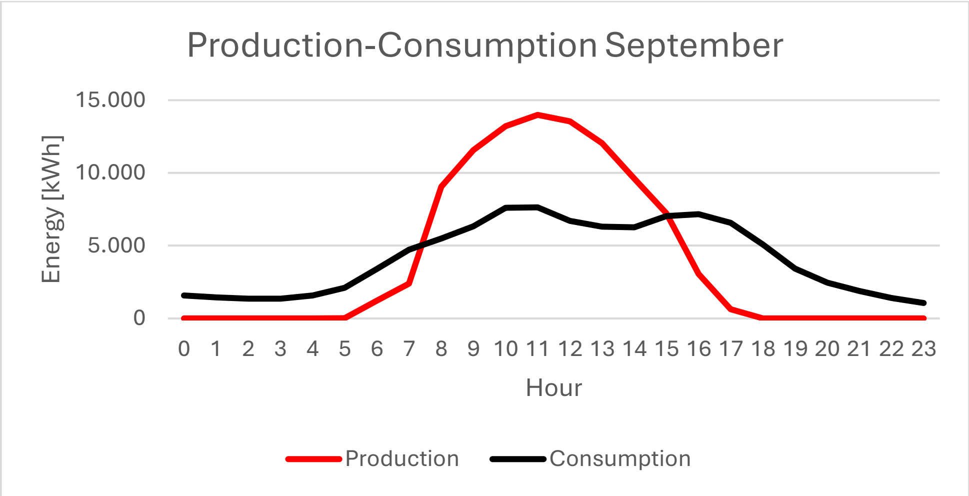

Figure 97 . Hourly production-consumption September - Morgex

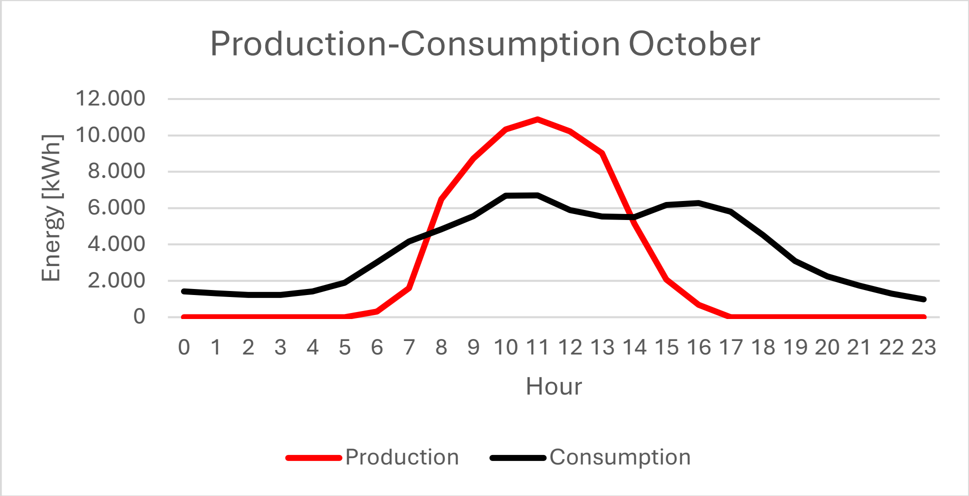

Figure 98 . Hourly production-consumption October - Morgex

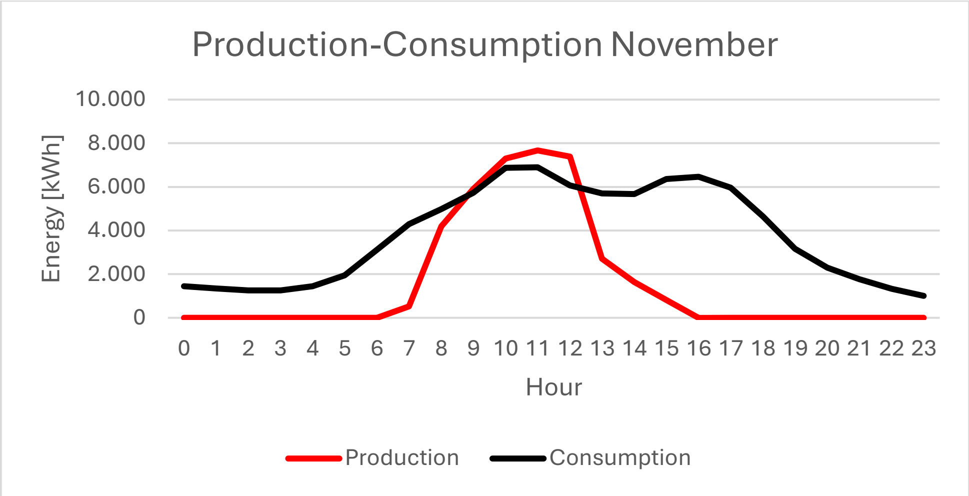

Figure 99 . Hourly production-consumption November - Morgex

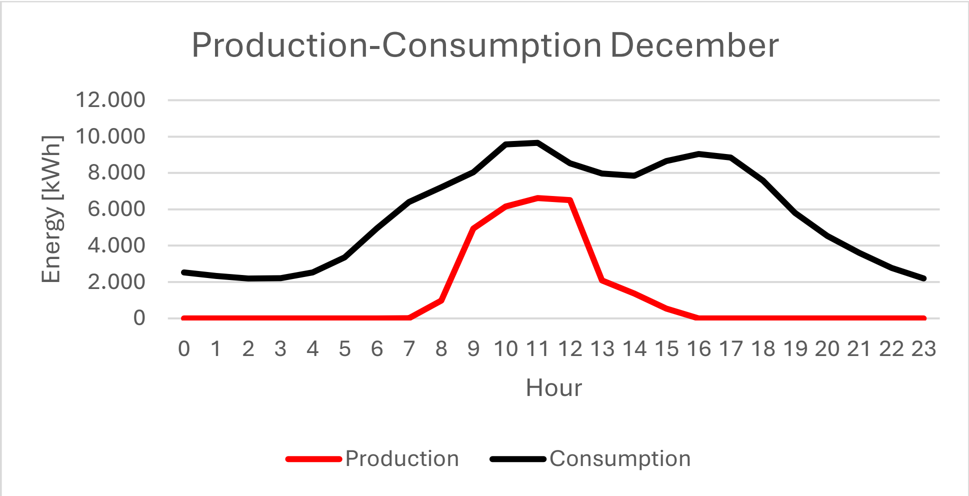

Figure 100. Hourly production-consumption December - Morgex

7.3. P.S.Didier

The P.S. Didier substation area is characterized by a relatively high number of buildings but a lower share of energy-intensive users. Compared with Entrèves that is hosting both the Courmayeur Mont Blanc domain skiable and the Sky Way Mont Blanc (that have an overall load of M8,8 kWh/year), the load due to ski infrastructures under the P.S.Dider substation is lower (M5,4 kWh/year consumed by La Thuile domain skiable). As a result, overall demand is shaped primarily by households (both primary and second homes) which tend to consume less electricity on average than large hotels or ski operations.

This composition produces a demand profile that is more moderate and less volatile throughout the year. Seasonal peaks linked to tourism are still visible, especially in winter and summer, but the absence of highly energy-intensive loads makes the annual curve smoother compared with Entrèves.

On the generation side, the photovoltaic potential is substantial, and during spring, summer, and early autumn production consistently exceeds the relatively modest local demand. This leads to pronounced surpluses that surpass those of Entrèves and highlight the capacity of P.S. Didier to contribute large volumes of shared energy within the Renewable Energy Community framework.

The total consumption and production are shown in the graph and table below.

