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# Technologie-Monitoring

## Untersuchung der Wirkungsgrade von Photovoltaikmodulen sowie der Investitions- und Betriebskosten von PV-Systemen

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# Long-term technology monitoring

Survey of photovoltaic module efficiencies as well as investment and operating costs of PV systems

**Matthias Hügi, Christof Bucher, Domenico Chianese, Ebrar Özkalay, Mauro Caccivio**
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# Photovoltaic power data sheet

Assumptions for the calculation of future system capital costs and electricity generation costs: Only the module power changes due to the increased efficiency, everything else such as labour costs, operating costs, interest, etc. remains the same.

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[1] All data provided here refers to building-attached or -integrated PV. Large open-ground PV installations have not been addressed.
[2] Including PV module, inverter, labor and other costs according Preisbeobachtungsstudie 2023. The future costs are assumptions made by the authors.
[3] Calculation includes system capital costs as well as costs for operation and maintenance (including replacement of inverter and balance of system during the lifetime). Ranges today are based on the ranges of investment costs and on the following assumptions: irradiation $G_0$ 1200kWh/m$^2$, operating time 25 years, WACC 2 %, PR 80 %, Degeneration 0 %. The future costs are assumptions made by the authors.

# Summary

Average module efficiencies in Switzerland are increasing by around 0.5-0.6 % annually and stood at 21.5 % in 2023; an average value of around 22.5 % is expected by 2025/2026. PERC technology is approaching its efficiency limit, which is why there is an increasing switch to new technologies such as TOPCon and back contact (BC). The first modules with over 25 % efficiency were presented in 2024, while tandem cells with perovskite can achieve over 30 %, but are not yet ready for the market. At the same time, mainly current module technologies are continuing to develop in order to reduce losses.

The average product warranty for solar modules in Switzerland increased to 15 years by 2021. While modern modules only lose around 0.5 % output per year according to manufacturers, independent studies show higher losses, particularly at system level, with partly reversible causes such as soiling or inverter failures. Although new technologies such as TOPCon show progress according degeneration, they also bring with them new degradation mechanisms, which is why research and long-term field measurements are necessary to determine realistic degradation rates.

Compared to roof, agri-pv and carport-pv, which supply around 25 to 30 % of their annual electricity in winter, façade systems perform significantly better at around 39 % and alpine systems at around 43 %. They are particularly valuable in view of the increased demand for electricity during the cold season. Nevertheless, alpine and façade systems have not been widely used to date - mainly due to high investment costs and complex authorisation procedures.

The 2023 price observation study analyses around 3000 rooftop PV systems in Switzerland and shows that the specific costs (CHF/kW) fall with increasing system size. Smaller systems cost an average of CHF 3141/kW, while large systems are significantly cheaper. The main cost drivers for small systems are materials and fixed expenses such as installation and security. Modules account for up to 35 % of the costs for large systems and only 16 % for small ones. The costs for planning, assembly logistics and others make up the rest.

Façade PV (BIPV) is on the upswing in Switzerland but remains expensive and complex. Prices for BIPV façades range between CHF 500 and 950/m² (approx. CHF 2500-4750/kW), depending on the design and project requirements. High costs are incurred due to complex installation, building regulations, including fire safety regulations and design adjustments. This also complicates standardisation. Alpine PV systems are also expensive, with costs between CHF 2640 and 4050/kW, due to difficult construction conditions in the mountains. Agri-PV systems cost between 1546 and 2400 CHF/kW, depending on the construction method and height, plus grid connection costs of up to approx. 500 CHF/kW.

Car park PV systems range in price from 1200 to 3500 CHF/kW, depending on the construction, design and grid connection.

The operating costs of rooftop photovoltaic systems are made up of various items that vary in importance depending on the type of system. These include maintenance and replacement of inverters and other components, insurance, cleaning, monitoring, administration and - for certain systems - also the maintenance of medium-voltage transformers and green roofs.

Nine typical rooftop systems (pitched roof and flat roof with gravel or greenery, in three sizes: 10 kW, 100 kW, 1 MW) were defined for the analysis. Depending on the system concept (e.g. private or professional management, self-consumption or feed-in), individual costs are incurred in full, in part or not at all. The specific operating costs for small systems (10 kW) are around 4.0 Rp./kWh, for medium-sized systems (100 kW) 3.8-5.5 Rp./kWh and for large systems (1 MW) 2.3-3.6 Rp./kWh.

Cost trends show that operating costs for the defined plants have risen slightly since 2018, which is partly due to higher assumed investment costs for inverters. However, an estimate of the operating costs for the average 15 kW system installed today results in lower costs of approx. 3.1 Rp./kWh.

The following values result for other system types: façade PV is at 4.0 Rp./kWh, agri-pv at 4.6 Rp./kWh and carport-pv at 3.9 Rp./kWh. Significantly higher operating costs are assumed for alpine systems (5.0 Rp./kWh), in particular due to more difficult access and higher maintenance costs. However, hardly any empirical values are yet available for agri-pv, carport-pv and alpine systems.

# Zusammenfassung

Die durchschnittlichen Wirkungsgrade von Photovoltaikmodulen in der Schweiz steigen jährlich um etwa 0,5–0,6 Prozentpunkte und lagen 2023 bei 21,5 %. Für 2025/2026 wird ein Durchschnittswert von rund 22,5 % erwartet. Die PERC-Technologie (Passivated Emitter and Rear Cell) stösst an ihre Wirkungsgradgrenze, weshalb zunehmend auf neue Technologien wie TOPCon und Back Contact (BC) umgestellt wird. Die ersten Module mit einem Wirkungsgrad von über 25 % wurden 2024 vorgestellt, während Tandemzellen mit Perowskit über 30 % erreichen können, aber noch nicht marktreif sind. Gleichzeitig werden hauptsächlich die aktuellen Modultechnologien weiterentwickelt, um die Verluste zu reduzieren.

Die durchschnittliche Produktgarantie für Solarmodule in der Schweiz wurde seit 2021 auf 15 Jahre verlängert. Während moderne Module laut Herstellerangaben nur etwa 0,5 % Leistung pro Jahr verlieren, zeigen unabhängige Studien höhere Verluste, insbesondere auf Systemebene, mit teilweise reversiblen Ursachen wie Verschmutzung oder Wechselrichterausfällen. Obwohl neue Technologien wie TOPCon Fortschritte bezüglich Degenerationsverlusten zeigen, gehen sie auch mit neuen Degradationsmechanismen einher, welche aktuell erforscht werden. Daher sind Langzeitmessungen im Feld notwendig, um realistische Degradationsraten zu ermitteln.

Im Vergleich zu Dach-, Agri- und Carport-PV-Anlagen, die etwa 25 bis 30 % ihrer jährlichen Stromproduktion im Winterhalbjahr bereitstellen, schneiden Fassadenanlagen mit rund 39 % und alpine Anlagen mit rund 43 % deutlich besser ab. Angesichts des erhöhten Strombedarfs in der kalten Jahreszeit sind sie besonders wertvoll. Dennoch sind alpine und Fassadenanlagen bisher nicht weit verbreitet – hauptsächlich aufgrund hoher Investitionskosten und komplexer Genehmigungsverfahren.

Die Preisbeobachtungsstudie 2023 analysiert rund 3000 Dach-PV-Anlagen in der Schweiz und zeigt, dass die spezifischen Kosten (CHF/kWp) mit zunehmender Anlagengrösse sinken. Kleinere Anlagen (2–10 kWp) kosten durchschnittlich 3141 CHF/kWp, während grössere Anlagen deutlich günstiger sind. Die Hauptkostentreiber bei kleinen Anlagen sind Materialkosten und Fixkosten wie Installation und Sicherheit. Die eigentlichen Module machen bis zu 35 % der Kosten grosser Anlagen und nur 16 % der Kosten kleiner Anlagen aus. Die Kosten für Planung Logistik und Sonstiges machen den Rest aus.
Fassaden-Photovoltaik (Building-integrated photovoltaics, BIPV) ist in der Schweiz auf dem Vormarsch, bleibt aber teuer und komplex. Die Preise für BIPV-Fassaden liegen je nach Design und Projektanforderungen zwischen CHF 500 und CHF 950/m² (ca. CHF 2500–4750/kWp). Hohe Kosten entstehen durch die aufwendige Installation, die Einhaltung von Bauvorschriften unter anderem bezüglich Brandschutzes und die notwendigen Designanpassungen, was auch die Standardisierung erschwert.
Auch alpine Photovoltaikanlagen sind teuer und kosten zwischen CHF 2640 und 4050/kWp, bedingt durch die schwierigen Baubedingungen in den Bergen. Agri-Photovoltaikanlagen kosten je nach Bauweise und Höhe zwischen CHF 1546 und 2400/kWp, zuzüglich Netzanschlusskosten von bis zu ca. 500 CHF/kWp.
Die Preise für Photovoltaikanlagen auf Parkplätzen liegen je nach Bauweise, Design und Netzanschluss zwischen 1200 und 3500 CHF/kWp.

Die Betriebskosten von Dach-Photovoltaikanlagen setzen sich aus verschiedenen Kostenfaktoren zusammen, deren Bedeutung je nach Anlagentyp variiert. Dazu gehören Wartung und Austausch von Wechselrichtern und anderen Komponenten, Versicherung, Reinigung, Überwachung, Verwaltung und – bei bestimmten Anlagen – auch die Wartung von Mittelspannungstransformatoren und Gründächern. Für die Analyse wurden neun typische Dachsysteme (Schrägdach und Flachdach mit Kies oder Begrünung, in drei Grössen: 10 kWp, 100 kWp, 1 MWp) definiert. Je nach Systemkonzept (z. B. private oder gewerbliche Nutzung, Eigenverbrauch oder Einspeisung) fallen die einzelnen Kosten vollständig, teilweise oder gar nicht an. Die spezifischen Betriebskosten für kleine Anlagen (10 kW) liegen bei etwa 4,0 Rp./kWh, für mittelgrosse Anlagen (100 kW) bei 3,8–5,5 Rp./kWh und für grosse Anlagen (1 MW) bei 2,3–3,6 Rp./kWh.

Die Kostenentwicklung zeigt, dass die Betriebskosten der genannten Anlagen seit 2018 leicht gestiegen sind, was teilweise mit höher angenommenen Investitionskosten von Wechselrichtern zu tun hat. Eine Schätzung der Betriebskosten für eine durchschnittlich heute installierte 15-kW-Anlage ergibt jedoch niedrigere Kosten von ca. 3,1 Rp./kWh.
Für andere Systemtypen ergeben sich folgende Werte: Fassaden-PV 4,0 Rp./kWh, Agri-PV 4,6 Rp./kWh und Carport-PV 3,9 Rp./kWh. Für alpine Anlagen werden deutlich höhere Betriebskosten (5,0 Rp./kWh) angenommen, insbesondere aufgrund des schwierigeren Zugangs und der höheren Wartungskosten. Allerdings liegen bisher kaum empirische Werte für Agri-PV-, Carport-PV- und alpine Anlagen vor.

# Résumé

En Suisse, le rendement moyen des modules photovoltaïques progresse d'environ 0,5 à 0,6 point de pourcentage par an, pour atteindre 21,5 % en 2023. Une valeur moyenne d'environ 22,5 % est attendue pour 2025/2026. La technologie PERC (Passivated Emitter and Rear Cell) atteint ses limites de rendement, ce qui explique le recours croissant à de nouvelles technologies telles que TOPCon et Back Contact (BC). Les premiers modules affichant un rendement supérieur à 25 % ont été commercialisés en 2024, tandis que les cellules tandem à pérovskite peuvent dépasser les 30 %, mais ne sont pas encore prêtes pour le marché. Parallèlement, les efforts se concentrent principalement sur la réduction des pertes des technologies de modules actuelles.

En Suisse, la garantie moyenne des modules solaires a été étendue à 15 ans depuis 2021. Si, selon les fabricants, les modules modernes ne perdent qu'environ 0,5 % de leur puissance par an, des études indépendantes font état de pertes plus importantes, notamment au niveau du système, dues à des causes parfois réversibles comme l'encrassement ou les défaillances d'onduleurs. Bien que de nouvelles technologies comme TOPCon présentent des améliorations en matière de réduction des pertes par dégradation, elles impliquent également de nouveaux mécanismes de dégradation actuellement à l'étude. Par conséquent, des mesures sur le terrain à long terme sont nécessaires pour déterminer des taux de dégradation réalistes.

