



From Policy Failure to Collective Self-Consumption: The Penthéréaz Agrivoltaic Energy Community in Switzerland [†]

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Abstract

Policy instability and regulatory barriers remain key obstacles to the long-term viability of agriphotovoltaics (APV) deployment. The Penthéréaz case in Switzerland provides empirical evidence of how cooperative governance and collective self-consumption can restore project feasibility after subsidy withdrawal. Using a single-case study and process-tracing approach based on cooperative documentation and regulatory records, the analysis explains how Penthéréaz Énergie Photovoltaïque S.A. cooperative (PEP), initially structured as a subsidy-dependent venture, transitioned into a resilient collective self-consumption network supported by a private micro-grid. Following the withdrawal of federal feed-in tariffs, the project faced major economic risk and responded through decentralized financial restructuring, including community-funded debt at a 2% interest rate. The installation comprises 1180 photovoltaic panels with an installed capacity of 283 kWp, producing approximately 290,000 kWh per year while providing water-tightness and light permeability for agricultural infrastructure. The findings further indicate that operational success contributed to Swiss regulatory adjustments, enabling private distribution networks to cross public roads and secure geographic continuity for local energy sharing. With a reported self-consumption rate of 40% across a diversified user base including agri-food and residential consumers, the case demonstrates the operational value of local load-matching. The findings propose six context-dependent lessons derived from a single case, emphasizing governance capacity, tariff risk management, regulatory adaptability, and demand-oriented system design.

Keywords: solar energy; ground-mounted photovoltaic systems; global warming; land productivity; renewable energy; food production; water scarcity



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1. Introduction: Why Do Agrophotovoltaics Matter Today?

APV systems, also referred to as agrivoltaics or solar dual-use, increase land-use efficiency by enabling photovoltaic electricity generation and agricultural production on the same parcel of land [1,2], as shown in Figure 1. By combining two outputs within one spatial footprint, agrivoltaics offers a practical response to rising energy demand, climate-related stress on farming systems, and increasing competition for land resources. The efficiency of this dual-use approach is commonly assessed through the Land Equivalent Ratio (LER), which compares the combined yield of food and electricity to the yield achieved

by separate, single-use agricultural and photovoltaic systems [2]. Reported results indicate substantial gains: in specific configurations, one hectare can deliver the equivalent of 103% of agricultural output plus 83% of solar electricity that would otherwise require two separate hectares, corresponding to 186% combined efficiency [1]. Reviews of the literature further report typical LER values ranging from 1.35 to 1.7, with optimized designs reaching 2.0 to 3.0 in favorable contexts [2].



Figure 1. Orchard cultivation under an agrivoltaic installation at Kressbronn on Lake Constance [3].

At the macro scale, APV has been discussed as a land resource optimization strategy capable of supporting decarbonization without displacing agriculture. Under favorable assumptions, dedicating only 1% of current arable land to APV electricity production has been estimated to theoretically offset global energy demand [1]. Similarly, pathways toward global net-zero emissions by 2050 have been associated with an estimated requirement of approximately 65.5 million hectares for solar photovoltaic deployment, representing around 1.5% of the land currently used for agricultural production [2]. Taken together, these estimates highlight the strategic relevance of dual-use systems for balancing renewable energy expansion with long-term food-security constraints.

Beyond land metrics, APV can generate productivity and economic synergies at farm scale. Economic value can rise by more than 30%, with revenues reported to be 4 to 15 times higher than those of standalone agricultural systems under certain conditions [1,2]. Resource efficiencies have also been reported, including improved water-use efficiency up to 150–300% and reductions in irrigation demand of approximately 14% [2]. In arid and semi-arid climates, panel shading can reduce crop heat stress and evaporation, thereby sustaining or increasing yields under water-stressed conditions [1,2]. These benefits, however, require careful design choices: preserving agricultural operations often necessitates higher panel elevation or wider spacing, which may reduce energy generation density by roughly 17% compared to conventional ground-mounted PV systems [2]. Even under these constraints, overall land productivity remains higher because the site is no longer restricted to a single use [2].