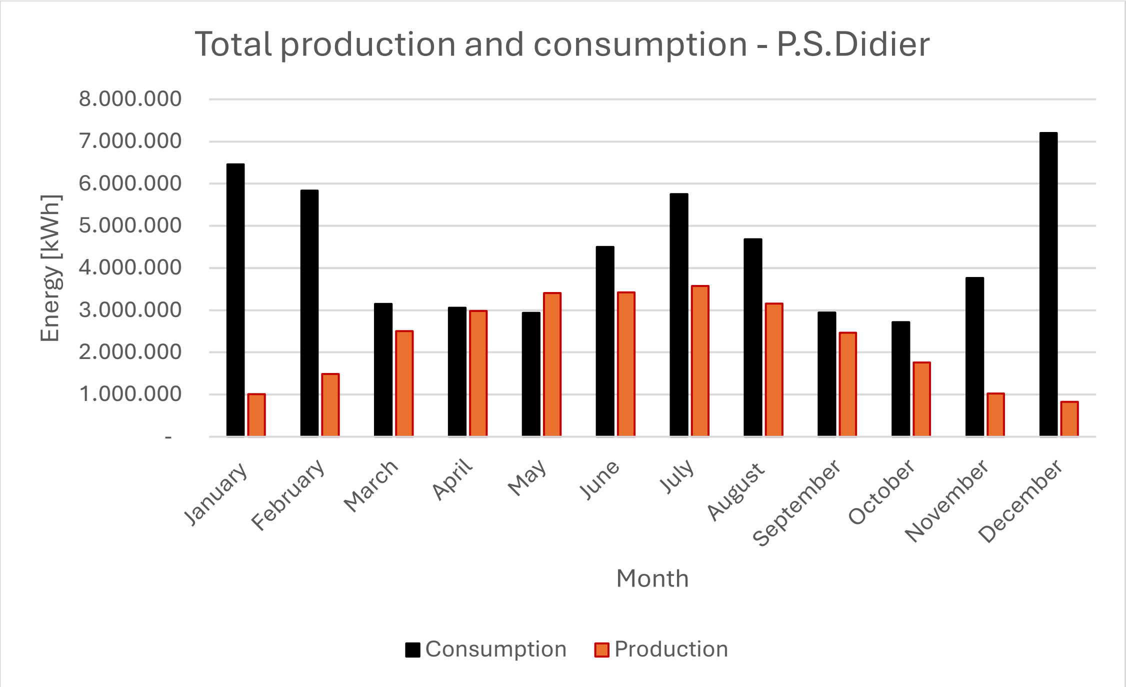

Figure 101 . Total production and consumption entire year – P.S.Didier

Table 89 . Total consumption, production and energy requested – P.S.Didier

Month	Consumption [kWh]	Production [kWh]	Production/Consumption	Energy requested [kWh]
January	6.189.664	798.234	13%	5.391.430
February	5.539.859	1.185.969	21%	4.353.890

March	3.704.022	2.019.940	55%	1.684.082
April	3.423.091	2.434.669	71%	988.423
May	3.208.389	2.808.471	88%	399.918
June	4.407.908	2.828.960	64%	1.578.947
July	5.289.088	2.947.976	56%	2.341.112
August	4.085.657	2.589.293	63%	1.496.364
Septemb er	3.199.061	2.003.323	63%	1.195.738
October	2.946.812	1.410.332	48%	1.536.480
Novemb er	4.683.436	807.248	17%	3.876.188
Decemb er	7.136.917	669.162	9%	6.467.756

As can be seen from the graph, only during may the production surpasses the consumption. This is mainly due to the presence of the ski area of La Thuile.

For a CER, this structure is highly advantageous: a broad residential base ensures widespread participation and steady, diversified consumption, while the absence of major energy-hungry infrastructures keeps demand at manageable levels. The result is a substation area where renewable penetration can reach very high percentages and where members benefit from both local self-consumption and significant economic returns from shared surpluses.

In the following graphs total hourly production and total hourly consumption are compared for every month for the substation of P.S.Didier. The monthly profile of hourly production versus consumption at the Entrèves substation indicates that, during peak hours from February through November, generation frequently surpasses load. This highly supports the feasibility of establishing an energy community (CER).