Comparés aux systèmes photovoltaïques installés sur toiture, en agriculture ou sur abri de voiture, qui produisent environ 25 à 30 % de leur production annuelle d'électricité durant l'hiver, les systèmes intégrés en façade (environ 39 %) et les systèmes alpins (environ 43 %) affichent des performances nettement supérieures. Compte tenu de la demande accrue d'électricité pendant les mois les plus froids, ils sont particulièrement intéressants. Néanmoins, les systèmes alpins et intégrés en façade restent encore peu répandus, principalement en raison de leurs coûts d'investissement élevés et de la complexité des procédures d'autorisation.

L'étude de suivi des prix de 2023, portant sur environ 3 000 installations photovoltaïques en toiture en Suisse, montre que les coûts spécifiques (CHF/kWc) diminuent avec la taille de l'installation. Les petites installations (2 à 10 kWc) coûtent en moyenne 3 141 CHF/kWc, tandis que les grandes installations sont nettement moins chères. Les principaux facteurs de coût pour les petites installations sont le coût des matériaux et les coûts fixes tels que l'installation et la sécurité. Les modules représentent jusqu'à 35 % du coût des grandes installations et seulement 16 % du coût des petites installations. La planification, la logistique et les autres dépenses constituent le reste.
Le photovoltaïque intégré au bâtiment (PVIB) gagne du terrain en Suisse, mais demeure coûteux et complexe. Les prix des façades PVIB varient de 500 à 950 CHF/m² (environ 2 500 à 4 750 CHF/kWc), selon la conception et les exigences du projet. Les coûts élevés s'expliquent par la complexité de l'installation, le respect des normes de construction (notamment en matière de sécurité incendie) et les adaptations nécessaires à la conception, ce qui complique également la normalisation.
Les systèmes photovoltaïques alpins sont également onéreux, leur coût se situant entre 2 640 et 4 050 CHF/kWc en raison des conditions de construction difficiles en montagne. Les systèmes photovoltaïques agricoles coûtent entre 1 546 et 2 400 CHF/kWc, selon la conception et l'altitude, auxquels s'ajoutent des frais de raccordement au réseau pouvant atteindre environ 500 CHF/kWc.
Les prix des systèmes photovoltaïques sur les parkings varient de 1 200 à 3 500 CHF/kWc, selon la conception, la construction et le raccordement au réseau.

Les coûts d'exploitation des systèmes photovoltaïques en toiture comprennent divers facteurs, dont l'importance varie selon le type de système. Ces coûts incluent la maintenance et le remplacement des onduleurs et autres composants, l'assurance, le nettoyage, la surveillance, l'administration et, pour certains systèmes, la maintenance des transformateurs moyenne tension et des toitures végétalisées. Pour cette analyse, neuf systèmes de toiture types (toitures inclinées et plates, recouvertes de gravier ou végétalisées, de trois puissances différentes : 10 kWc, 100 kWc et 1 MWc) ont été définis. Selon le mode d'utilisation (usage privé ou commercial, autoconsommation ou injection dans le réseau), les différents coûts sont supportés intégralement, partiellement ou pas du tout. Les coûts d'exploitation spécifiques sont d'environ 4,0 Cts/kWh pour les petits systèmes (10 kW), de 3,8 à 5,5 Cts /kWh pour les systèmes de taille moyenne (100 kW) et de 2,3 à 3,6 Cts /kWh pour les grands systèmes (1 MW).

L'évolution des coûts montre que les coûts d'exploitation des systèmes susmentionnés ont légèrement augmenté depuis 2018, notamment en raison de l'augmentation des coûts d'investissement prévus pour les onduleurs. Cependant, une estimation des coûts d'exploitation d'un système moyen de 15 kW installé aujourd'hui aboutit à des coûts inférieurs, d'environ 3,1 Cts/kWh.
Pour les autres types de systèmes, les valeurs suivantes s'appliquent : photovoltaïque intégré en façade : 4,0 Cts/kWh ; photovoltaïque agrivoltaïque : 4,6 Cts/kWh ; et photovoltaïque intégré à un abri de voiture : 3,9 Cts/kWh. Des coûts d'exploitation nettement plus élevés (5,0 Cts/kWh) sont prévus pour les systèmes alpins, principalement en raison d'un accès plus difficile et de coûts de maintenance plus importants. Toutefois, il existe actuellement très peu de données empiriques disponibles pour les systèmes agrivoltaïques, intégrés à un abri de voiture et alpins.

# Riepilogo

In Svizzera, l'efficienza media dei moduli fotovoltaici sta aumentando di circa 0,5-0,6 punti percentuali all'anno, raggiungendo il 21,5 % nel 2023. Si prevede un valore medio di circa il 22,5 % per il 2025/2026. La tecnologia PERC (Passivated Emitter and Rear Cell) sta raggiungendo i suoi limiti di efficienza, il che spiega il crescente utilizzo di tecnologie più recenti come TOPCon e Back Contact (BC). I primi moduli con un'efficienza superiore al 25 % sono stati commercializzati nel 2024, mentre le celle tandem in perovskite possono superare il 30 %, ma non sono ancora pronte per il mercato. Allo stesso tempo, gli sforzi si concentrano principalmente sulla riduzione delle perdite nelle attuali tecnologie dei moduli.

In Svizzera, la garanzia media per i moduli solari è stata estesa a 15 anni dal 2021. Mentre i produttori affermano che i moduli moderni perdono solo circa lo 0,5 % della loro potenza all'anno, studi indipendenti segnalano perdite maggiori, soprattutto a livello di sistema, dovute a cause talvolta reversibili come sporcamento o guasti agli inverter. Sebbene nuove tecnologie come TOPCon offrano miglioramenti nella riduzione delle perdite dovute al degrado, esse implicano anche nuovi meccanismi di perdita di efficienza attualmente in fase di studio. Pertanto, sono necessarie misurazioni sul campo a lungo termine per determinare tassi di degrado realistici.

Rispetto ai sistemi fotovoltaici montati su tetti, in agricoltura o su tettoie, che producono circa il 25-30 % della loro produzione elettrica annua durante l'inverno, i sistemi integrati in facciata (circa il 39 %) e i sistemi alpini (circa il 43 %) mostrano prestazioni significativamente più elevate. Data la maggiore domanda di elettricità durante i mesi più freddi, sono particolarmente interessanti. Tuttavia, i sistemi fotovoltaici alpini e integrati in facciata rimangono relativamente poco comuni, principalmente a causa dei loro elevati costi di investimento e della complessità dei processi autorizzativi.

Lo studio di monitoraggio dei prezzi del 2023, che ha preso in esame circa 3.000 impianti fotovoltaici su tetto in Svizzera, mostra che i costi specifici (CHF/kWp) diminuiscono con l'aumentare delle dimensioni dell'impianto. Gli impianti di piccole dimensioni (da 2 a 10 kWp) costano in media 3.141 CHF/kWp, mentre gli impianti più grandi sono significativamente meno costosi. I principali fattori di costo per i piccoli impianti sono il costo dei materiali e i costi fissi come l'installazione e la sicurezza. I moduli rappresentano fino al 35 % del costo degli impianti di grandi dimensioni e solo il 16 % di quelli di piccole dimensioni. La restante parte è costituita da progettazione, logistica e altre spese. Il fotovoltaico integrato negli edifici (BIPV) sta prendendo piede in Svizzera, ma rimane costoso e complesso. I prezzi delle facciate BIPV variano da 500 a 950 CHF/m² (circa 2.500-4.750 CHF/kWp), a seconda della progettazione e dei requisiti del progetto. I costi elevati sono dovuti alla complessità dell'installazione, al rispetto delle normative edilizie (in particolare quelle antincendio) e ai necessari adattamenti progettuali, che complicano ulteriormente la standardizzazione.
Anche gli impianti fotovoltaici alpini sono costosi, con un costo compreso tra 2.640 e 4.050 CHF/kWp a causa delle difficili condizioni di costruzione nelle regioni montuose. Gli impianti fotovoltaici agricoli costano tra 1.546 e 2.400 CHF/kWp, a seconda del progetto e dell'altitudine, a cui si aggiungono i costi di allacciamento alla rete fino a circa 500 CHF/kWp.
I prezzi degli impianti fotovoltaici sui parcheggi variano da 1.200 a 3.500 CHF/kWp, a seconda del progetto, della costruzione e dell'allacciamento alla rete.

I costi di esercizio degli impianti fotovoltaici su tetto includono diversi fattori, la cui importanza varia a seconda del tipo di impianto. Questi costi includono la manutenzione e la sostituzione di inverter e altri componenti, l'assicurazione, la pulizia, il monitoraggio, l'amministrazione e, per alcuni impianti, la manutenzione dei trasformatori di media tensione e dei tetti verdi. Per questa analisi, sono stati definiti nove tipici impianti su tetto (tetti inclinati e piani, ricoperti di ghiaia o piantumati, con tre diverse capacità: 10 kWp, 100 kWp e 1 MWp). A seconda del modello di utilizzo (uso privato o commerciale, autoconsumo o immissione in rete), i diversi costi vengono sostenuti interamente, parzialmente o per niente. I costi operativi specifici sono di circa 4,0 Rp/kWh per gli impianti di piccole dimensioni (10 kW), da 3,8 a 5,5 Rp/kWh per gli impianti di medie dimensioni (100 kW) e da 2,3 a 3,6 Rp/kWh per gli impianti di grandi dimensioni (1 MW).

L'andamento dei costi mostra che i costi operativi dei sistemi sopra menzionati sono leggermente aumentati dal 2018, principalmente a causa dei maggiori costi di investimento previsti per gli inverter. Tuttavia, una stima dei costi operativi per un sistema medio da 15 kW installato oggi risulta inferiore, attestandosi a circa 3,1 Rp/kWh.
Per altre tipologie di impianto, si applicano i seguenti valori: fotovoltaico integrato in facciata: 4,0 Rp/kWh; agrivoltaico: 4,6 Rp/kWh; e fotovoltaico integrato in pensilina: 3,9 Rp/kWh. Si prevedono costi operativi significativamente più elevati (5,0 Rp/kWh) per gli impianti alpini, principalmente a causa della maggiore difficoltà di accesso e dei maggiori costi di manutenzione. Tuttavia, sono attualmente disponibili pochissimi dati empirici per gli impianti agrivoltaici, integrati in pensilina e alpini.

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# 1 Introduction

The efficiency of photovoltaic (PV) modules is constantly increasing due to ongoing technical development. The costs of procuring a PV system and its operating costs are also changing. Planair last produced a publication in 2024 on behalf of EnergieSchweiz, in which the investment costs of rooftop systems from 2023 were analysed [1]. Basler & Hofmann also produced a study on the operating costs of PV systems in 2015 [2]. There was another update to this study in 2018, but it was never published.

This project aims to update the investment and operating costs of PV systems. This for roof and façade systems, but also for Agri PV, Alpine PV and car park PV. In addition, current efficiencies of PV modules are to be analysed and the lifetime and degradation of PV modules are to be determined. The various system types from this report are briefly explained below.

**Roof PV systems**
With PV systems on roofs, a basic distinction can be made between two different types: Rooftop systems and in-roof systems. In this study, the focus is on rooftop systems, as these are built much more frequently. In Planair's 2023 price observation study, 95 % of all systems analysed were rooftop systems. This price observation study is used to illustrate the investment costs for rooftop systems and thus forms an important basis for the analyses. Of the PV systems analysed in this report, the rooftop system places the lowest demands on planning and installation.

**Façade PV systems**
Well known also as cold or ventilated façade, this system consists of a load-bearing substructure, an air gap, and cladding [3]. PV elements are typically integrated in a similar way to non-active building claddings. During the summer, heat from the sun is dissipated through the cavity, which is naturally ventilated via bottom and top openings. The cold façade is particularly effective for improving rear ventilation. There are various construction models and technological solutions available on the market, offering a range of joint and fixing options.

**Alpine PV systems**
Alpine PV systems can be planned and realised more easily since the amendment to the Energy Act in September 2022. Due to the location far above the fog line and the existing reflections in the snow or on the water surface (high albedo values), the systems produce a large proportion of energy, especially in the winter months. This should lead to a reduction in the winter electricity gap. Only very few plants are currently in operation in Switzerland. These are five plants on dams and one each on a retaining wall, on a lake and on a slope. However, none of these installations provide sufficiently relevant information for the new installations planned in accordance with EnG 71a, as they are small or already relatively old.