In practice, APV layouts are designed to maintain agricultural continuity, with 70–80% of land area reserved for farming activities [4,5]. Structures can allow machinery circulation, with support poles reaching up to 5 m, while direct module coverage may occupy at most 5% of the land area [5]. Panel angles can be adjusted to balance solar harvesting with

crop requirements, contributing to microclimatic moderation and improved soil moisture retention [5]. Reported co-benefits include water savings of 20–30% [5], protection against frost, heatwaves, and hail, and yield increases of 60–70% under appropriate crop selection and climatic conditions, with some studies reporting gains up to 80% [4,5]. Shaded areas can also reduce heat stress for livestock, supporting animal well-being and productivity [5].

Aim, Research Objectives, and Novelty

The aim of this research is to analyze the Penthéreaz APV initiative in Switzerland as a governance and financial transition case in which an APV project moved from subsidy dependence to operational continuity through collective self-consumption and local energy sharing. The study pursues three objectives: first, to document the project's institutional and economic pathway following the withdrawal of federal feed-in remuneration; second, to identify the mechanisms that enabled resilience, particularly cooperative ownership, local load-matching, and private micro-grid implementation; and third, to clarify how regulatory constraints shaped project feasibility and contributed to legal adaptation over time. The novelty of this paper lies in its mechanism-focused reconstruction of a real-world APV project confronted with policy discontinuity, providing a case-based explanation of how decentralized governance and demand-oriented system design can stabilize APV investments under changing national incentive regimes.

2. Methodology

This investigation adopts a single-case study design to examine the Penthéreaz APV project [6], selected for its documented technical performance, cooperative governance structure, and tariff-related institutional transition. To explain how the project evolved from subsidy dependence to decentralized collective self-consumption, the analysis applies process tracing, which conceptualizes causal mechanisms as successive links connecting an initial condition to a final outcome [7]. This approach is consistent with established applications of process tracing in environmental and energy-governance research, particularly in cases involving cooperative actors and regulatory change [8].

The study triangulates three main data sources. First, it draws on financial documentation and grid-access records produced by the PEP. Second, it examines relevant municipal- and cantonal-level regulatory documents. Third, it integrates secondary literature on agri-voltaics and Swiss energy policy to contextualize the project's institutional environment. In particular, the analysis follows the transition from federal feed-in remuneration arrangements to collective self-consumption and private micro-grid implementation, in line with Swiss legal definitions of self-consumption clusters and later local energy communities enabling locally shared photovoltaic electricity [9].

Process tracing is used to reconstruct the project's pathway from policy disruption to operational stabilization and to identify the mechanisms underpinning economic viability. Specific attention is given to how local energy exchange, shared ownership, and regulatory negotiation contributed to maintaining project continuity following the withdrawal of federal feed-in tariffs.

3. Penthéreaz Case Study

3.1. Community Vision

The Penthéreaz APV project was a community initiative from the canton of Vaud in 2012 to develop the production of photovoltaic electricity in the area with the objective of reaching energy self-sufficiency at the local level. The project arose in a general context of deepening concern about the effects of climate change on energy systems and the Swiss national strategy to reduce the use of fossil and nuclear energy. The village had a significant

photovoltaic potential with approximately 6000 m² of available surface using APV. The first installation, completed in 2013, covered 1800 m² (1180 modules) on the roof of a farm building [10], with a capacity of 283 kWp (kilowatt-peak) and a yearly total estimated at around 290,000 kWh [10]. Beyond electricity production, the 1180 panels also functioned as the building envelope by ensuring guaranteed water tightness for the farm hangar, while maintaining light permeability to preserve a functional environment beneath the roof structure [10].