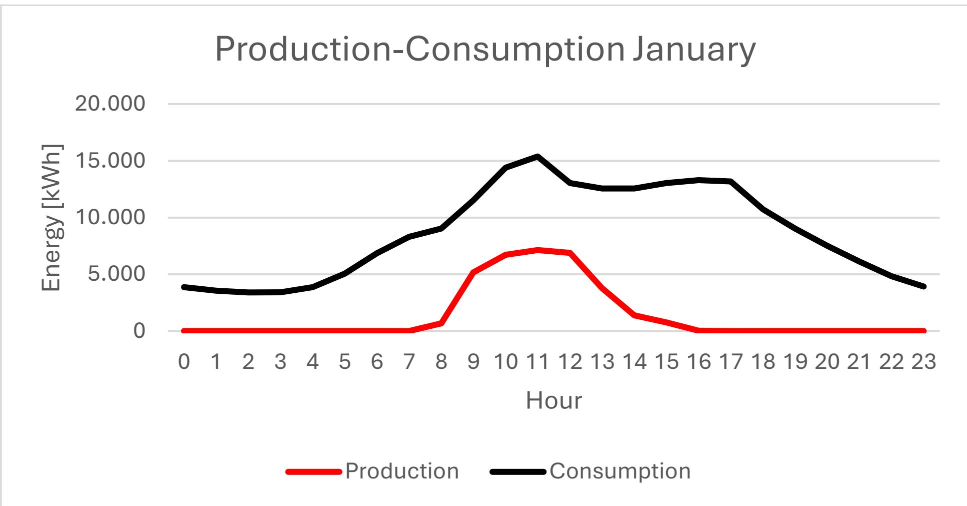

Figure 102 . Hourly production-consumption January – P.S.Didier

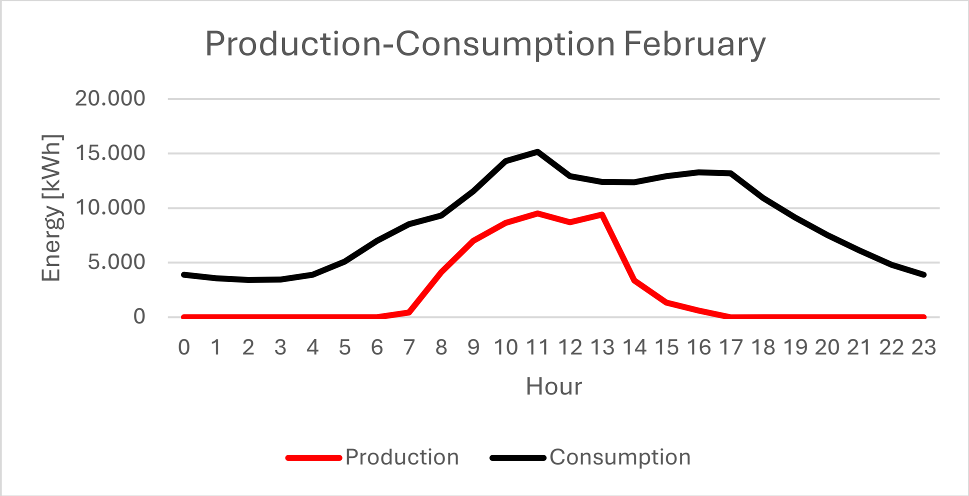

Figure 103 . Hourly production-consumption February – P.S.Didier

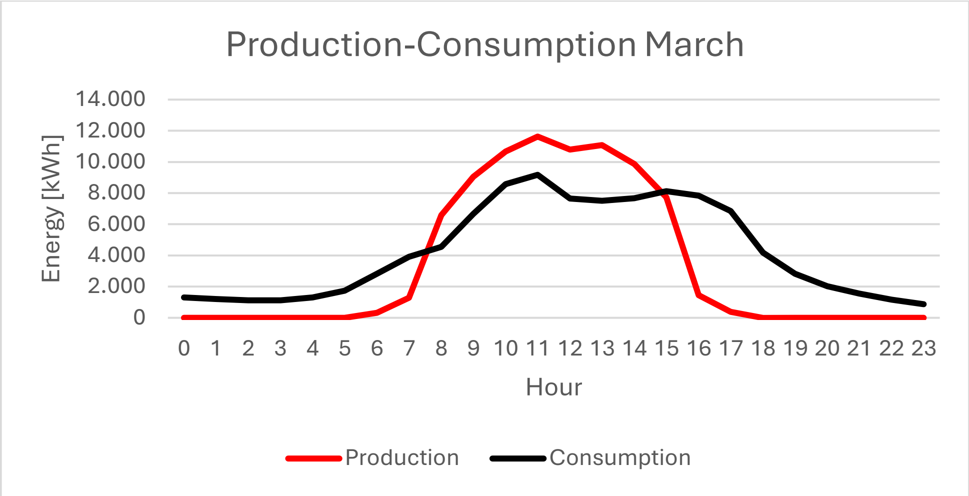

Figure 103 . Hourly production-consumption March – P.S.Didier

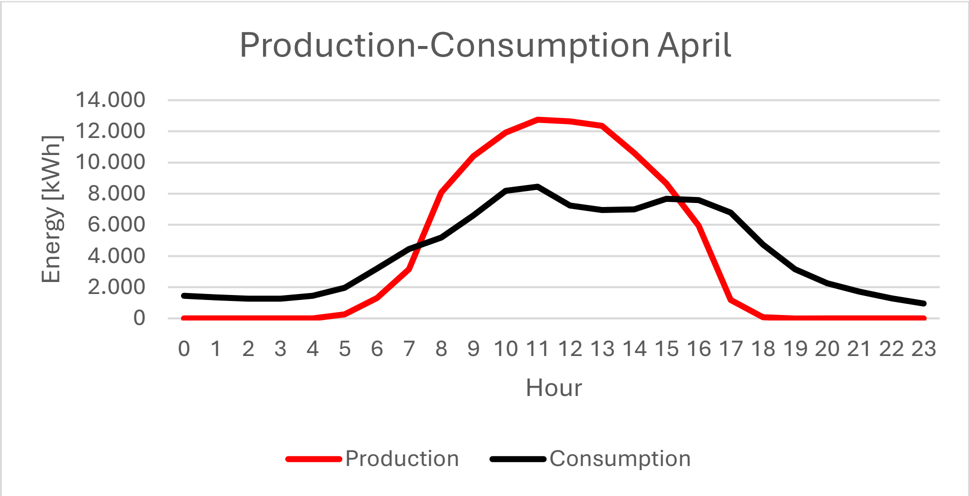

Figure 104 . Hourly production-consumption April – P.S.Didier

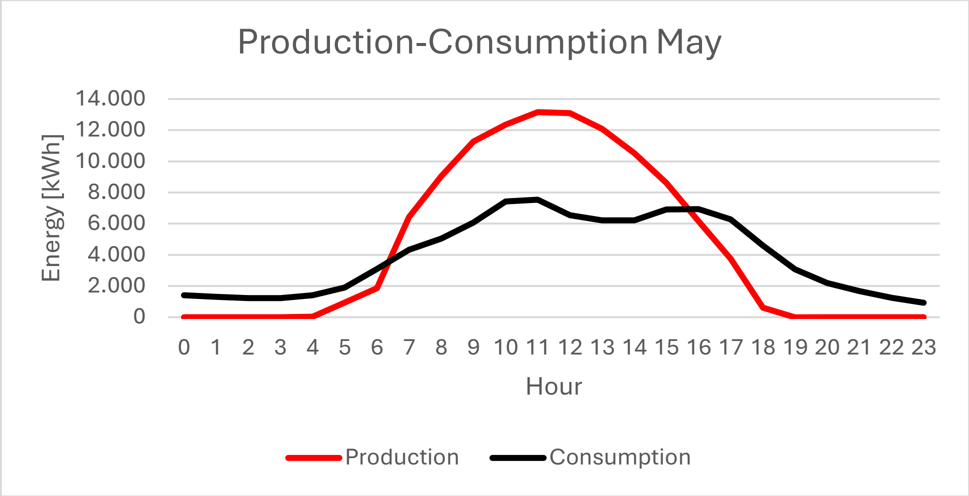

Figure 105 . Hourly production-consumption May – P.S.Didier

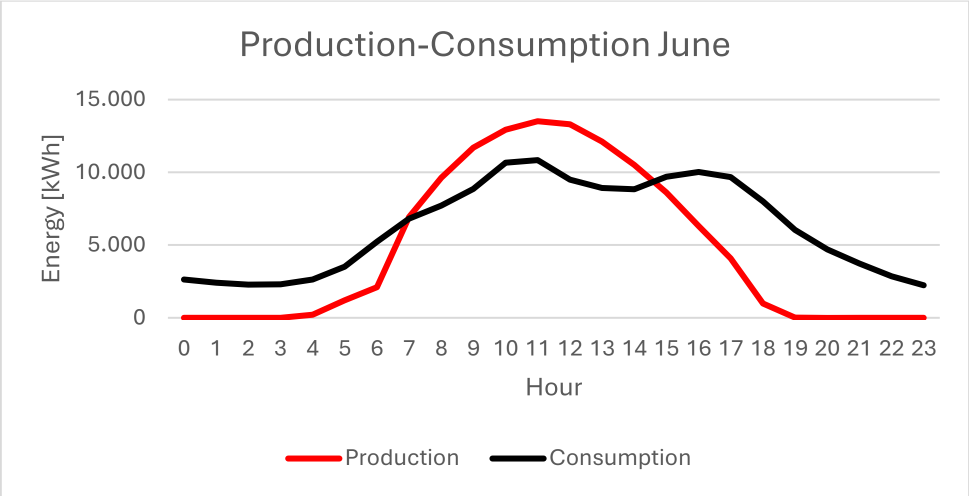

Figure 106 . Hourly production-consumption June – P.S.Didier

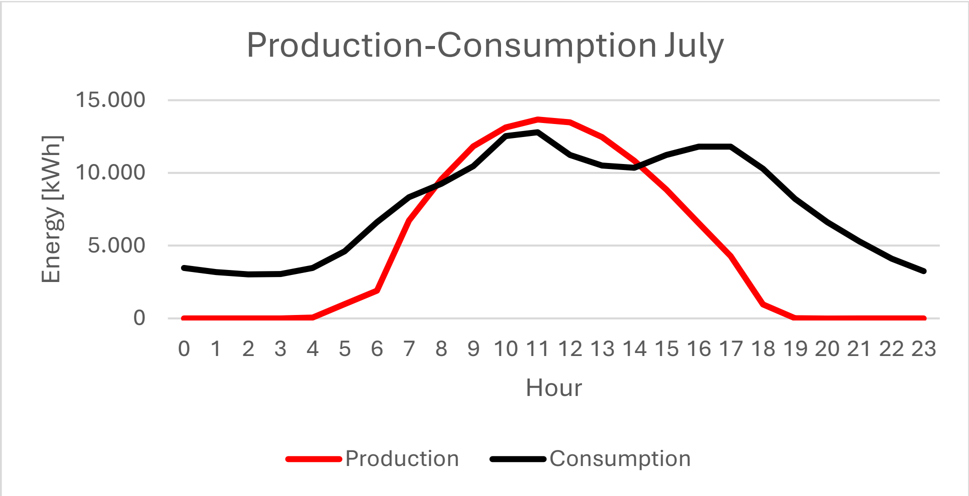

Figure 107 . Hourly production-consumption July – P.S.Didier

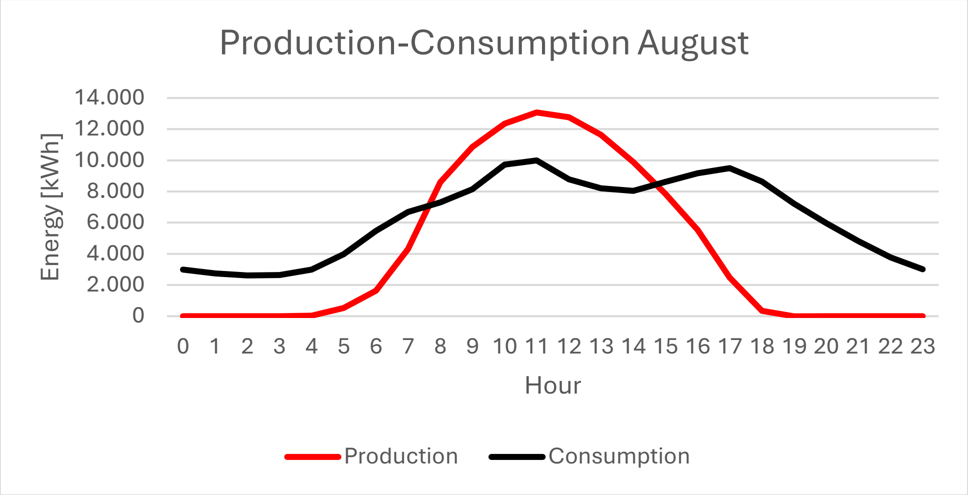

Figure 108 . Hourly production-consumption August – P.S.Didier

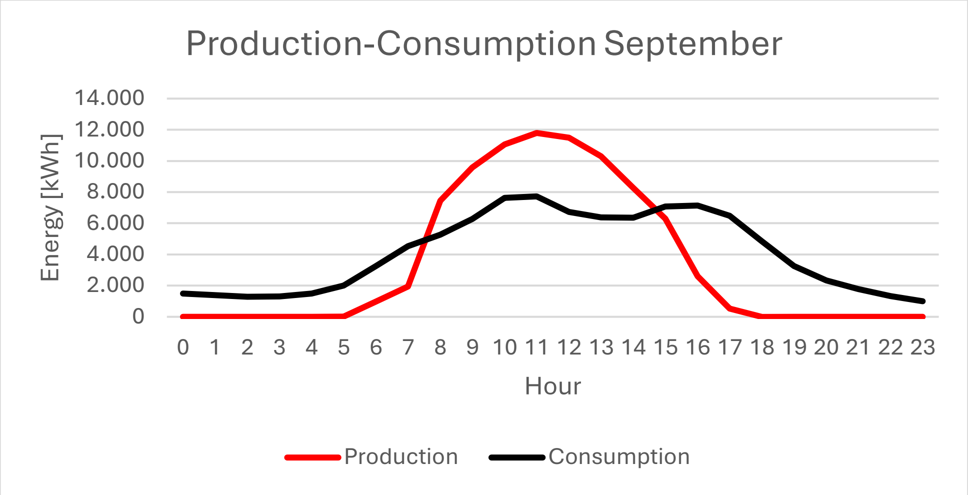

Figure 109 . Hourly production-consumption September – P.S.Didier

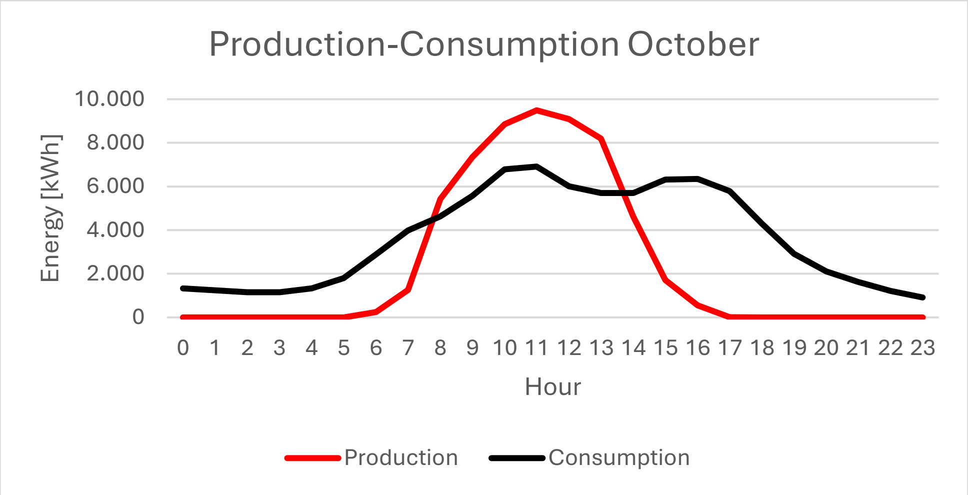

Figure 110 . Hourly production-consumption October – P.S.Didier

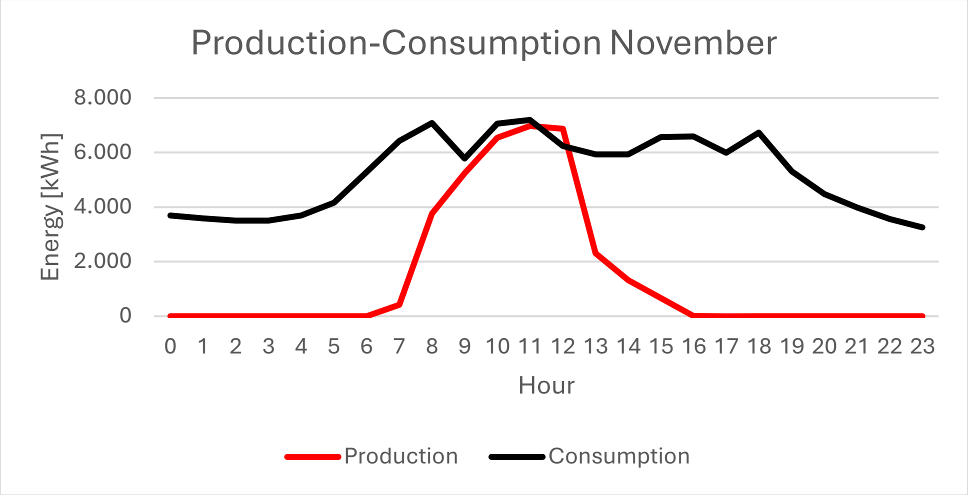

Figure 21. Hourly production-consumption November – P.S.Didier

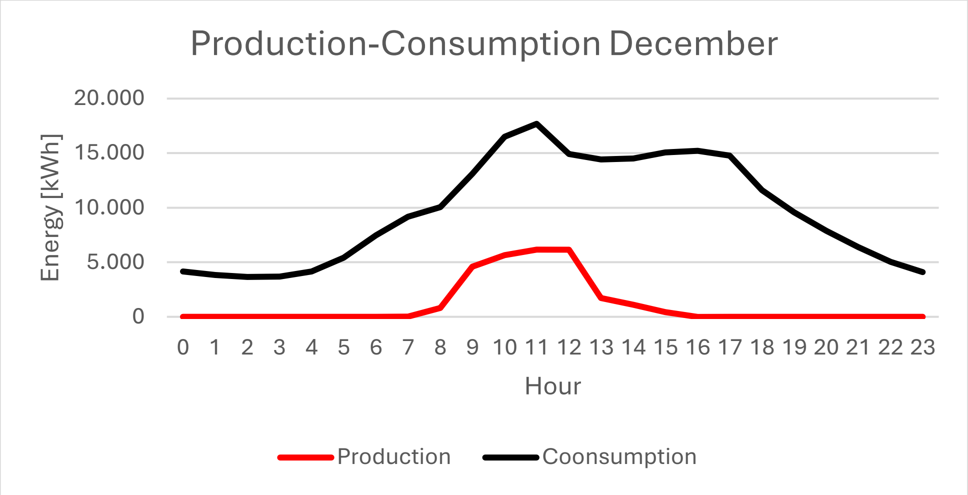

Figure 112 . Hourly production-consumption December – P.S.Didier

8. Economic analysis

Once the producibility and consumption have been calculated and estimated for each primary substation, across all building categories and parking areas, the final phase of this thesis is carried out: the economic analysis. The aim of this analysis is not limited to providing a simple estimation of aggregated data; rather, it is designed to unfold over time, offering a realistic time reconstruction of the Energy Community (CER). Furthermore, it seeks to optimize the balance between consumers and prosumers within the CER, in order to identify the most advantageous configuration that maximizes the economic benefits for all participants.

8.1. Prosumer

Prosumers play a pivotal role within the CER, as they export their surplus generation and thereby enable local energy exchange. In this study, prosumers are defined as follows:

- Primary residences with an average PV system of 3 kWp (typical for apartments and small houses).
- Second homes with an average PV system of 1,5 kWp, smaller than primary residences due to limited occupancy during the shoulder seasons.