**Agri PV systems**
The amendment to the Spatial Planning Ordinance in July 2022 makes it possible to realise Agri PV facilities. The plant must either be located in less sensitive areas and provide benefits for agricultural production or serve appropriate experimental and research purposes. Since then, some plants such as Bioschmid or Beerenland have been realised, but hardly any results are yet available from these plants. In Switzerland, the focus is currently mainly on permanent crops, although it would also be possible to create such systems on meadows or arable land. Accordingly, most systems are located above berry or fruit plantations.

**Car park PV systems**
With the new subsidy conditions for PV systems, bonuses can now also be obtained for car park PV systems with a installed power of at least 100 kW. This should lead to PV systems being installed above large car parks with the idea that electric charging stations will also be installed there, and the electricity can be consumed on site. For this reason, the focus of this study is on systems with a installed power of at least 100 kW. Small carport systems for a few cars, which are often installed in private households, are not considered. There are a few systems of this size in Switzerland, but only a few of them have empirical values regarding costs.

# 2 Methodology

### 2.1 Trend of module efficiency

The increase in efficiency of PV modules is determined from various sources. The sources used for this analysis are listed below:

- Database of the company Eturnity
- Module database of California Energy Commission [4]
- Database of BFH with new product announcements
- International Technology Roadmap for Photovoltaic (ITRPV)

Procedure:

1. The median efficiencies from available module databases are calculated per year (California module database and Eturnity).
2. The volume-weighted median efficiency of modules sold in Switzerland is determined using data from Eturnity.
3. The delay between best modules and modules with volume-weighted average efficiency is estimated on the basis of the PV modules announced on the market (Database of BFH). This allows an estimate to be made of the expected efficiencies over the next 2-3 years.
4. Based on the research successes of recent years, the efficiencies effectively available on the market for the next few years are estimated. This is based on the assumption that the delay between research success and market launch is roughly constant.
5. Outlook on what further developments can be expected for modules in the future.

Description of the sources:
The company Eturnity has developed software that can be used to create and calculate PV projects and generate indicative offers and quotations. A large proportion of all quotations created in Switzerland are generated using this software. This database is analysed to determine module efficiency trends. On the one hand, the database contains all the modules you have offered in Switzerland, including the date of entry and module efficiency. On the other, the number of offers with the same modules can be determined. This information can be used to determine the average efficiency (median) of the modules over the various years. It is also possible to calculate a volume-weighted efficiency trend based on the number of offers.

The module database of the California Energy Commission contains all PV modules that meet the national safety and performance standards in the USA. In this list, there is a separate entry for each performance of a module type. Among other things, the listing date, the power at STC and the module area are listed. The module efficiency can be determined from the last two entries using the following formula:

$$\eta = \frac{P_{Mod_{STC}}}{G_{STC} * A_{Mod}}$$

Modules without a listing date are not included in this analysis as they cannot be assigned to a year. Using the calculated efficiency, the average efficiency (median) of the modules over the various years can be determined in the same way as Eturnity.

The BFH database contains module announcements of manufacturers since 2021, including the publication date and module efficiency of these announcements. Only the most efficient module of a particular type is listed. Modules without a publication date are not included in the analysis. The remaining modules are used to determine the average efficiency (median) of the modules over the various years, analogous to Eturnity.

The document “International Technology Roadmap for Photovoltaic” (ITRPV) shows technological trends, challenges and progress in the solar energy sector. It is compiled by companies in the solar industry and industry associations. Among other things, it shows the development of improvements in energy yield at cell and module level for various technologies.

## 2.2 Degradation (lifetime) of modules

The degradation (and lifetime) of the modules is determined based on manufacturer guarantees, the ITRPV report and real-life degradation rate studies of commercial products from literature. The product and performance guarantee of modules is specifically calculated using the Eturnity database. This contains the product guarantee[1] (for each module type), as well as the performance guarantee after a certain number of years. The degradation rate is calculated from these values according to the following formula:

$$\text{degradation rate}[\%/year] = \frac{100\ \% - Normalized\ performance\ [\%]}{Duration\ [year]}$$

As an example, 85 % performance after 25 years results in a degradation rate of 0.6 % per year. The annual change in the performance guarantee per year and the guarantee period are given as an indicator of the life expectancy of the technology.

## 2.3 Winter electricity share

Due to their design and location, the different types of system have different behaviour in the production of winter electricity. For this reason, the winter electricity share of the following plant types is to be determined using various sources:

| Type of PV system | Source |
|---|---|
| Roof | • Study «Studie Winterstrom Schweiz» [5] |
| Façade | • Study «Studie Winterstrom Schweiz» [5] |
| Alpine PV | • Published project data on alpine-pv.ch [6]<br>• Study: «Harnessing solar power in the Alps: A study on the financial viability of mountain PV systems» [7] |
| Agri PV | • Feedback Bioschmid<br>• Study «Potenzialabschätzungen für Agri-PV in der Schweizer Landwirtschaft» [8]<br>• Comparison with Rooftop systems |
| Car park PV | • Comparison with Rooftop systems |

Table 1: Sources for determining the winter electricity share

In the case of roof and façade systems, results from the existing study are explained. In the case of alpine systems, a study is used on the one hand and the information provided by project participants is analysed on the other. As almost no free-standing alpine PV systems exist in Switzerland, no real data from such systems can be analysed.

As there are no comprehensive studies or information on Agri PV and car park PV, these two are also assessed on the basis of rooftop systems. In contrast to rooftop systems, Agri PV and car park PV systems are elevated and have a bifacial share. In particular, both systems are often located in similar places to rooftop systems.

## 2.4 Trend of investment costs

The investment costs of systems are constantly changing due to changes in product prices, but also because the amount of labour required or the cost of certain work changes. The investment costs for the types of plant listed below are therefore evaluated using different sources:

[1] Manufacturer's promise to repair, replace, or refund a product if it has defects or malfunctions within a specified period.

| Type of PV system | Source |
| --- | --- |
| Roof | • Report «Photovoltaikmarkt: Preisbeobachtungsstudie 2023» [1] |
| Façade | • BIPV status report 2020 and 2024<br>• Interviews with installers |
| Alpine PV | • Published project data on alpine-pv.ch [6]<br>• Study: «Harnessing solar power in the Alps: A study on the financial viability of mountain PV systems» [7] |
| Agri PV | • Markus Markstaler (OST/Swissolar) [9]<br>• Feedback Insolight + Bioschmid<br>• Study: «Potenzialabschätzungen für Agri-PV in der Schweizer Landwirtschaft» [8] |
| Car park PV | • Study «Photovoltaik-Potenzial auf Infrastrukturbauten und bei weiteren sehr grossen Anlagen im Kanton Zürich»<br>• Interview with Helion<br>• Offers from various manufacturers out of the internet |

Table 2: Sources for determining the investment costs

The investment costs of rooftop systems are not reassessed. Planair has been conducting this annually since 2020 on behalf of EnergieSchweiz. The most important results from the current study "Photovoltaic market: price observation study 2023" will be adopted and evaluated. For façade systems, the results from the BIPV study are considered in particular. In the case of Agri PV, the existing study is compared with information from interviews and an attempt is made to draw conclusions from this. In the case of parking spaces, a distinction is made between rooftop and integrated in order to compare the options.

### 2.5 Trend of operating costs

The operating costs are determined on the basis of different interviews with professional plant operator and feedback of contracting companies. The methodology is basically taken from the study «Betriebskosten von PV-Anlagen» by ZHAW and Basler & Hofmann [2] and the not published update of this study. In the original 2015 study, a survey was also created and sent out in addition to this personal survey. However, only a few responses were received from this survey. For this reason, a general survey was dispensed with in this new study and only personal interviews have been conducted. Interviews are conducted with the following companies:

- Youdera (information based on a survey among seven PV contracting companies)
- ADEV (information about contracting PV systems)
- Solarify (information about contracting PV systems)
- BE Netz AG (information about service and maintenance costs and a detailed company-internal statistics conducted over 500-1'000 PV systems with focus on monitoring)
- Mobiliar (information about natural hazard insurance and liability insurance)
- Electrosuisse (information about GO and re-audit)
- Eight different cleaning companies (information about costs of cleaning plants)

Another finding of the Basler & Hofmann study was that not all costs can be directly attributed to the photovoltaic system. There are costs that would also be incurred without PV. This was also adopted in the same way.

Assumptions are made for the other system types (façade, Alpine PV, Agri-PV and car park PV), if available also with the help of experts from the industry.

## 2.6 Trend of Levelized Cost of Electricity (LCOE)

The LCOE of the various plants are determined using the different sources listed below. They are categorised by plant type and size as far as possible, assuming the OPEX of the various plant types (if not known). Assumptions are also made regarding the expected energy production of the plants. The LCOEs are calculated for the Burgdorf, Lugano and Sedrun sites, with the exception of the Alpine plant.

| Type of PV system | Source |
|---|---|
| Roof | • Calculation out of investment and operating costs |
| Façade | • Calculation out of investment and operating costs |
| Alpine PV | • Calculation out of investment and operating costs<br>• Study: «Harnessing solar power in the Alps: A study on the financial viability of mountain PV systems» [7] |
| Agri PV | • Calculation out of investment and operating costs<br>• Markus Markstaler (OST/Swissolar) [9]<br>• Study: «Potenzialabschätzungen für Agri-PV in der Schweizer Landwirtschaft» [8] |
| Car park PV | • Calculation out of investment and operating costs<br>• Study «Solarstrom auf Parkplatzüberdachungen» [10] |

Table 3:Sources for determining the LCOE

# 3 Calculation and Results

### 3.1 Trend of module efficiency

Figure 1 shows the development of module efficiency over the last few years from the various sources, including an outlook for the coming years. The data from the California Energy Commission (CalEnCo) and the data from Eturnity are almost identical. It can also be seen that the data from Eturnity hardly changes if a weighting is made based on the number offered. In 2023, modules with an average efficiency of 21.5 % were sold in Switzerland. The efficiency of the modules sold has increased by 0.5 - 0.6 % per year in recent years. A comparison with the development of the efficiency of new module announcements shows that the average module efficiency currently sold is around two to three years behind, based on BFH's database. It can therefore be assumed that the average efficiency of the modules sold in 2025/2026 will be around 22.5 % in Switzerland.