To implement the project, seven local individuals founded PEP. Through this company collective governance was possible and distributed investment was facilitated. About 10% of the village population became shareholders, contributing nearly USD 253,000 by the shareholders out of the total project cost of around USD 600,000 (All monetary values are originally denominated in Swiss francs (CHF) and, where converted, use an approximate 2019 exchange rate of 1 CHF = 1.0 USD; the figures are intended as order of magnitude benchmarks rather than inflation adjusted cross year dollar values) [10]. The initiative was driven primarily by environmental and social motives rather than financial returns.

The installation's economic viability was dependent on the federal feed-in cost-covering remuneration (Rétribution à Prix Coûtant, RPC) scheme that at that time was securing the tariff of USD 0.30–0.31/kWh for a period of 25 years [5]. In September 2012, PEP made its RPC application anticipating that the stable revenue generated would be sufficient for the full amortization of the investment [5]. Hence, the undertaking was not only a technical deployment of decentralized photovoltaic infrastructure but also an institutional experiment of community-based renewable energy governance during the national energy policy transition phase.

3.2. Project Viability: Policy Failure and Regulatory Barriers

The Penthéreaz photovoltaic project was no longer financially viable after the expected federal feed-in tariff (RPC > 0.30 USD/kWh) was not granted. As a result of a country-wide boom in the number of requests for subsidies, the federal allocation criteria were made more stringent after the date of the project's submission, and the plant was thus remunerated only at the normal buy-back rate offered by the utility.

The cooperative thus received:

$$P_{\text{buy-back}} = 0.0821 \text{ USD/kWh} \quad (1)$$

More specifically, electricity reinjected into the grid was remunerated at approximately 0.13 USD/kWh during the period of June 2019–December 2022, offering a concrete reference point for the post-RPC revenue structure [10].

This rate was below the cost of production, leading to a structural deficit:

$$P_{\text{buy-back}} < P_{\text{cost}} \Rightarrow \text{Negative operating margin} \quad (2)$$

The sudden disappearance of the expected tariff undermined the original business model and caused confusion among the cooperative members who had jointly financed the installation. Financial instability was exacerbated because the initial investment could be only partially compensated by a one-time payment, and the bank began applying financial pressure. In response, the cooperative launched a renewed community subscription mechanism, raising funds internally at an interest rate of 2%, which effectively created low-cost cooperative debt and reduced exposure to commercial banking constraints. The project also expected a one-off remuneration (Rémunération Unique, RU) of approximately USD 210,000, partially stabilizing the financial balance after the subsidy collapse [10].

Community members expressed disappointment and a sense of betrayal that the project they had trusted could no longer be sustained under the centralized subsidy regime.

The second hurdle came from distribution rules. At first, Swiss law banned the private transfer of electricity across public roads, considering such crossings as part of the public domain. This made it impossible for the cooperative to provide energy to nearby commercial users needed for demand balancing and load matching at the local level. Therefore, even though self-consumption was more economically beneficial, its execution was legally prohibited.

In an effort to solve this problem, the cooperative transformed the project into a collective self-consumption (Groupement pour la consommation propre, GPC) network that was officially registered as PEP.

Hence, electricity could be sold directly to the local users who were participating at:

$$P_{\text{local}} = 0.201 \text{ USD/kWh} \quad (3)$$

The local sale price met two key conditions:

$$P_{\text{buy-back}} < P_{\text{local}} < P_{\text{retail}} \quad (4)$$

with the regional retail tariff

$$P_{\text{retail}} = 0.242 \text{ USD/kWh} \quad (5)$$

This structure generated mutual benefit:

(a) Consumer savings

$$P_{\text{retail}} - P_{\text{local}} = 0.040 \text{ USD/kWh} \quad (6)$$

(b) Cooperative revenue gains relative to utility buy-back

$$\Delta R = P_{\text{local}} - P_{\text{buy-back}} = 0.119 \text{ USD/kWh} \quad (7)$$

This business margin restored the project's economic feasibility, thus enabling debt repayment in about ten years, and without the need to rely on the withdrawn RPC or the one-off RU subsidy.