- Hotels with a representative PV system of 40 kW. A common, average size is assumed to provide generalizable benchmarks, given the wide heterogeneity in hotel scale and form.
- Commercial and industrial activities with a representative PV system of 40 kW, following the same rationale adopted for hotels.
- Parking lots and municipal building rooftops, identified and sized in the previous chapters.

After defining categories and representative capacities, the number of prosumers in each category that join the CER over 1, 2, 5, and 10 years (with the exception of parking facilities, which are assumed to be fully active from Year 1) is determined. This staged adoption reflects the realistic, gradual enrollment of Valdigne prosumers over time.

To quantify each category's contribution to the CER, the monthly sets of hourly producibility profiles previously computed for all roofs in the Valdigne is used. Contributions are then derived by scaling these profiles by the representative installed capacity and the number of participating units in each year, and by allocating self-consumption and exports accordingly, using the following equation:

$$E_{i,h} = E_{tot,h} * \frac{P_i}{P_{tot}} * n_i$$

Where:

- $E_{i,h}$ is the energy produced at hour h by all prosumers of category i connected to the primary substation under analysis;
- $E_{tot,h}$ is the total energy produced at hour h by all suitable roofs within the same primary substation, previously computed from QGIS;
- P_i is the representative PV capacity for a prosumer in category iii (e.g. 3kWp for primary residences);

- P_{tot} is the total installable PV capacity estimated with QGIS for the primary substation;
- n_i is the number of prosumers of category iii that have joined the CER in the substation and in the specific analysis year;
- i is the counter of the i-th year.

This approach preserves the diversity of roof tilts and orientations embedded in $E_{tot,h}$ applying it to only the prosumer that enters the CER.

- For each prosumer category, hourly self-consumption and exports (and, symmetrically, grid import when there is a deficit) are obtained by subtracting the category's hourly demand, scaled to the actual number of enrolled prosumers n_i in that year, from $E_{i,h}$:
- Hourly self-consumption per category;
- Hourly energy exported to the grid per category (potentially shared within the CER, subject to the consumer/prosumer demand balance);
- Hourly energy drawn from the grid per category.