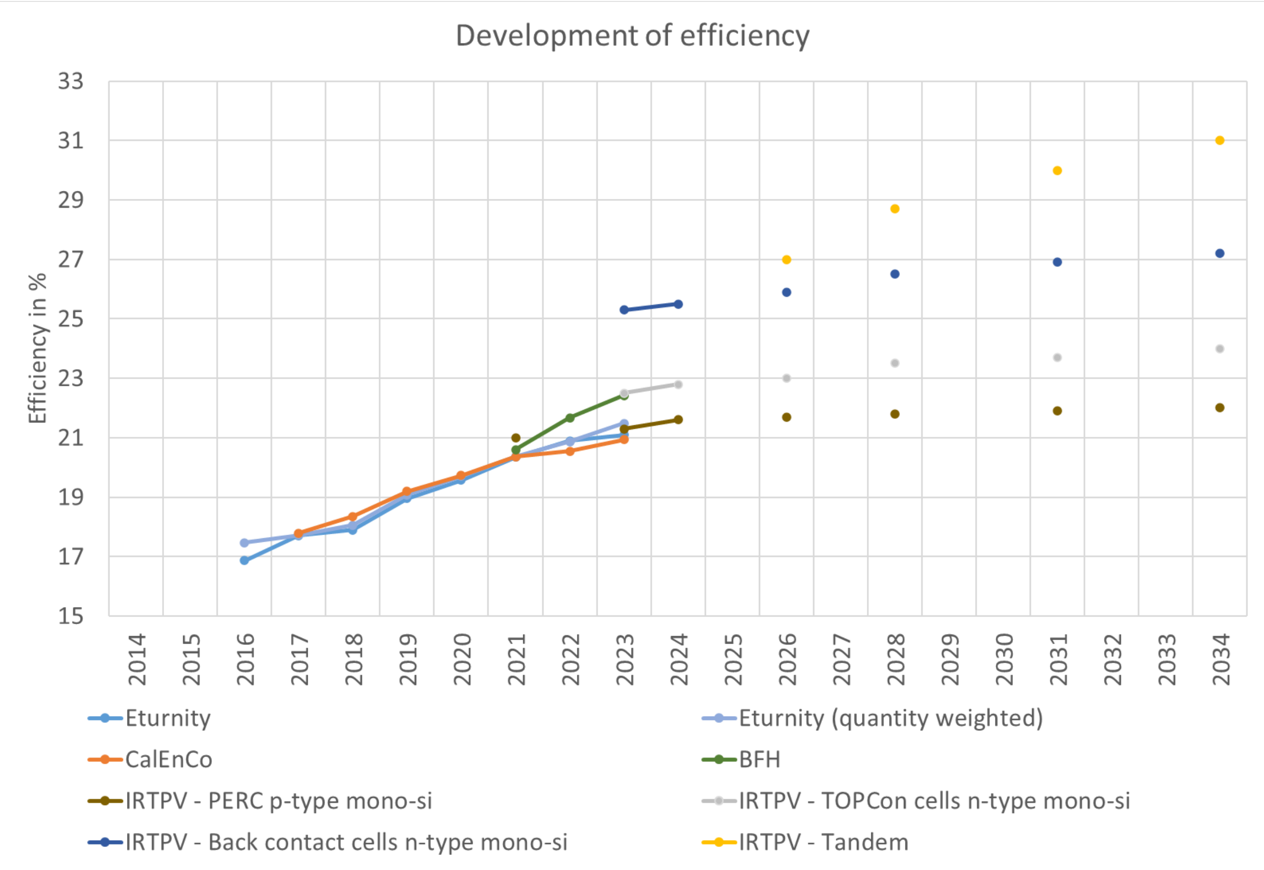


Figure 1: Development of efficiency out of different sources

Based on IRTPV's assessment, the increase in efficiency with PERC are approaching its limit, with the module efficiency plateauing around 22 %. As shown in Figure 2, the Fraunhofer Institute for Solar Energy Systems (ISE) estimates a maximum efficiency of 23.5 % for PERC cells [11]. Considering the additional losses in the module array, it is evident that new technologies will be required in the coming years to achieve further efficiency improvements. The currently available most efficient PERC module has an efficiency of 21.7 % [12]. According to Martin Green et al., the most efficient crystalline silicon module in 2023 has an efficiency of 24.7 % [13]. By the end of 2024, Longi introduced the "Hybrid Passivated Back Contact (HPBC) 2.0" module, certified by Fraunhofer ISE, with an efficiency of 25.4 %. For the first time, a module has now exceeded the 25 % efficiency mark. In addition, at the Back Contact Workshop in late 2024, AIKO presented its target to achieve modules efficiencies above 25 % (cell efficiencies above 27.5 %) in 2025 with their All-Back-Contact (ABC) technology. Despite these advancements, the most efficient commercially available module in 2024 has an efficiency of 24.2 % [12].

The industry experienced a significant transition in 2024, as manufacturers shifted from PERC to TOPCon technology. Another transition, to Back Contact (BC) technology, is expected before 2030. However, PERC modules still dominate current inventories. According to S&P Global Commodity Insights, the normalization of module inventories is projected for 2025, at which point PERC technology is expected to be largely phased out, except in select markets that lag behind in adopting new technologies. As BC technology and Heterojunction (HJT) cell modules are also expected to gradually replace PERC, it is important to note that all these single junction technologies have inherent efficiency limitations, with maximum cell efficiencies at approximately 30 %.
Higher efficiencies can only be reached with tandem cells. The most promising candidate is crystalline silicone combined with perovskite cells. Efficiencies exceeding 30 % have been demonstrated at small-scale cell level, for limited durations. However, there are still significant stability and reliability challenges that need to be solved. Therefore, it is yet unclear when products based on this technology will enter the market.

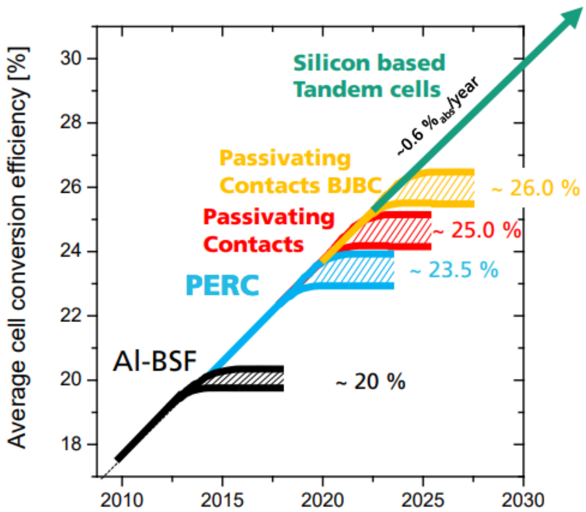


Figure 2: Different cell technologies and their efficiency [11]

In addition to the development of cell technologies, module technologies are also undergoing further development. The introduction of half-cells, multi-busbar and zero-busbar technologies, along with the efforts to towards minimizing inactive areas on the module front surface, have played an important role in improving module efficiencies by decreasing cell to module losses. In addition, with the introduction of large-size module, modules with high power capacities have occurred in the market, which brought doubts on mechanical stability of that large glass area considering glass thicknesses decreased in last years for further cost reduction. Ongoing research and development focus on busbar technologies, glass and mechanical stability and minimizing cell-to-module losses. Additionally, there is a growing trend toward modules designed for specific applications, such as floating PV, alpine PV, residential PV, building-integrated PV (BIPV), and Agri PV. These advancements collectively aim to reduce cell-to-module losses, thereby increasing module-level efficiency and creating more resilient modules capable of withstanding environmental stresses.

### 3.2 Degradation (lifetime) of modules

The warranties provided by module manufacturers for solar modules have increased in recent years, covering both product and performance guarantees. As shown in Figure 3, the product warranty in Switzerland rose from 12 to 15 years in 2021. In previous editions of the ITRPV report, the authors had anticipated that the product warranty was initially too low and predicted it would increase over time. By 2023, these assumptions were validated, with data from the Eturnity database aligning with ITRPV's calculations of sold modules. According to ITRPV, a further significant increase is not expected until around 2030.

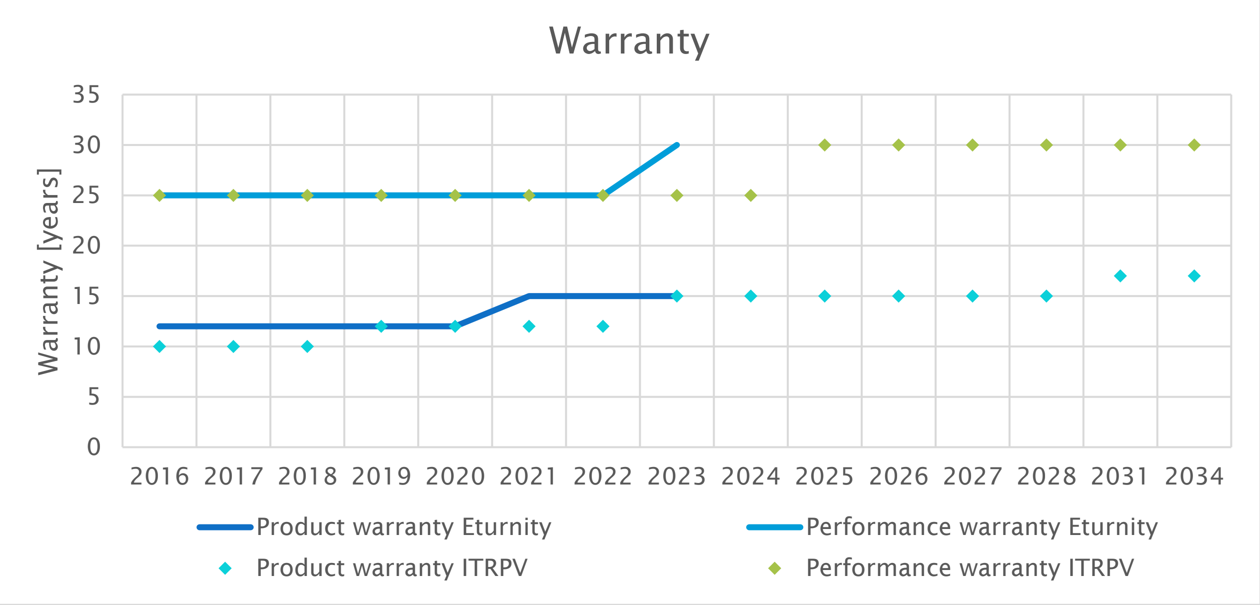


Figure 3: Development of the warranty for solar modules (ITRPV 2016-2024 Edition 8-15 [14] [15] [16] [17] [18]).

The module degradation rate is evolving, driven mainly by rapid technological advancements. However, in some cases degradation rates are increasing, meaning higher power losses per year, due to introduction of new technologies with novel degradation mechanisms, improper selection of bill-of-materials (BOM), and suboptimal production processes. It is important to note that each PV technology may be vulnerable to specific stressors, which can affect the intensity of degradation rate. For example, as shown in [19], although the new TOPCon technology has demonstrated superior performance in certain aspects, including reliability, critical degradation effects related to moisture ingress and UV irradiation under accelerated aging conditions have been uncovered. These findings stand in stark contrast to the ambitious warranty conditions provided by manufacturers. As a result, degradation rate of each PV technology may vary depending on the cell technology and module materials used in the module sandwich. Today, manufacturers promise an average performance of 87.4 % for c-Si-based module technologies after 30 years.

Sufficient time is required to generalize degradation rates for each technology. To accurately determine the degradation and performance loss rate, a technology must be monitored under outdoor conditions for at least four years, accounting for initial stabilization and ensuring precise degradation and performance loss rate calculations [20].
Figure 4 illustrates that the performance loss rate of solar modules has steadily decreased in recent years, dropping from -0.8 %/year in 2016 to -0.5 %/year in 2023, according to data sheets provided by module manufacturers. This indicates that modern modules are expected to lose no more than 0.5 % of their output per year on average. Studies have shown that both commercial and utility-scale PV systems frequently experience higher performance loss rates than the industry standard of -0.5 %/year (see Table 4). In 2024, Louwen et al. published median performance loss rates of -0.82 %/year for 631 mono-silicon PV systems and -0.93 %/year for 1'487 poly-silicon PV systems [21]. It should be noted that these performance losses include all components of the system, including inverter. Additionally, some of these losses may be reversible, such as inverter failures or soiling. For example, while the average performance loss rate for a fleet of 44 commercial rooftop systems in Germany was -0.7%/year,

indoor measurements of some modules from six of these systems revealed an average change in the nominal power of only -0.15%/year [22].
Furthermore, the new measurement campaign (14th test cycle), launched in January 2022 by SUPSI PVLab within the project ATTRACT (financed by BFE), aimed to demonstrate and analyze the impact of various technological changes on energy output and early lifetime stability. All the modules in this study procured from the Swiss PV market. The findings revealed that different PV technologies have varying module degradation rates calculated from the difference in indoor module measurements at standard testing conditions (STC) before and after outdoor monitoring, which is due to distinct degradation mechanisms of each technology. Furthermore, the mounting configuration of the modules was found to influence the rate of performance changes [23]. It should be noted that module degradation rate calculation based on indoor module measurement at STC do not include the effect of low light, angle of incidence and varying spectrum on the performance change.

| Reference | Short description | Performance Loss Rate (PLR) |
|---|---|---|
| [22] | A fleet of 44 commercial, roof-mounted systems in Germany (2019) | -0.7 %/year on average |
| [24] | A group of 174 systems analyzed in the framework of the IEA PVPS Task13 with different PLR observed depending on the climate of operation (2019) | -0.5 %/year to -1.0 %/year |
| [25] | A fleet of over 8'400 residential PV systems mainly in Europe (2021) | -0.74 %/year to -0.89 %/year |
| [26] | System-level data for 585 PV systems installed in the USA (2022) | -0.68 %/year median value |
| [27] | 34 systems installed in South-East Asia (2019) | -0.8 %/year to -1.2 %/year on average |

Table 4: Examples of performance loss rates in PV systems from literature. It should be noted that these performance loss rates include all components of the system, including inverter.