Changes in regulation were also facilitated by the cooperative's model. PEP's successful operation was instrumental in changing federal ordinances to allow private distribution networks to cross public roads under certain conditions. The project thus became a reference case for opening up the legal framework for communal self-consumption in Switzerland.

The implementation of the project required more investment in infrastructure:

$$C_{\text{infrastructure}} = 95,637 \text{ USD} \quad (8)$$

The work included installing an electric balancing panel and underground wiring connecting the buildings that were part of the project. The financing of the investment was done jointly; hence, the cooperative governance model was confirmed again.

Penthéréaz demonstrates how local energy communities can restore project viability after losing national policy support by integrating production, distribution, and consumption within a territorially limited cooperative network.

3.3. The Decentralized Self-Consumption Model

The decentralized collective self-consumption model enabled locally generated electricity to be shared among users located in the close vicinity of the production site. In the Penthéréaz configuration, the initial consumption network included three households, a creamery, a cheese cellar, and the host agricultural operation where the photovoltaic installation was located [5]. This user composition is structurally significant because it combines residential demand with agri-food loads, improving consumption smoothing across daily cycles and supporting a reported self-consumption rate of approximately 40% [10]. Operationally, the network required a private micro-grid to distribute power between connected buildings and to maintain balancing across heterogeneous consumption profiles. By prioritizing local load matching, the system reduced reliance on grid export and stabilized revenues through predictable proximity-based consumption, demonstrating how demand configuration and micro-grid infrastructure function as core design variables in community-scale APV deployment [5,10].

4. Six Lessons Learned

The Penthéréaz project experience, together with the broader APV literature, highlights several actionable lessons for implementing dual-use renewable energy systems under real financial and regulatory constraints [11].

4.1. Lesson I: Local Self-Consumption Outperforms Grid Export in Community-Scale APV Projects

The Penthéréaz case shows that collective self-consumption can outperform grid export in community-scale APV projects.

The price gap was decisive: local electricity sales at approximately 0.201 USD/kWh generated sufficient revenue to cover operating costs and debt repayment, whereas the utility buy-back rate of 0.0821 USD/kWh structurally placed the project in deficit [2,7]. In practice, local consumption does not merely improve profitability—it keeps the economic value of energy production embedded in the territory where the infrastructure is deployed.

4.2. Lesson II: Subsidy-Dependent Business Models Are Structurally Fragile

The initial economic feasibility of Penthéréaz relied on receiving a cost-covering federal remuneration of >0.30 USD/kWh over 25 years, which was assumed to secure full investment amortization. When the remuneration scheme was withdrawn, the project entered immediate financial instability, exposing the vulnerability of business models built on uncertain and politically reversible incentives. The case demonstrates that feed-in tariffs may accelerate early deployment, but they cannot be treated as a guaranteed revenue foundation for long-term project survival.

4.3. Lesson III: Community Financing Provides Resilience During Policy and Banking Shocks

Penthéréaz illustrates that community ownership can function as an operational resilience mechanism, not only as an ethical governance principle. Approximately 10% of local residents became shareholders and contributed around USD 253,000 toward the initial capital investment [7]. When the project faced collapse following the subsidy disruption, the cooperative mobilized additional collective investment, about USD 100,000, to fund the private micro-grid infrastructure required for the decentralized self-consumption transition [7]. This capacity to raise internal capital buffered the project against commercial banking pressure and enabled continuity when external policy support failed.

4.4. Lesson IV: Demonstration Projects Can Unlock Regulatory Change When They Prove Feasibility

A major barrier to decentralized self-consumption in Switzerland was the prohibition on transferring electricity across public roads, preventing geographically continuous sharing between nearby plots [2]. Penthérez shows that technically successful pilots can accelerate legal adaptation by demonstrating feasibility and public value.