Parking lots are assumed to be fully active from Year 1, and their hourly production is taken directly from the profiles computed in the previous chapter.

The entire procedure is carried out for Years 1, 2, 5, and 10. The resulting production and exchange quantities vary across these milestones because the total number of enrolled prosumers increases over time, changing both the magnitude and the allocation of $E_{i,h}$ as well as the self-consumption, export, and import balances.

8.2. Consumption

The hourly demand for consumers, analogous to the approach used for prosumers, is derived from the total load calculated in earlier chapters but scaled to the actual number of CER participants. At this stage, both consumers and prosumers are included in the demand aggregate. This allows to determine, in the next section, the net energy available to the CER, since prosumers also draw from the grid whenever their own generation is insufficient, just like pure consumers.
In this stage, municipal PODs consumption data were not used: they were available for only a subset of municipalities and would have led to an incomplete picture. Given their negligible consumption, excluding them will not affect the energy or economic results of the simulation.

By contrast, ski resorts were included as consumers, since they comply with both the consumption thresholds and the maximum power per single grid connection (the CER limit is 1 MW and domains skiable typically have multiple connections). These facilities fall within the primary substations of Entrèves (Skyway and the Coumayur Mont Blanc ski area) and Pré-Saint-Didier (La Thuile- Espace San Bernardo ski area).

So, the consumer categories considered in this simulation are:

- Primary residences consumer;
- Primary residences prosumer;
- Second homes consumer;
- Second homes prosumer;

- Hotel consumer;
- Hotel prosumer;
- Commercial and industrial activites consumers;
- Commercial and industrial activites prosumers;
- Ski resort (where present).

8.3. Calculation of energy exported and consumed within the CER

The next step sums, for each hour of each month:

- the energy injected into the grid by each building category and by municipal rooftops/parking canopies. Of course, the injected energy of consumers (so, without PV power installed) is null for each hour each month. In the case of PV carports in parking areas, the injected energy is identical to the produced energy, as no primary self-consumption occurs (no co-located load on the same meter). On the other hand, for prosumer PV plants, injected energy equals production minus local self-consumption. The energy injected formula is:

$$E_{injected,i,h} = E_{produced,i,h} - E_{self-consumed,i,h}$$

Where:

- $E_{injected,h}$ is the energy injected by the category of building i at the hour h;
- $E_{produced,I,h}$ is the energy produced by the PV system of the category of building i at the hour h;
- $E_{self-confumed,I,h}$ is the energy self-consumed by the category of the building I at the hour h;

An example of the energy self-consumed and energy injected by a primary residence of Entréves is reported below.

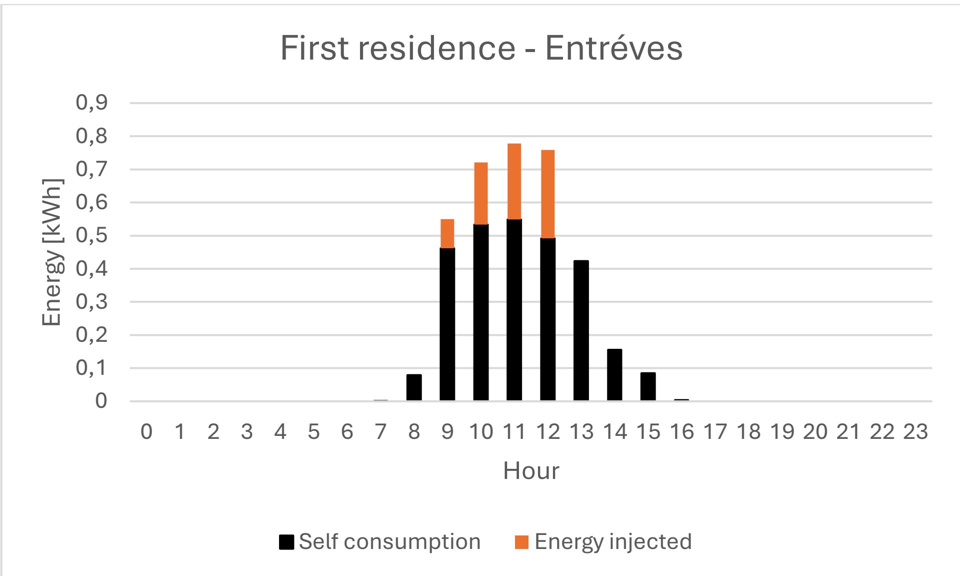

Figure 113 . Self-consumption and energy injected one primary residence – Entréves

- The energy withdrawn by each category and by municipal rooftops/parking canopies. The energy withdrawn is the difference between the consumption of a certain category and its self-consumption (consumption – energy produced). Of course the self-consumption of a consumer is zero, because it doesn't produce energy. In the case of PV carport s in parking area, both consumption and self-consumption are both null.

  The energy withdrawn energy formula is:

$$E_{withdrawn,i,h} = E_{consumed,i,h} - E_{self-consumed,i,h}$$

  Where:
  - $E_{withdrawn,i,h}$ is the energy withdrawn from the grid by the category i at the hour h;
  - $E_{consumed,I,h}$ is the energy consumption of the category I at the hour h.

  An example of the energy withdrawn by a primary residence of Entréves is reported below.

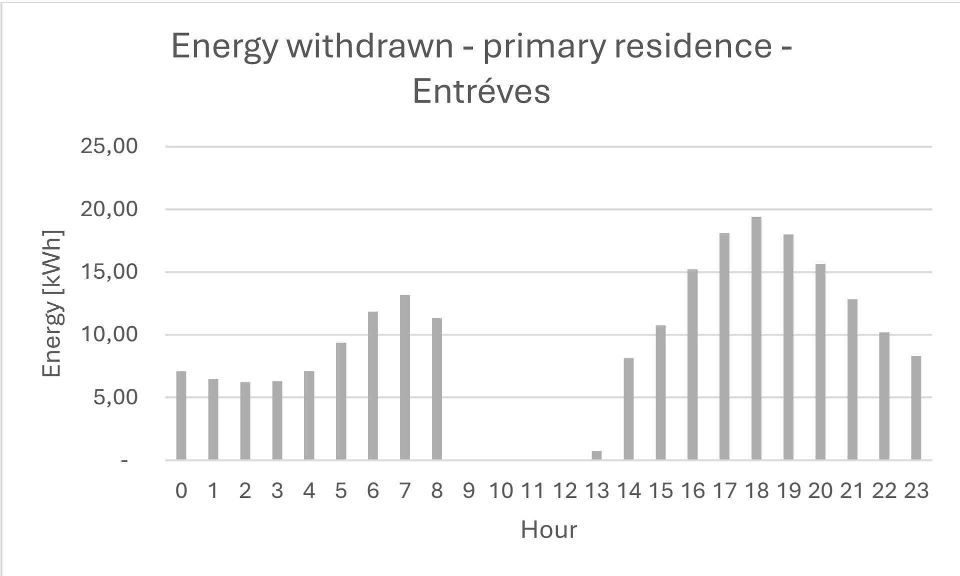

Figure 114 . Energy withdrawn by primary residence - Entéves

With these hourly totals, available exports and net CER demand, the energy shared locally is the hour-by-hour minimum of the two:

$$shared\ energy = min(injected\ energy, CER\ withdrawn\ energy)$$

This procedure is applied hour by hour every month in the analysis.

8.4. Prosumer economic analysis

The economic benefits for a prosumer who owns a PV system and joins a CER is quantified. In a standard (non-CER) setting, a prosumer has two revenue streams:

- self-consumption of PV energy, valued here at 25 c€/kWh (the same value is later used for each primary substation);
- RID (Ritiro Dedicato) where the payment from GSE for surplus energy injected into the grid, assumed at 9 c€/kWh.

By joining a CER, the prosumer gains an additional compensation linked strictly to shared energy, the portion of energy produced by CER members and simultaneously consumed by other members (consumers or prosumers temporarily in deficit) within the community's perimeter. In Northern Italy, the CER incentive on shared energy is valued at about 12 c€/kWh; this amount is paid by GSE (Gestore dei Servizi Energetici, an Italian state-owned entity that manages renewable-energy incentives, purchases and sells incentivized electricity, and supports mechanisms such as energy communities) to the CER, which then redistributes it as follows:

- 10% retained by the CER for management/common purposes;
- 35% to consumers;
- 55% to producers (prosumers);

This distribution is a hypothesis, based on previous CERs in Italy (described in the previous chapters), but it can be chosen arbitrarily by the CER.