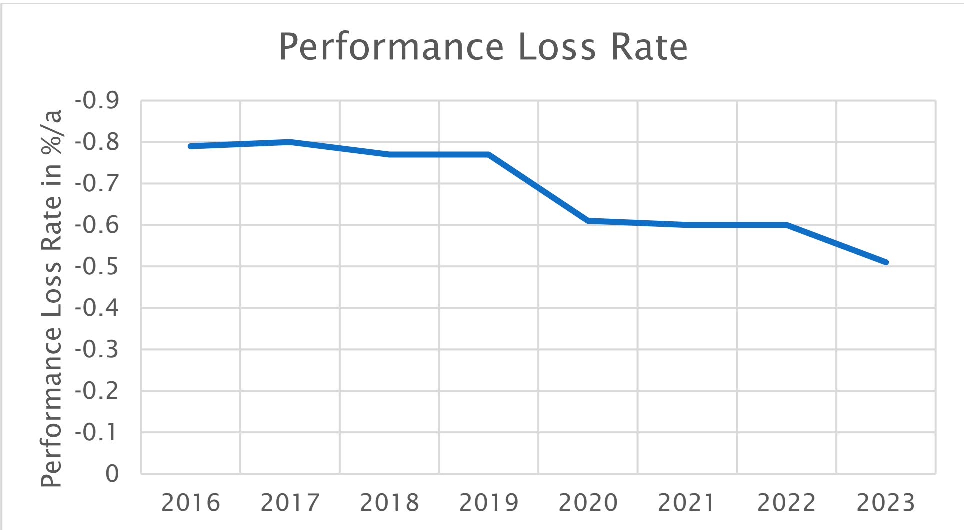


Figure 4: Development of the performance loss rate according to datasheets

### 3.3 Winter electricity share

The potential for solar energy in Switzerland is significant. With a national electricity consumption of just under 60 TWh, the potential for PV systems is around 50 TWh on roofs and 17 TWh on façades [28].
The study «Studie Winterstrom Schweiz» [5] assumes that 30 TWh of this potential is realised. However, while electricity consumption is higher in winter than in summer, most Swiss photovoltaic systems produce more electricity in summer than in winter.
The study examines electricity production in winter (October to March) in detail with three scenarios and the different types of installations.
The uncertainties of this study concern in particular: The potential and the actual choice of roofs differs from the theoretical potential; The amount of snow can lead to distorting the production data in rooftop systems; The average irradiation taken into consideration concerns the years from 2004 to 2018. The annual irradiation varies by 20 % from year to year and the monthly one is even greater.

The second scenario "Maximum winter electricity potential" taken into account is calculated as follows:

1. The 108 categories are sorted according to their maximum specific winter electricity yield (energy yield per square meter in winter).
2. As many categories are selected until the total yield exceeds 30 TWh.
3. The production profiles are created and corrected to exactly 30 TWh.

#### 3.3.1 Roof

The production of rooftop systems is concentrated mainly during the summer months and winter production is therefore low. Flat roofs form a special category of system: while in the past the modules were raised and oriented towards the south to make better use of the PV modules, the now very cheap PV modules are now installed as flat as possible to make better use of the roof area. The annual yield per PV module is thus reduced and winter share even further, but the system output and thus the overall annual yield almost doubles.

Table out of the study "Winterstrom Schweiz" with calculation of the winter share and the specific production.

| Secondary scenario | Energy year [TWh] | Energy winter [TWh] | Installed power [GWp] | Spec. winter yield [kWh/kWp] | Share [%] |
|---|---|---|---|---|---|
| Only roofs | 30.0 | 7.7 | 31.6 | 243.7 | 25.7 |

Table 5: Specific winter yield and winter share of roof systems

#### 3.3.2 Façade

As presented in BIPV Status report in 2024 [3], the installed capacity of BIPV in Switzerland grown at a compound annual growth rate of approximately 41 % between 2006 and 2023, and at around 13 % between 2018 and 2023. During the same period, the installed capacity of conventional attached photovoltaic systems increased by roughly 40 % from 2018 to 2023. In 2023, the annual installed BIPV capacity reached 62 MWp, with the expectation to reach 100 MWp installed capacity in 2028. Notably, approximately one-third of installed BIPV system are façades. However, achieving the production potential of 16.7 TWh from these systems seems challenging with the current growth of façade installations.

Table 6 presents the calculation of the winter share and the specific production out of the study "Winterstrom Schweiz". Although the installation of photovoltaic façades is not yet widespread, the energy produced during the winter months is notably high, accounting for nearly 40 % of total production.

| Secondary scenario | Energy year [TWh] | Energy winter [TWh] | Installed power [GWp] | Spec. winter yield [kWh/kWp] | Share [%] |
|---|---|---|---|---|---|
| Only façades* | 30.0 | 11.8 | 46.9 | 251.6 | 39.3 |

Table 6: Specific winter yield and winter share of façade systems. *: PV potential of façades is only 17 TWh. These figures have been used to compare the results with rooftop data.

### 3.3.3 Alpine PV

A total of 56 systems are listed on the platform for Alpine PV systems, 49 of which are from the Solarexpress. However, the specific winter electricity yield is only known for 33 systems. The proportion of energy production in winter is shown for 34 systems. These values are shown in Figure 5.

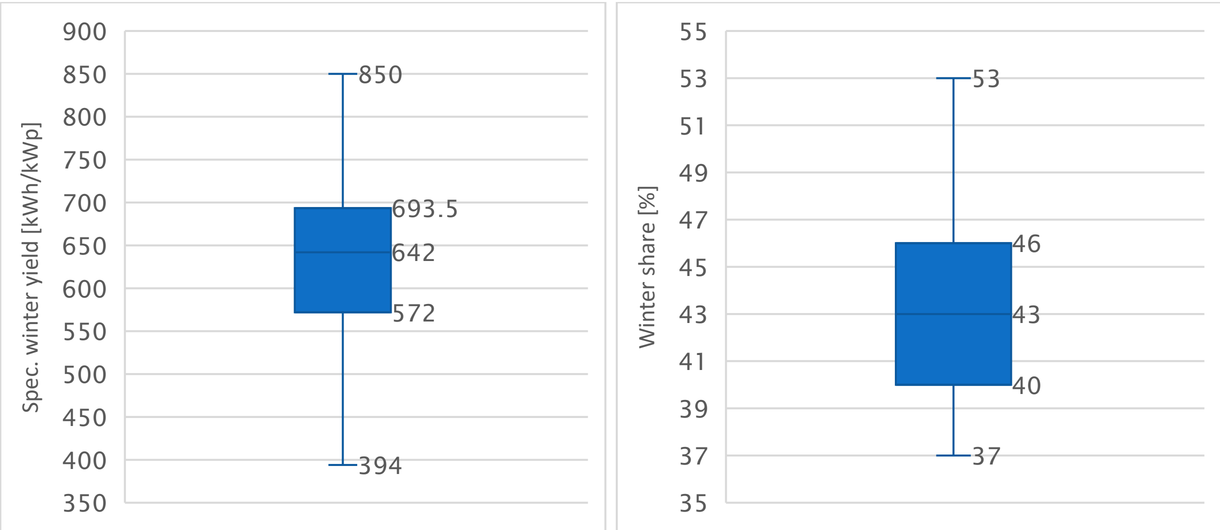


Figure 5: Specific winter yield of alpine PV systems incl. winter share, based on 33 projects of Solar Express

It can be seen that alpine PV systems have a median winter production of 642 kWh/kW. This corresponds to an average share of 43 % of the annual production of the systems. With the exception of five systems, these figures are based on the planning/simulation of the systems. There are no measurement data.

The study "Harnessing solar power in the Alps" [7] shows that the production in wintertime is around 876 kWh/kWp. For the whole year it is 1851 kWh/kWp. This means that 47 % of the energy produced is generated in winter.

### 3.3.4 Agri PV

Studies carried out last year on the Bioschmid system show that an east-west system with a 90° tilt delivers a specific yield of approx. 900 kWh/kWp (approx. 280 kWh/kWp in winter). This corresponds to a winter electricity share of approx. 30 %. A west-facing system with a 12° tilt (60 % light transmission of the modules) results in a specific annual yield of approx. 1070 kWh/kWp (approx. 295 kWh/kWp in winter). This corresponds to a winter electricity share of 27 %. In its study, the ZHAW calculates a winter electricity share of 28 % for permanent grassland, 30 % for open arable land and 31 % for permanent crops [8]. In principle, these systems are located in similar areas to most rooftop systems and also have similar inclinations. It can therefore be assumed that the winter electricity yield is similar to that of rooftop systems, although vertical systems would increase the winter share somewhat.

### 3.3.5 Car park PV

If a car park PV system is built like a rooftop system (on roof), the winter electricity share can be assumed to be similar to roof systems with the same orientation/inclination. If the solar panels themselves form the roof, the situation is slightly different. A bifacial share can then also be calculated. This is mainly due to the reflection of the floor and a little of the cars parked under the system. However, asphalt has a very low reflection with an albedo of around 0.15. From studies of bifacial yields (PV Bench), a maximum bifacial share of around 10 % can be expected for modules with 52° inclination if the rear side does not experience any additional losses. In the case of car parks, the inclination and also the albedo value will be lower than in PV Bench and there will be more shading. This depends on the design of the car park PV system. If the system is only above the parking bays, the shading will be somewhat less than if the system covers the entire car park including the lanes. The expectation of the authors is a bifacial additional yield of 1-5 % compared with roof systems. Ultimately, however, it can be assumed that the proportion of winter electricity will be more or less the same as for roof systems.

### 3.3.6 Summary

It can be seen that roofs, agricultural PV and car park PV have roughly the same winter electricity shares. Higher values are found for façade systems and alpine systems. However, far fewer façade systems are built than roof systems. Alpine systems are also planned/realised only hesitantly due to the high investment costs and complex approval process.