4.5. Lesson V: System Sizing and User Composition Must Be Designed for Demand Matching, Not Maximum Export

The long-term viability of a community APV project depends on aligning generation capacity with local consumption patterns rather than maximizing exported electricity volumes. Penthérez became viable once electricity could be shared locally among complementary users, including households and agri-food activities, supporting demand balancing at the community scale [2]. This local load matching enabled a reported self-consumption level of approximately 40%, reinforcing that user configuration is not a secondary variable but a core design decision that determines financial performance and system stability [7].

4.6. Lesson VI: Long Implementation Delays Are Normal, but Social Success Remains Possible

Penthérez required more than five years of regulatory adjustment, approval processes, and infrastructure adaptation, far exceeding initial expectations. This confirms that APV deployment operates within slow-moving institutional timelines, particularly when legal frameworks are not designed for decentralized distribution and collective ownership structures. However, the case also shows that high administrative difficulty does not necessarily lead to failure: despite the complexity, overall project satisfaction was rated “Good,” suggesting that community-led projects can sustain legitimacy and support when stakeholders perceive tangible local benefits.

5. Contextual Analysis

The Penthérez project can be situated within a growing body of research on agrivoltaics that examines how dual land use, local governance, and farm-scale energy management shape project performance. Reviews of APV systems show that cooperative or locally anchored ownership, proximity-based energy use, and farmer participation are important mechanisms for improving productivity, profitability, and local value retention in dual-use configurations [2,4,11–13]. In this respect, the Penthérez case corroborates existing findings by empirically illustrating how these mechanisms interact under conditions of policy disruption and subsidy withdrawal [4].

At the same time, the case underscores the importance of institutional and regulatory context for APV deployment. Recent reviews emphasize that policy design, regulatory clarity, and local social acceptance strongly condition APV outcomes, and that supportive legal frameworks can enable agrivoltaics to contribute to local “energy sovereignty” [14–16]. Switzerland’s relatively stable legal environment, cooperative traditions, and high levels of social trust shaped both the pace and form of adjustments related to collective self-consumption and private distribution infrastructure, distinguishing Penthérez from APV projects in more volatile contexts [14–17].

The contribution of the Penthérez case therefore lies not in proposing a universally replicable APV model but in providing context-dependent lessons derived from a single empirical setting. This is consistent with agrivoltaics research that treats case studies as sources of mechanism-based insights, such as how community governance, local load-matching, and regulatory interaction can support long-term continuity of APV investments, while warning that concrete designs must be adapted to local legal frameworks, market structures, and agricultural systems [4,15].

6. Conclusions

The Penthéreaz case demonstrates that the long-term success of agrophotovoltaics depends more on governance, community ownership, and regulatory adaptability than on the technology itself, which is increasingly mature. This paper documents how a renewable energy initiative transitioned from “policy failure”, triggered by the withdrawal of federal feed-in tariffs, to a resilient decentralized model sustained through collective self-consumption, private micro-grid investment, and community-backed financing mechanisms. In doing so, the cooperative reduced exposure to utility constraints and commercial banking pressure by mobilizing low-cost internal capital, including community-funded debt at a 2% interest rate.

Beyond operational viability, Penthéreaz illustrates how agrivoltaics projects can function as institutional experiments capable of driving regulatory change: the demonstrated performance of the network contributed to adjustments in Swiss ordinances, enabling private distribution infrastructure to cross public roads and maintain geographic continuity for local energy sharing. At the same time, the system’s multi-functionality, based on 1180 panels providing both water tightness for agricultural infrastructure and light permeability beneath the structure, reinforces the dual-use value proposition of agrophotovoltaics.

Ultimately, Penthéreaz offers a replicable roadmap for rural energy autonomy grounded in local load-matching, approximately 40% self-consumption, and an evolutionary infrastructure vision that includes hydrogen production as a pathway toward greater energy independence. While regional legal frameworks vary, the central lesson remains transferable: when communities retain control over production and consumption, they can convert administrative complexity into social legitimacy, long-term investment protection, and durable energy transitions.

While derived from one Swiss case, the lessons highlight mechanisms that may inform similar projects, although transferability depends on local regulatory and market conditions.

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