Consequently, for each kilowatt-hour that is actually shared within the CER, a producer receives (in addition to self-consumption value and any RID on non-shared exports), 6,6 €/kWh (55% of 12 c€/kWh.

In the table below the prices and the energy inflation rates used for this thesis are shown.

Table 90 . Values of energy and energy inflation rates

	Self-consumption	**RID**	**CER**
Value [c€/kWh]	0,25	0,09	0,066
Energy inflation rate	2,50%	1,50%	-

It's important to notice that the CER contribution is a fixed incentive tariff, granted for 20 years, and it does not increase with energy price inflation.

In this simulation, the distribution of revenues to each prosumer is computed as follows:

- the hourly percentage contribution of each prosumer category (including parking facilities) to the total energy exported to the grid is calculated for every hour of every month;
- these hourly percentages are then applied to the energy shared and consumed within the CER, yielding the portion that each category effectively contributes, and thus gets credited, hour by hour;
- The hourly contributions are summed over all hours and months to obtain the annual kWh of shared energy attributable to each prosumer category, which is then multiplied by €0,066/kWh to derive the annual CER revenue per category;
- The total is then divided by the number of prosumers of each category, so the single revenue of each category is obtained.

This procedure is run for Years 1, 2, 5, and 10 to capture how revenues evolve as CER participation grows. By working at hourly resolution on the energy actually exported by prosumers and consumed within the CER, the method yields differentiated, precise allocations for each category.

It is important to note that municipal parking assets have no on-site self-consumption; they therefore receive only CER incentive revenues and RID (where applicable).

The results for each primary substation are presented and discussed in the respective subsequent sections.

8.5. Consumption economic analysis

The analysis is structured as follows:

- compute, for each hour of each month, the percentage share of demand by category relative to the total demand of CER participants (prosumers are included net of self-consumption, since they draw energy when their PV does not meet their load)
- apply each category's demand percentage to the hourly shared-and-consumed energy within the CER, obtaining the category-specific consumption contributions
- multiply each category's annual total by 0,042 c€/kWh (e.g. 35% of o,12c€/kWh) to obtain the annual compensation per category
- divide each category's total compensation by the number of participants in that category to obtain the average per-participant compensation

This yields the annual earnings for a single consumer or prosumer in each category. As with the prosumer economic analysis, the procedure is run for Years 1, 2, 5, and 10.

The results for each primary substation are presented and discussed in the respective subsequent sections.

8.6. Entréves

In this section, we present the results after 1, 2, 5, and 10 years, tracing the evolution of the CER as households, businesses, and hotels join as either consumers or prosumers, using the methods described above.

8.6.1. First year

For Year 1, we assume that the parking facilities identified for the relevant primary substation are already operational and join the CER. The table below reports, for each category, the number of consumers and prosumers entering the CER in the first year. We also assume that a subset of newer PV systems (already compliant with current CER requirements) joins in Year 1 and begin contributing to the community from the outset.

Table 91 . Number of buildings for each category – Entréves first year

Category	Prosumer	Consumer	Total in substation area
Primary residences	30	20	1.082
Second homes	5	30	4.289
Hotels	2	2	37
Activites	5	10	512

Using the methods outlined above, we obtain the following annual results for both consumers and prosumers,covering CER revenues as well as self-consumption and RID.

Table 92 . Consumer revenues – Entréves first year

Consumer						
	First residence consumer	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Courmayeur ski area**	**Skyw ay**
Total of each category	564,01 €	220,23 €	2.958,81 €	7.926,33 €	29.205,72 €	15.196 ,47 €
Total of one for each category	28,20 €	7,34 €	1.479,41 €	792,63 €	29.205,72 €	15.196 ,47 €

Table 93 . Prosumer revenues – Entréves first year

Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activit es**	**Parking lots and municipality roofs**
Self-consumption	337,90 €	104,52 €	6.888,9 9 €	8.466,3 7 €	
RID	163,14 €	104,54 €	1.325,45 €	763,13 €	127.695,89 €
CER - energy delivered	108,85 €	69,26 €	877,25 €	512,78 €	83.637,06 €
CER - energy consumed	1,98 €	0,42 €	2.085,14 €	75,64 €	
Totale	**611,86 €**	**278,74 €**	**11.176,8 3 €**	**9.817,9 2 €**	**211.332,96 €**

8.6.2. Second year

In Year 2, we assume further growth in both consumers and prosumers, though at a slower pace than in Year 1, since fewer pre-existing installations remain to be onboarded. The number of consumers and prosumers entering the CER and the resulting revenues for prosumer and consumer, are reported in the tables below.

Table 94 . Number of buildings for each category – Entréves second year

Category	**Prosumer**	**Consumer**	**Total in substation area**
Primary residences	45	55	1.082
Second homes	10	140	4.289
Hotels	3	4	37
Activites	15	25	512

Table 95 . Prosumer revenues – Entréves second year

Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	337,90 €	104,52 €	6.888,99 €	8.466,37 €	
RID	163,14 €	104,54 €	1.325,45 €	763,13 €	127.695,89 €
CER - energy delivered	113,66 €	72,58 €	912,69 €	533,94 €	88.456,38 €
CER - energy consumed	0,94 €	0,23 €	1.408,22 €	43,05 €	
Total	**615,63 €**	**281,87 €**	**10.535,34 €**	**9.806,49 €**	**216.152,27 €**

Table 96 . Consumer revenues – Entréves second year

Consumer						
	First residence consumer	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Courmayeur ski area**	**Skyway**
Total of each category	1.272,80 €	837,69 €	4.823,25 €	16.696,06 €	26.535,08 €	13.905,33 €
Total of one for each category	**23,14 €**	**5,98 €**	**1.205,81 €**	**667,84 €**	**26.535,08 €**	**13.905,33 €**

8.6.3. Fifth year

By Year 5, participation in the CER is expected to grow sharply, driven by word-of-mouth, incentives, and municipal outreach initiatives. The tables below first report the number of participants joining the CER and then present the corresponding annual revenues for consumers and prosumers.

Table 97 . Number of buildings for each category – Entréves fifth year

Category	**Prosumer**	**Consumer**	**Total in substation area**
Primary residences	80	120	1.082
Second homes	20	480	4.289
Hotels	8	7	37
Activites	40	60	512

Table 98 . Prosumer revenues – Entréves fifth year

Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	337,90 €	104,52 €	6.888,99 €	8.466,37 €	- €
RID	163,14 €	104,54 €	1.325,45 €	763,13 €	127.695,89 €

CER - energy delivered	117,37 €	75,20 €	950,97 €	549,10 €	91.874,74 €
CER - energy consumed	46,30 €	3,75 €	6.489,80 €	1.684,43 €	
Total	**664,71 €**	**288,00 €**	**15.655,20 €**	**11.463,03 €**	**219.570,63 €**

Table 99. Consumer revenues – Entréves fifth year

Consumer						
	First residence consumer	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Courmayeur ski area**	**Skyway**
Total of each category	2.142,01 €	2.104,49 €	6.184,83 €	32.032,34 €	24.125,36 €	12.716,02 €
Total of one for each category	17,85 €	4,38 €	883,55 €	533,87 €	24.125,36 €	12.716,02 €

8.6.4. Tenth Year

By Year 10, the CER is assumed to be near saturation, with a very high level of participation across households, hotels, and commercial/industrial sites. Further growth is expected to be marginal, reflecting practical ceilings such as roof/area availability, grid connection limits, and the natural tapering of adoption once early and mid-adopters have joined. Any additional increases are likely to come from new constructions, major retrofits, or targeted municipal programs rather than from the existing stock. Under these assumptions, the community operates close to its steady state: shared-energy volumes stabilize, while incremental gains in revenues stem mainly from operational optimization rather than expansion.

The resulting figures, both the number of participants and the annual revenues for consumers and prosumers (including CER allocations, self-consumption value, and RID on non-shared exports), are reported in the tables below.