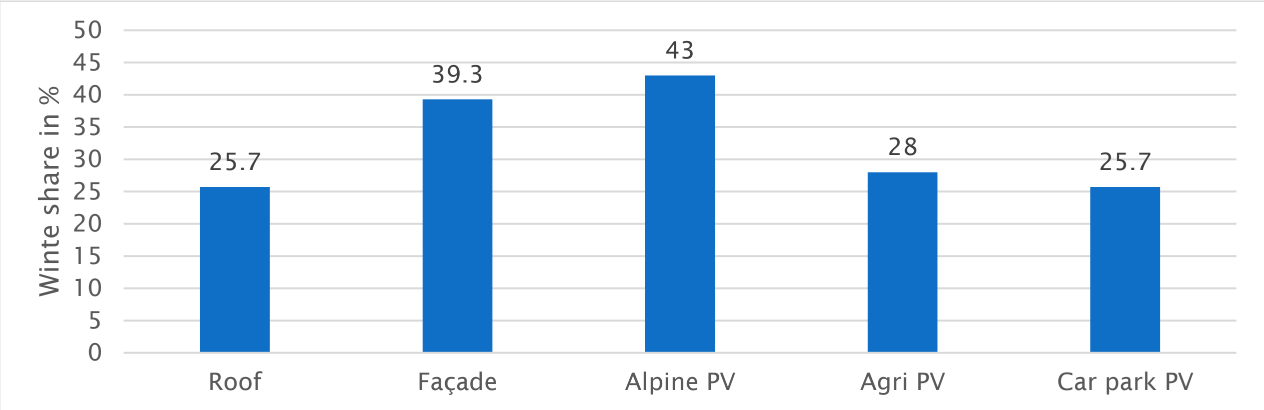


Figure 6: Winter share of the different plant types

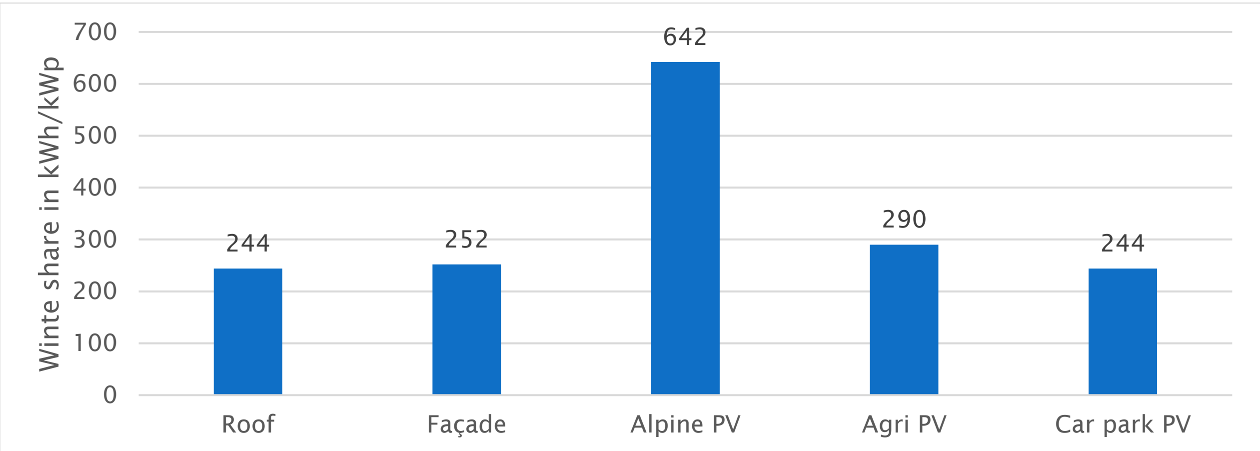


Figure 7: Approximate Specific winter production of the different plant types

### 3.4 Trend of investment costs

3.4.1 Roof

The report "Photovoltaikmarkt: Preisbeobachtungsstudie 2023" contains data from almost 3’000 PV installations. This extensive dataset enabled to perform a cost analysis based on system size, which is not possible to be performed for other types of installations, such as façade, alpine PV, agri PV and car park PV, due to limited data. The power of the roof PV installations is between 2 and 1’500 kW. Only 5 % of the installations are BIPV. In 85 % of cases, monitoring and safety on the construction site are included in the offer. However, permanent fall protectionis only present in 24 % of the installations. 68 % of the inverters are string inverters, while 28 % have optimizers and only 5 % with micro-inverters. The efficiency of the modules is typically between 20 % and 23 %.

Figure 8 shows the costs for rooftop systems below 300 kW for the year 2023: the dependence of the cost on the power is not linear. The specific cost, expressed in CHF/kW, decreases with the power. This reduction in the specific cost is the consequence of the presence of fixed costs, in particular administrative and logistical costs, and permanent safety.

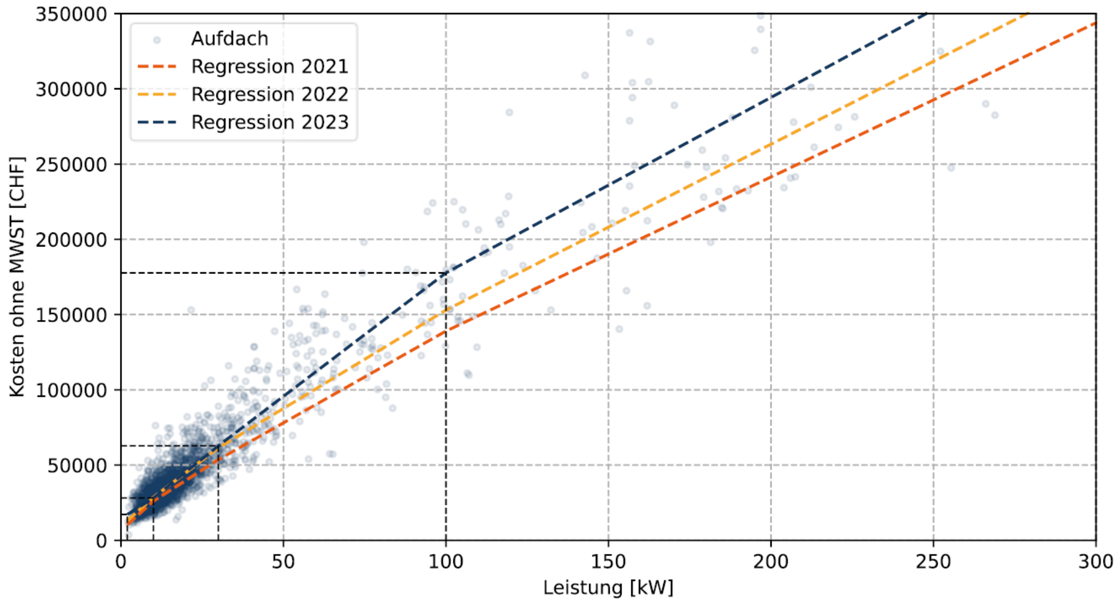


Figure 8: Cost of rooftop installations (BAPV) in 2023, below 300 kW. The blue curve is a piecewise linear regression of these costs for the year 2023 [1].

For each power range and cost category (PV modules, inverters, structures, electrical material, construction site safety, labour, administration and planning, logistics and transport, and others), the median of the specific cost in CHF/kW and the percentage relative to the median of the specific cost of the range were calculated.

In small installations, half of the costs correspond to the material, while in large installations above 300 kW the material share increases to 61 %. The share of modules increases significantly with the power from 16 % for small installations to almost 35 % for large installations. In contrast, the share of inverters decreases from 12 % to 5 %. The shares of structure and labour are relatively homogeneous across all power ranges.

The following Figure 9 shows the investment costs of PV systems on roofs for different system sizes. The development of costs over the last five years is also shown in Figure 10 [1].

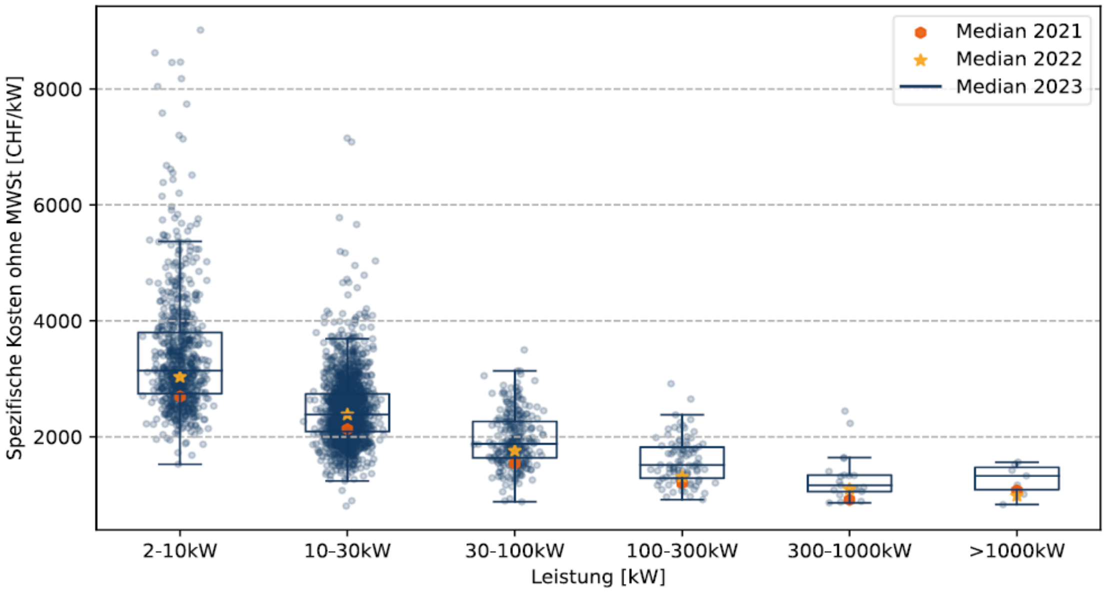


Figure 9: Specific costs of rooftop systems

| Leistungsbereich [kW] | Median Spezifische Kosten [CHF/kW] 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | Veränderung im Vergleich zum Vorjahr 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-10 | 2953 | 2914 | 2692 | 2696 | 3032 | 3141 | -1% | -8% | 0% | 12% | 4% |
| 10-30 | 2214 | 2201 | 2071 | 2131 | 2384 | 2384 | -1% | -6% | 3% | 12% | 0% |
| 30-100 | 1589 | 1466 | 1407 | 1529 | 1759 | 1879 | -8% | -4% | 9% | 15% | 7% |
| 100-300 | 1236 | 1217 | 1132 | 1202 | 1312 | 1513 | -2% | -7% | 6% | 9% | 15% |
| 300-1000 | 1016 | 990 | 919 | 913 | 1097 | 1163 | -3% | -7% | -1% | 20% | 6% |
| >1000 | | 777 | 819 | 1075 | 982 | 1326 | | 5% | | -9% | |

Figure 10: Development of the specific costs of rooftop systems over the last five years

It can be seen that the costs of all system sizes have risen in 2023 compared to 2018, although they have fallen in the meantime (2019/2020). These costs rose sharply again in 2022 in particular. The reasons for the price increase are declining competitive pressure due to maximum capacity utilisation of installation companies, inflation, an increase in the price of aluminium and a larger proportion of green roofs. Costs of 3’141 CHF/kW must be expected for small roof systems in 2023. The larger the system, the lower the specific costs will be. For 100-300 kW systems, they are already half as high, and for systems around 1 MW, the costs are almost a third of this [1].

### 3.4.2 Façade

According to European market analysis, Switzerland is emerging as one of the most promising markets for the development of solar architecture, including solar façades. In 2023, the installed capacity of Building-Integrated Photovoltaics (BIPV), encompassing both roof and façade systems, exceeded 60 MWp, surpassing countries such as Germany, the Netherlands, Italy, and Spain [3]. While façades are essential components of BIPV systems, they present challenges in terms of technical, safety, fire protection, and building code compliance. Although BIPV products offer customizable solutions, the façade BIPV market remains underdeveloped, occupying a niche within both the photovoltaic and construction sectors, despite its significant potential (estimated at 17 TWh in Switzerland).

The total BIPV market in Europe is currently around 200 MWp per year, covering the EU-27, UK, Switzerland, and Norway. Most of this capacity is attributed to “simplified” BIPV systems, which use conventional PV modules and specialized mounting systems to replace traditional building envelope solutions, with façades playing a minor role.

In PV façades, integrating building and solar processes requires coordinating multiple stakeholders, which remains challenging. This complexity is reflected in the higher investment costs. BIPV façades are often considered cost-ineffective compared to traditional building materials like fibrocement or glass, or conventional ground-mounted or roof-applied PV systems. The higher upfront costs of façades depend on the specific project.

The new BIPV Status Report 2024 [3] includes data from 16 BIPV case studies in Switzerland. The report associates end-user prices with complete BIPV systems installed as building envelopes. The cost of a BIPV system encompasses the total end-user price for the entire building envelope solution. This includes the BIPV modules (serving as the cladding), anchoring and mounting components, electrical parts like cabling and inverters, and soft costs such as labour, transport, and permitting fees. For complex projects, additional components may raise the cost further.

For ventilated façades (rainscreens), the price in the EU ranges from 380 CHF/m² to 980 CHF/m² (Figure 11), while in Switzerland it ranges from 500 CHF/m² to 950 CHF/m² (Figure 12). While the price per unit of power for BIPV products varies due to factors like colour, material, and efficiency, a simple conversion into CHF/kW has been made using an average module yield of 20 % for non-coloured products and an exchange rate of 1 CHF = 1 €. For non-coloured, c-Si-based cladding, the cost ranges from 500 CHF/m² to 950 CHF/m², corresponding to system costs of 2’500 CHF/kW to 4’750 CHF/kW.