Table 100 . Number of buildings for each category – Entréves tenth year

Category	**Prosumer**	**Consumer**	**Total in substation area**
Primary residences	200	450	1.082
Second homes	50	1500	4.289
Hotels	20	30	37
Activites	100	250	512

Table 101 . Prosumer revenues – Entréves tenth year

Prosumer					
Month	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	337,90 €	104,52 €	6.888,99 €	8.466,37 €	- €
RID	163,14 €	104,54 €	1.325,45 €	763,13 €	127.695,89 €

CER - energy delivered	117,87 €	75,53 €	957,63 €	551,36 €	92.259,76 €
CER - energy consumed	0,21 €	0,06 €	488,86 €	13,86 €	
Total	**619,11 €**	**284,65 €**	**9.660,93 €**	**9.794,72 €**	**219.955,65 €**

Table 102 . Consumer revenues – Entréves tenth year

Consumer						
	First residence consumer	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Courmayeur ski area**	**Skyway**
Total of each category	3.485,90 €	4.881,68 €	6.784,62 €	64.203,34 €	23.103,40 €	12.163,35 €
Total of one for each category	13,94 €	3,37 €	678,46 €	428,02 €	23.103,40 €	12.163,35 €

8.6.5. Considerations

For the Entrèves primary substation, the results show a clear shift in who benefits most over time. In the early years, consumers capture the larger share of value because they are few relative to the available prosumer generation and can absorb virtually all of the energy shared within the CER; as participation expands, the balance progressively turns in favor of prosumers, since the pool of consumers grows much faster and consistently draws down all locally produced energy, raising the fraction of production that is actually shared (and thus remunerated) rather than spilled to RID. The onboarding of the Courmayeur ski lifts and the Skyway is pivotal: their sizeable, daytime-oriented loads during operating seasons increase the coincidence between CER exports and internal demand, stabilizing shared-energy volumes and reducing residual grid interactions. This higher simultaneity improves both community revenues and the predictability of cash flow, while also mitigating curtailment risk for prosumers. Additional factors that reinforce performance at Entrèves include the diversification of demand profiles (homes, hotels, commercial/industrial sites, and municipal assets), which smooths hourly variability; the early activation of municipal parking PV (pure producers without self-consumption), which boosts shared energy from Year 1.

8.7. Morgex

As with the Entrèves primary substation, the Morgex primary substation was assessed using the same economic methodology and assumptions outlined above. To reflect the progressive onboarding of new participants, we applied the same category mix and relative proportions of consumers and prosumers used for Entrèves, scaled and adapted to Morgex's context, across the staged horizons (Years 1, 2, 5, and 10). In the following paragraphs, we report only the tables summarizing the economic outcomes and the corresponding numbers of prosumers and consumers that join the Morgex CER over time.

8.7.1. First year

The results for the first year are reported in the tables below.

Table 103 . Number of buildings for each category – Morgex first year

Category	Prosumer	Consumer	Total in substation area
Primary residences	40	30	1.989
Second homes	5	35	4.935
Hotels	1	2	27
Activites	5	5	444

Table 104 . Prosumer revenues – Morgex first year

Single Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	338,78 €	104,38 €	3.872,00 €	8.752,67 €	- €
RID	168,85 €	107,60 €	2.481,24 €	741,34 €	56.757,19 €
CER - energy delivered	44,78 €	30,64 €	681,78 €	160,47 €	18.956,37 €
CER - energy consumed	2,84 €	0,99 €	118,22 €	231,43 €	- €
Total	**555,24 €**	**243,61 €**	**7.153,24 €**	**9.885,91 €**	**75.713,56 €**

Table 105 . Consumer revenues – Morgex first year

Consumer				
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**
Total of each category	1.766,55 €	600,38 €	1.487,93 €	8.996,32 €
Total of one for each category	58,88 €	17,15 €	743,97 €	1.799,26 €

8.7.2. Second year

The results for the second year are reported in the tables below.

Table 106 . Number of buildings for each category – Morgex second year

Category	Prosumer	Consumer	Total in substation area
Primary residences	75	108	1.989
Second homes	10	163	4.935
Hotels	2	3	27
Activites	15	20	444

Table 107 . Prosumer revenues – Morgex second year

Single Prosumer					
Type	Primary residence	Second home	Hotel	Activites	Parking lots and municipality roofs
Self-consumption	338,78 €	104,38 €	3.872,00 €	8.752,67 €	
RID	168,85 €	107,60 €	2.481,24 €	741,34 €	56.757,19 €
CER - energy delivered	96,84 €	62,85 €	1.434,56 €	383,46 €	34.222,17 €
CER - energy consumed	0,90 €	0,32 €	39,02 €	80,33 €	
Total	**605,36 €**	**275,15 €**	**7.826,82 €**	**9.957,79 €**	**90.979,35 €**

Table 108 . Consumer revenues – Morgex second year

Consumer				
Type	First residence consumer	Second home consumer	Hotel consumer	Activites consumer
Total of each category	4.069,77 €	1.696,11 €	1.356,17 €	23.810,48 €
Total of one for each category	37,69 €	10,42 €	452,06 €	1.190,52 €

8.7.3. Fifth year

The results for the fifth year are reported in the tables below.

Table 109 . Number of buildings for each category – Morgex fifth year

Category	Prosumer	Consumer	Total in substation area
Primary residences	184	184	1.989
Second homes	23	552	4.935
Hotels	6	4	27
Activites	35	55	444

Table 110 . Prosumer revenues – Morgex fifth year

Single Prosumer					
Type	Primary residence	Second home	Hotel	Activites	Parking lots and municipality roofs
Self-consumption	338,78 €	104,38 €	3.872,00 €	8.752,67 €	- €
RID	168,85 €	107,60 €	2.481,24 €	741,34 €	56.757,19 €

CER - energy delivered	119,17 €	76,17 €	1.756,59 €	512,71 €	40.243,02 €
CER - energy consumed	0,38 €	0,13 €	16,74 €	38,54 €	- €
Total	**627,18 €**	**288,27 €**	**8.126,57 €**	**10.045,26 €**	**97.000,21 €**

Table 111 . Consumer revenues – Morgex fifth year

Consumer				
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**
Total of each category	4.916,13 €	3.931,31 €	1.235,27 €	47.196,49 €
Total of one for each category	26,74 €	7,12 €	308,82 €	858,12 €

8.7.4. Tenth Year

The results for the tenth year are reported in the tables below.

Table 112 . Number of buildings for each category – Morgex tenth year

Category	**Prosumer**	**Consumer**	**Total in substation area**
Primary residences	368	459	1.989
Second homes	58	1.668	4.935
Hotels	15	5	27
Activites	95	140	444

Table 113 . Prosumer revenues – Morgex tenth year

Single Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	338,78 €	104,38 €	3.872,00 €	8.752,67 €	- €
RID	168,85 €	107,60 €	2.481,24 €	741,34 €	56.757,19 €
CER - energy delivered	121,92 €	77,71 €	1.792,06 €	534,87 €	40.987,08 €
CER - energy consumed	0,16 €	0,05 €	7,53 €	20,88 €	- €
Total	**629,71 €**	**289,74 €**	**8.152,82 €**	**10.049,76 €**	**97.744,26 €**

Table 114 . Consumer revenues – Morgex tenth year

Consumer				
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**

Total of each category	9.091,95 €	8.721,87 €	1.133,64 €	85.786,60 €
Total of one for each category	19,78 €	5,23 €	226,73 €	635,46 €

8.7.5. Considerations

In Morgex, the absence of ski facilities changes the early balance of benefits. With fewer large daytime loads to soak up local generation, prosumers enjoy an initial advantage: a higher share of their output becomes shared within the CER rather than flowing to RID, so their unit revenues are stronger in the first phase. The flip side is visible on the demand side. Both at the outset and even by Year 10, consumers face a relative disadvantage compared with Entrèves and Pré-Saint-Didier: there is simply less coincident load to absorb community generation, so the pool of shared energy (and the related compensation) remains smaller. The results tables make this clear, with lower consumer receipts and a more modest lift over time despite the gradual growth in participation.

8.8. P.S.Didier

For the Pré-Saint-Didier primary substation, the economic assessment is carried out using the same framework described previously, with inputs and assumptions aligned to local conditions. The staged adoption horizons (Years 1, 2, 5, and 10) mirror the Entrèves approach, while the mix of categories and the consumer/prosumer split are calibrated by applying the same relative proportions used in Entrèves and scaling them to the Pré-Saint-Didier context. This yield results that are comparable across substations while reflecting site-specific demand and PV potential (including the local ski facilities). In the pages that follow, only the summary tables are provided: annual economic outcomes and the time-evolving counts of prosumers and consumers joining the Pré-Saint-Didier CER.

8.8.1. First year

The results for the first year are reported in the tables below.