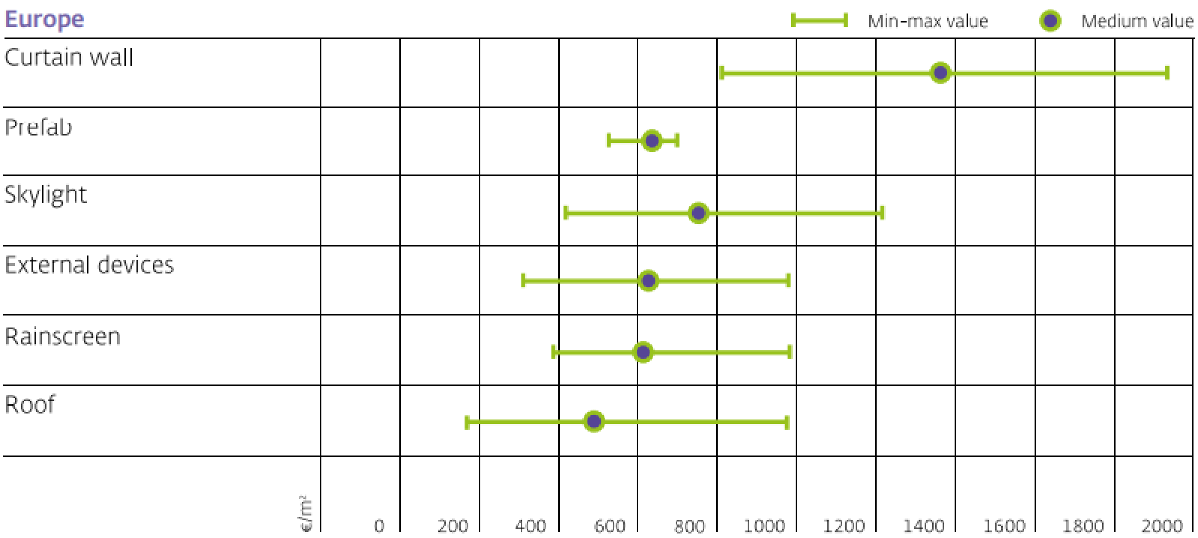


Figure 11: System Cost [€/m²] of BIPV ventilated façades (rainscreen) and roof in Europe [3]

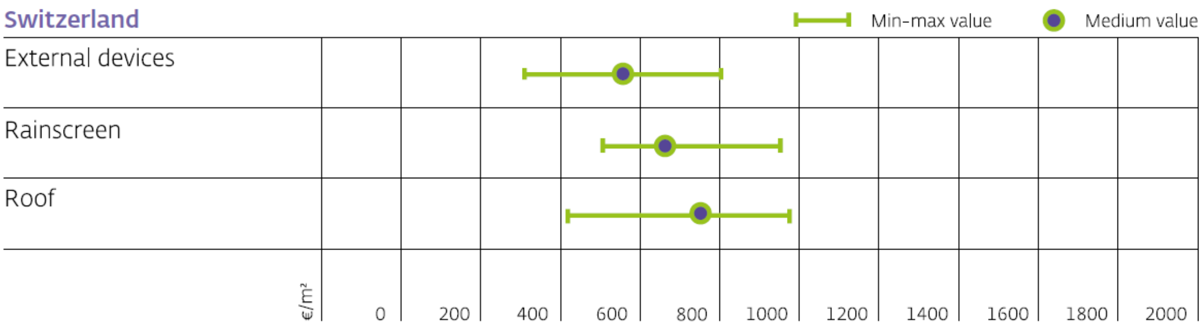


Figure 12: System Cost [€/m²] of BIPV ventilated façades (rainscreen) and roof in Switzerland [3]

Façade PV systems can be competitive with some conventional envelop systems, or on the same level as high-end systems, such as glazed warm façades or stone opaque claddings. The wide range of costs at system level can be explained by multiple factors. First, the variety of projects’ characteristics that can exist on the market, including the size, type and thickness of the modules, the building skin technological alternatives, the complexity of the project, the location of the building or the size of the installation. Then, the local regulation, which can impact the permitting as well as legal and administrative planning, can increase costs.

### 3.4.3 Alpine PV

On the platform for Alpine PV systems, there are 19 plants in accordance with EnG 71a, which show costs. These are all ground-mounted systems that are currently in planning or at the very beginning of construction. Figure 13 shows the average costs of these plants.

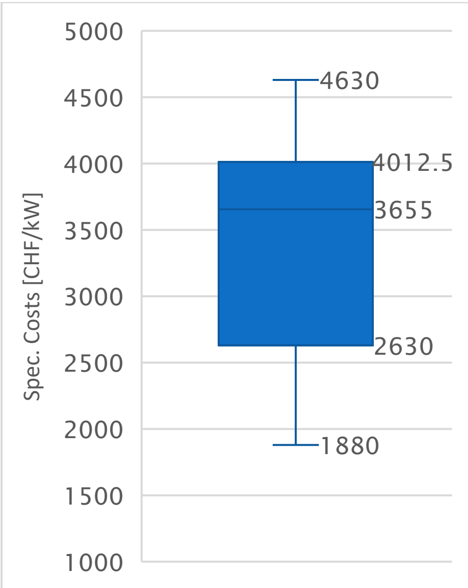


Figure 13: Specific costs of alpine PV systems

Half of the systems have costs in the range of 2’630 to 4’013 CHF/kW. In median, an alpine PV system costs 3’655 CHF/kW.

The study «Harnessing solar power in the Alps» [7] calculated for the costs of PV systems in alpine regions between 2’231 CHF/kW and 4’182 CHF/kW with the assumption of 1 CHF per €. These numbers are linked to ground mounted systems.

### 3.4.4 Agri PV

The costs of agrivoltaic systems cover a wide range. This is due to the fact that there are very different types of agrivoltaic systems. On the one hand, there are overhead systems, but on the other hand there are also systems on intermediate areas (where agricultural work takes place between the PV rows). There are static and dynamic versions of both types. There are currently few sources in Switzerland that show the costs of such systems. Sources from Germany are also only partially applicable, as the cost structure there differs from ours. Permanent crops are currently the most interesting for Switzerland, as they meet with the greatest acceptance. Three sources show figures for agrivoltaic systems for permanent crops. None of these sources include the connection line.

| Costs [CHF/kWp] | Source |
|---|---|
| 1’800 – 2’400 | Markus Markstaler |
| 1’729 – 2’109 | Insolight |
| 1’546 | ZHAW |

Table 7: Estimates of investment costs for Agri PV

With Agri PV, there are two cost-driving factors. These are the substructure and the connecting cable. The substructure depends on how high the system needs to be elevated. With a high elevation, much more steel/aluminium has to be used, which increases the costs. For the connection line, the question is how close the PV system is to the nearest connection point. If the system is located directly at a connection point, the costs are low. However, if it is located far out in a field or if a road or railway line has to be crossed, the costs increase massively. The ZHAW study shows costs of 272.5 CHF/kWp for the grid connection. This is for a 1 MW system with a cable length of 250 metres. Other sources speak of costs of up to 500 CHF/kWp. A tool for estimating grid connection costs for agrivoltaics is currently being developed as part of a student project. With such a tool, it may be possible to estimate these costs more accurately in the future.

It should also be noted that due to the light transmission of the modules for permanent crops (e.g. 50-60 % for berries), a lower power can be installed on the same area.

In the area of Agri PV, there is great potential to install the systems more cheaply. On the one hand, a farmer may be able to do a lot of the work himself as he is a skilled craftsman and, on the other hand, he also has machines at his disposal that can be used to dig trenches or set supports, for example.

### 3.4.5 Car park PV

According to the studies used and an online publication, the investment costs are between 1’200 CHF/kWp and 3’500 CHF/kWp. This depends on the basic mechanical structure, the type of design (integrated or surface-mounted modules) and the size. The ZHAW study for the canton of Zurich shows additionally costs for the grid connection between 16 and 362 CHF/kWp. The median of this additionally costs is 139 CHF/kWp [29]. Other installers display turnkey cost between 1’400 CHF/kWp and 3’300 CHF/kWp where some of the installations are wallbox ready.

Below are a few examples of prices for car park PV systems:

| Site | Area [m²] | Power [kWp] | Energy [MWh] | Total cost [CHF] | Spec. cost [CHF/kWp] |
|---|---|---|---|---|---|
| Courgenay JU | 43’000 | 6’700 | 6’700 | 13’000’000 | 1’940.30 |
| Jakobsbad AI | 2’640 | 429 | 350 | 1’500’000 | 3’496.50 |
| European Park [30] | 200’000 | 25’000 | 25’000 | 30’000’000 | 1’200.00 |
| Example 4 | | 941 | | 1’300’000 | 1’382.00 |
| Example 5 | | 532 | | 1’500’000 | 2’820.00 |
| Example 6 | | 95 | | 313’000 | 3’295.00 |

Table 8: Examples of investment costs for car park PV

Quotations for car park facilities are also available online. For example, a system for 200 car parks. This costs € 534’310.00 and has an output of 620 kW. Assuming € 1 = CHF 1, this would correspond to costs of 862 CHF/kWp. These costs do not include the installation of the car park PV system [31]. Another source from Switzerland shows costs for systems with 51-90 parking spaces (and around 3 kWp per parking lot) between 2’000 and 2’450 CHF/kWp, including the installation of the entire construction with an in-roof solar system without the AC installation part.

### 3.4.6 Summary

The costs for rooftop systems have increased again in the last three years. Up to 1’000 kW, the larger the system, the lower the specific costs. After that, the price level stabilises. In addition to façade systems, alpine PV systems are the most expensive due to the difficult accessibility and construction methods in alpine terrain. However, these are cost estimates by the project participants, mostly from preliminary projects, which are sometimes very far apart. Façade systems also have a very wide range. Few costs are published for agrivoltaics and car park photovoltaics, as there are not yet many such systems. However, the connection cable is a decisive but often unknown cost driver, especially for agrivoltaics. It was not taken into account in the costs presented. Furthermore, the costs of Agri PV and car park PV are higher compared to roof systems with the same size due to the distinctive substructure and the potentially lower installed power per m² (due to the higher light transmission). In the case of

Agri PV, there are opportunities to reduce costs. This is demonstrated by the Bioschmid project, where the modules were installed in the existing construction of the berries. However, the team of authors assumes that the costs can also be significantly higher than CHF 2’400.

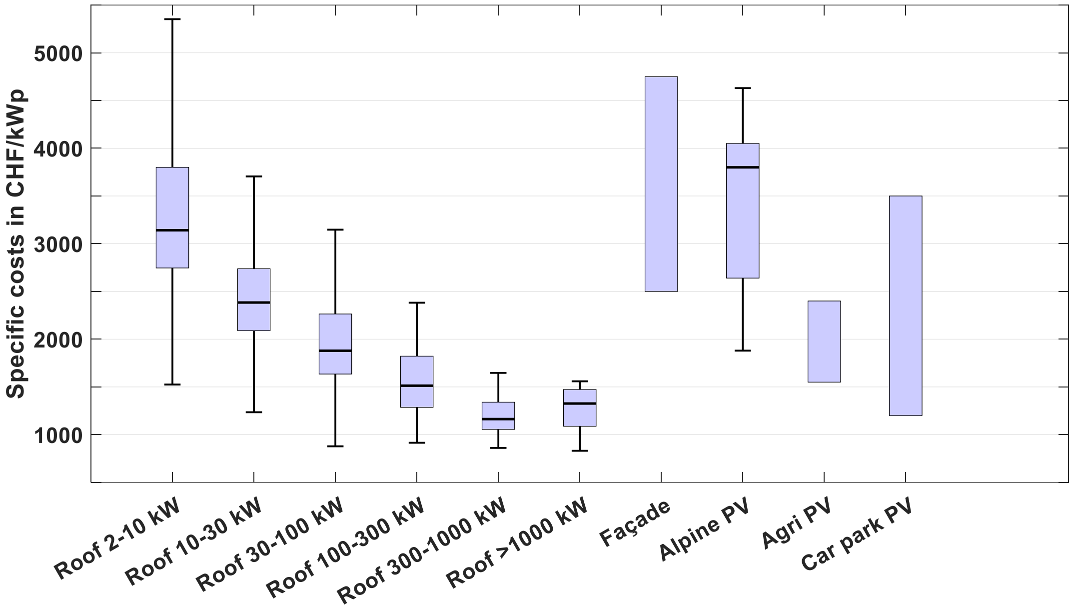


Figure 14: Comparison of the specific investment costs for the various systems

The figure compares the investment costs of the different system types. The systems represented by box plot with error lines are based on statistical analyses derived from expert interviews and other studies. The ones with bar charts (i.e. façade, Agri PV and car park PV) only indicate a range generated from a few limited data sets, rather than expert interviews.