Table 115 . Number of buildings for each category – P.S.Didier first year

Category	Prosumer	Consumer	Total in substation area
Primary residences	33	22	1.183
Second homes	7	43	6.168
Hotels	3	3	44
Activites	5	10	437

Table 116 . Prosumer revenues – P.S.Didier first year

Single Prosumer					
Type	Primary residence	Second home	Hotel	Activites	Parking lots and municipality roofs
Self-consumption	338,34 €	105,09 €	7.360,02 €	8.764,25 €	- €
RID	169,71 €	107,70 €	1.247,19 €	746,60 €	40.242,25 €

CER - energy delivered	120,61 €	76,41 €	876,54 €	532,58 €	28.660,84 €
CER - energy consumed	0,52 €	0,10 €	1.010,39 €	32,08 €	
Total	**629,17 €**	**289,30 €**	**10.494,15 €**	**10.075,52 €**	**68.903,09 €**

Table 117 . Consumer revenues – P.S.Didier first year

Consumer					
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Ski area La Thuile**
Total of each category	328,69 €	140,26 €	2.460,56 €	4.725,06 €	15.177,66 €
Total of one for each category	15,03 €	3,25 €	820,19 €	472,51 €	15.177,66 €

8.8.2. Second year

The results for the second year are reported in the tables below.

Table 118 . Number of buildings for each category – P.S.Didier second year

Category	**Prosumer**	**Consumer**	**Total in substation area**
Primary residences	49	60	1.183
Second homes	14	202	6.168
Hotels	4	4	44
Activites	15	20	437

Table 119 . Prosumer revenues – P.S.Didier second year

Single Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	338,34 €	105,09 €	7.360,02 €	8.764,25 €	- €
RID	169,71 €	107,70 €	1.247,19 €	746,60 €	40.242,25 €
CER - energy delivered	122,34 €	77,63 €	897,72 €	538,09 €	29.022,48 €
CER - energy consumed	0,30 €	0,06 €	753,97 €	21,20 €	
Total	**630,69 €**	**290,49 €**	**10.258,90 €**	**10.070,14 €**	**69.264,72 €**

Table 120 . Consumer revenues – P.S.Didier second year

Consumer					
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Ski area La Thuile**
Total of each category	802,11 €	590,09 €	2.957,70 €	8.540,09 €	15.467,73 €
Total of one for each category	13,34 €	2,93 €	739,43 €	427,00 €	15.467,73 €

8.8.3. Fifth year

The results for the fifth year are reported in the tables below.

Table 121 . Number of buildings for each category – P.S.Didier fifth year

Category	Prosumer	Consumer	Total in substation area
Primary residences	109	110	1.183
Second homes	29	690	6.168
Hotels	9	9	44
Activites	35	55	437

Table 122. Prosumer revenues – P.S.Didier fifth year

Single Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	338,34 €	105,09 €	7.360,02 €	8.764,25 €	- €
RID	169,71 €	107,70 €	1.247,19 €	746,60 €	40.242,25 €
CER - energy delivered	122,61 €	77,81 €	901,09 €	539,42 €	29.074,86 €
CER - energy consumed	0,14 €	0,03 €	433,09 €	12,59 €	
Total	**630,80 €**	**290,63 €**	**9.941,40 €**	**10.062,86 €**	**69.317,10 €**

Table 123 . Consumer revenues – P.S.Didier fifth year

Consumer					
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Ski area La Thuile**
Total of each category	1.152,47 €	1.541,92 €	5.071,88 €	19.179,38 €	15.331,38 €
Total of one for each category	10,54 €	2,23 €	563,54 €	348,72 €	15.331,38 €

8.8.4. Tenth Year

The results for the tenth year are reported in the tables below.

Table 124 . Number of buildings for each category – P.S.Didier tenth year

Category	Prosumer	Consumer	Total in substation area
Primary residences	219	273	1.183
Second homes	72	2.157	6.168
Hotels	22	38	44
Activites	90	210	437

Table 125 . Prosumer revenues – P.S.Didier tenth year

Single Prosumer					
Type	**Primary residence**	**Second home**	**Hotel**	**Activites**	**Parking lots and municipality roofs**
Self-consumption	338,34 €	105,09 €	7.360,02 €	8.764,25 €	- €
RID	169,71 €	107,70 €	1.247,19 €	746,60 €	40.242,25 €
CER - energy delivered	122,61 €	77,81 €	901,09 €	539,42 €	29.074,86 €
CER - energy consumed	0,07 €	0,02 €	338,14 €	8,73 €	
Total	**630,73 €**	**290,62 €**	**9.846,44 €**	**10.059,00 €**	**69.317,10 €**

Table 126 . Consumer revenues – P.S.Didier tenth year

Consumer					
Type	**First residence consumer**	**Second home consumer**	**Hotel consumer**	**Activites consumer**	**Ski area La Thuile**
Total of each category	2.829,97 €	4.350,86 €	8.422,36 €	42.178,77 €	17.655,65 €
Total of one for each category	10,35 €	2,09 €	526,40 €	351,49 €	17.655,65 €

8.8.5. Considerations

Here the dynamics resemble Entrèves, but at a smaller scale. The La Thuile lifts provide useful, seasonally concentrated daytime demand that improves the match between exports and internal consumption; however, because these plants are fewer and smaller than the Courmayeur–Skyway set, revenues and shared-energy volumes come in slightly below Entrèves. Even so, Pré-Saint-Didier performs noticeably better than Morgex: the presence of the ski loads increases simultaneity, reduces spill to RID, and sustains more stable cash flows for prosumers, while consumers benefit from a larger and more regular stream of shared energy throughout the operating seasons.

9. Conclusions

The analysis carried out across the Entrèves, P.S.Didier and Morgex primary substations offers a coherent picture of what a CER can deliver in a mountainous district where seasonal tourism, dispersed settlements and public assets coexist. The combination of rooftop and parking-canopy PV mapping with category-specific demand models makes it possible to move beyond generic statements about potential and to quantify, hour by hour, when and where shared energy actually materializes. This is the decisive quantity in the current Italian framework, as it governs both environmental performance and the stream of incentives that sustain the community over time.

Three findings stand out:

- First, simultaneity between production and load is the main driver of value. Where sizeable daytime uses exist, such as the Courmayeur lifts and the Skyway in Entrèves or the La Thuile lifts in Pré-Saint-Didier, the community can absorb a larger share of local generation within the substation perimeter. This increases the portion of energy remunerated as shared energy and stabilises cash flows for members, while reducing residual exchanges with the grid. Conversely, in Morgex, the absence of ski facilities limits the early hours of high coincidence. Prosumers benefit initially because fewer consumers compete for the available output; yet consumers receive less, both at the start and, despite growth, after ten years, as the results tables show.
- Second, the composition and timing of enrolment matter as much as aggregate capacity. By staging participation over Years 1, 2, 5 and 10, the study captures the transition from consumer-led benefits (when demand is scarce and can absorb almost all exports) to prosumer-led benefits (when the consumer base has expanded enough to draw down nearly all local production). Parking canopies, which lack self-consumption, are particularly effective in the first phase: they lift shared energy from the outset and reduce the reliance on RID. Over time, the widening consumer base tightens the coupling between exports and internal demand, ensuring that prosumer production is more often valued within the CER rather than at wholesale-linked RID prices.
- Third, results are sensitive to operational choices that fall within the control of the community. The internal allocation rule adopted in this work (retaining a share for management and distributing the remainder between consumers and producers) proves both transparent and adaptable. Because revenues derive from the hourly minimum between aggregated exports and aggregated demand, improvements in flexibility directly translate into higher shared-energy volumes. Practical measures include aligning hotel and commercial operations with sunny hours when feasible, promoting load-shifting behaviours among households, and, where justified, integrating storage at sites with recurrent afternoon surpluses. These actions do not require changes to the regulatory perimeter; they leverage the same assets more effectively.

Methodologically, the thesis contributes to a reproducible approach. It links building-scale producibility (from rooftop geometry and HelioScope simulations for carports) to empirically shaped demand profiles for each user class; allocates both to the substation level; and evaluates hourly balances to compute self-consumption, exports, shared energy and residual grid exchanges. The economic layer then translates these flows into participant-level outcomes by applying the GSE incentive to shared energy and the RID channel to non-shared exports, while valuing on-site use at a representative retail price. Because the same steps can be executed with publicly accessible datasets and open tools, the workflow is portable and suitable for replication by municipalities and utilities.

Taken together, the Entrèves, P.S.Didier and Morgex cases suggest a pragmatic roadmap for Alpine CERs. Start where simultaneity is highest (tourism hubs, municipal complexes, daytime commercial clusters) and build early critical mass with parking canopies and compliant rooftops. Use clear, statute-based redistribution rules to keep incentives aligned as participation scales. Plan for a steadystate around Year 10, when further gains depend less on adding members and more on coordinating operations and, selectively, storage. Within these boundaries, CERs can deliver measurable economic benefits to residents and businesses while improving the resilience of local grids and accelerating the deployment of renewables in the Valdigne.

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