## 3.5 Trend of operating costs

### 3.5.1 General

The operating costs are made up of various expenses which, depending on the type of system, are more or less significant or are not incurred at all. The following costs were taken into account in this study:

| Designation | Description |
| --- | --- |
| Replacement/repair/maintenance inverter | Replacement or repair of inverters and associated components |
| Replacement/repair/maintenance other components | Replacement or repair of other elements such as solar modules, fuses, surge arresters, switches and diodes. |
| Meter and grid costs, GO | Typical periodic meter and grid costs, GO administration |
| Service and inspection rounds | Inspection of the system as required or periodic inspection voluntarily and/or in accordance with regulations |
| Operational monitoring | Costs for automatic operational monitoring, such as analysis of system performance, subscription fees and device replacement |
| Cleaning | Cleaning of the PV system |
| Insurance | • Natural hazard insurance<br>• Liability insurance |
| Administration | Expenses for the administrative management of the systems. |
| Miscellaneous | VAT, periodic inspections of medium-voltage (MV) transformer and switchgear checks |
| Green roof maintenance | Maintenance of the green roof without consideration of PV |

Table 9: Description of the various operating costs

To determine the operating costs for roof systems, nine different typical systems are defined, as was already done in the previous studies. Each system therefore has certain characteristics, which are described in the following table. The abbreviation PiR is used for pitched roofs and FR for flat roofs.

<table>
<tr><th>Plant</th><th>10 kW PiR</th><th>10 kW FRgravel</th><th>10 kW FRgreen</th><th>100 kW PiR</th><th>100 kW FRgravel</th><th>100 kW FRgreen</th><th>1 MW PiR</th><th>1 MW FRgravel</th><th>1 MW FRgreen</th></tr>
<tr><td>Location</td><td colspan="3">On private building</td><td colspan="6">On commercial building</td></tr>
<tr><td>Energy use</td><td colspan="6">Self-consumption</td><td colspan="3">Feed in</td></tr>
<tr><td>Contracting</td><td colspan="6">No</td><td colspan="3">Yes</td></tr>
<tr><td>Monitoring</td><td colspan="3">Owner</td><td colspan="6">Professional</td></tr>
<tr><td>Cleaning</td><td colspan="3">No / Owner</td><td colspan="6">Professional</td></tr>
<tr><td>Transformer maintenance</td><td colspan="6">No</td><td colspan="3">Yes</td></tr>
<tr><td>Admin</td><td colspan="3">Owner</td><td colspan="6">Professional</td></tr>
<tr><td>Green roof maintenance</td><td colspan="2">No</td><td>Owner</td><td colspan="2">No</td><td>Profes-sional</td><td colspan="2">No</td><td>Profes-sional</td></tr>
</table>

Table 10: Typical roof top systems

The various operating costs can be allocated on the basis of these definitions in Table 9. Depending on the type of operational costs, certain costs may or may not be taken into account. The following table shows which operating costs are fully, partially or not at all allocated to which typical plant.

| 2024 Size | 10 kW | 10 kW | 10 kW | 100 kW | 100 kW | 100 kW | 1 MW | 1 MW | 1 MW |
|---|---|---|---|---|---|---|---|---|---|
| Type | PiR | FR gravel | FD green | PiR | FD gravel | FD green | PiR | FD gravel | FD green |
| Replacement/Repair inverter | taken | taken | taken | taken | taken | taken | taken | taken | taken |
| Replacement/Repair other components | taken | taken | taken | taken | taken | taken | taken | taken | taken |
| Cleaning | not taken | not taken | not taken | partially/reduced | partially/reduced | partially/reduced | partially/reduced | partially/reduced | partially/reduced |
| Service and inspection rounds | not taken | not taken | not taken | taken | taken | taken | taken | taken | taken |
| Operational monitoring | not taken | not taken | not taken | taken | taken | taken | taken | taken | taken |
| Meter and grid costs, HKN | not taken | not taken | not taken | taken | taken | taken | taken | taken | taken |
| Insurance | taken | taken | taken | taken | taken | taken | taken | taken | taken |
| Administration | not taken | not taken | not taken | taken | taken | taken | taken | taken | taken |
| Miscellaneous | taken | taken | taken | taken | taken | taken | taken | taken | taken |
| Green roof maintenance | not taken | not taken | not taken | not taken | not taken | taken | not taken | not taken | taken |

PiR = Pitched Roof, FR gravel = Flat Roof with gravel, FR green = Flat Roof with greening

(green) is taken into account
(hatched) is partially/reduced taken into account
(red) is not taken into account

Table 11: Typical roof top systems

When forming these categories, it should be noted that the average installed system in 2024 had an output of around 14 kW. With the higher capacity, more energy can be produced, whereby the absolute operating costs (mainly for material replacement) are insignificantly higher. This results in lower operating costs in CHF/kWh for 14 kW systems than for 10 kW systems, provided the same assumptions as for 10 kW systems in Table 11 are taken into account. As a supplement, an estimate was therefore made of the costs to be expected for a 15kW and a 30kW system in chapter 3.5.4.

### 3.5.2 Basic assumptions and definitions for roof systems

The following assumptions were made to calculate the energy yield of a PV system and for outputs that could only be specified as time expenditure. With the exception of private individuals, the assumed numbers correspond to the study by Basler & Hofmann 2015.

Specific Energy yield: 950 kWh/kWp
Lifetime of a PV-plant: 25 years

Hourly rates for direction work:

| | | |
|---|---|---|
| Private individuals, personal contributions | 0.-[2] | CHF/h |
| Simple work for untrained personnel | 75.- | CHF/h |
| Admin, control, monitoring, miscellaneous | 100.- | CHF/h |
| Specialists, experts, engineers, according to KBOB/SIA category D | 132.- | CHF/h |

Table 12: Hourly rates for direction work

**Replacement of inverter**

It is generally assumed that the inverter will need to be replaced once during the service life of the PV system. However, the study "Life expectancy of PV inverters and optimizers in residential PV systems" [32] shows that over 65 % of inverters have no defects by the 15th year of operation. It can therefore be assumed that there are individual systems in which the inverter never needs to be replaced. If inverter replacement were to be omitted, the maintenance costs for small systems would be reduced by more than half.

[2] The time spent by private individuals is not taken into account, as this is not incurred as a cost in financial terms.

| Inverter size | Cost [CHF] |
|---|---|
| 10 kW | 3’000 |
| 100 kW | 9’000 |
| 1’000 kW | 75’000 |

Table 13: Replacement cost of inverters

When replacing an inverter, it is often not possible to take over the existing installation. In the past, single-phase inverters were used for small systems. This is hardly the case today. In medium-sized systems today, one inverter is installed where previously several were installed due to the lower output of the devices. And in large systems today, several multi-string inverters with an output of around 150 kW are installed where previously central inverters were used. These necessary adjustments to the installations lead to additional costs, which must be taken into account when replacing an inverter.

**Replacement of other components**
For the other components, it is assumed that they have the same service life as the PV system and theoretically do not break down prematurely. However, this does not correspond to reality. Costs are still incurred for repairs. There are modules with a defect or insulation faults can occur with cables that are not laid cleanly and are often located in wet areas.

**Meter rental**
The meter rental is not included for small systems. Even without a PV system, there is a meter that must be rented. Costs for load profile measurement for PV systems larger than 30 kVA have not been incurred since 2019 and an amendment to the Electricity Supply Ordinance. Since then, the costs have been billed via the grid utilisation tariffs [33]. The meters therefore do not incur any additional operating costs.

**Grid costs**
According to the Electricity Supply Act (StromVG, Art. 14), grid utilisation costs are paid by the consumer, not by the producer. This means that no further operating costs are incurred as a result of grid utilisation.

**GO acquisition**
In order for a system to be included in the guarantee of origin system (GO or in German: HKN), it must be certified. This is done either by an accredited inspection company, the grid operator or an authorized person. These costs are included in the investment costs. For the subsidized systems (EVS, EIV, MKF)[3], the fees for using the guarantee of origin system (with the exception of the transaction fees for EIV and MKF systems) are borne by the subsidy fund [34]. This means that for most systems, there are no additional fees for use. The transmission of guarantees of origin to a trader or buyer takes time. It is assumed that the guarantees of origin must be processed once a year. The associated costs are independent of the size of the installation. It is assumed that this takes 1.5 hour per year. This effort is not included for small systems, as the guarantees of origin are either submitted directly to the local distribution system operator with little effort or the effort involved in submitting the GO for such a small amount of energy is not worthwhile. Systems larger than 300 kWp must also be re-audited every five years. These costs are included in the operating costs.

**Service and inspection rounds**
Service and inspection rounds are only taken into account for systems of 100 kW and above. For small systems, this is usually done on an ongoing basis by the homeowner. Irrespective of these checks, the system is monitored online. However, this is integrated into the monitoring costs.

[3] EVS: Einspeisevergütungssystem; EIV: Einmalvergütung; MKF: Mehrkostenfinanzierung

**Monitoring**
In the case of professional system operators, monitoring includes technical monitoring (identifying, analysing and logging faults and preparing service calls if necessary) and yield monitoring (creating yield reports and starting in-depth analyses in the event of discrepancies). This is done either via the monitoring portals of the inverter manufacturers or via additionally installed external datalogger. For private individuals with smaller systems, this monitoring is usually carried out by the homeowner on the side and is therefore not included in the operating costs.

**Subscription fees**
Subscription fees are incurred if an external data logger is used to record the measurement data. This is the case with old inverters without integrated monitoring, with a mix of various inverter types or at the customer's request. However, there are also costs for transmitting the data, for the internet connection. In the case of small systems owned by private individuals, neither an external data logger nor the necessary internet connection is taken into account in the operating costs. It is assumed that the house would have an Internet connection even without a PV system

**Device replacement operation monitoring**
For small systems, it is assumed that monitoring is carried out via the portal provided by the inverter manufacturer. This means that there is no additional monitoring device that needs to be replaced in case of failure. For larger systems, an inverter-independent monitoring system is increasingly being installed. The defect and replacement of such a system usually leads to relatively high costs, as the device has to be replaced and the programming has to be set up again. It is assumed that the device will have to be replaced once during the service life of a PV system.

**Visual meter reading**
Costs for a visual meter reading are not taken into account, as it is assumed that all systems have a smart meter installed and that data is transmitted automatically.

**Cleaning**
The assumption from the study by Basler & Hofmann 2015 is adopted. The systems are cleaned every five years. Quotations from cleaning companies are compared to determine the costs. Typical costs for the three system types and three system sizes were requested. Some companies offer cleaning in conjunction with the service and inspection check. In this case, the effort is reduced as costs can be combined. For the present cost calculation, independently operating cleaning companies were assumed.

**Natural hazard insurance**
Natural hazard insurance is mandatory for everyone (with certain exceptions for GUSTAVO cantons). For homeowners, the PV system is usually insured together with the building. In the case of contractors, the system is insured independently of the building, as the system is owned by the contractor. An average value of 0.54 ‰ of the insured value was assumed for the insurance policies. The individual cantons have different approaches, depending on the building and risk potential.

**Liability insurance**
Liability insurance is not mandatory for PV systems in Switzerland. However, general plant owner liability applies. This means that the owner of a system is liable for damage caused by a defect in the system. Such damage can be insured with liability insurance. In the case of owner-occupied property, personal liability insurance is usually sufficient. As this is already in place, the small PV system does not incur any additional costs. For larger systems on commercially used buildings, building liability insurance is required, which mainly depends on the type of building and not on the building value. Therefore, no additional costs are taken into account even for medium-sized systems. In the case of contracting and large systems, the plant is insured without the building.

**Administration, management**

Many administrative expenses for larger systems are already included in the investment costs of the systems. For example, recording the installations in the system, creating the login for customers or instructing customers. In the case of small systems, administrative work is often carried out by the homeowner themselves. It is therefore not taken into account. For large installations, this results in expenses for the annual billing of services.

**Value added tax**

VAT of 8.1 % is levied on everything that generates added value. This means on all repairs but also on services. Insurance is not subject to VAT. As a rule, there is to pay a stamp duty of 5 %.

**Roof rental**

In the case of contracting systems, the contractor rents the roof area and rooms that are used for PV components. One example is rooms for the indoor installation of inverters. The costs for roof rentals are considered separately and are not included in the operating costs, as a large system is not always operated under contracting.

**Dismantling costs**

In the case of small systems, it is assumed that the systems will not be dismantled. In most cases, the system is renewed and continues to be operated. The same is assumed for medium-sized systems without contracting. In the case of large systems, especially those with contracting, dismantling is more common. For example, when contracts expire, and the owner wants to build a system themselves. According to various sources, up to 10 % of the plants are currently being dismantled. However, as these costs are only incurred for a small number of systems, they are not included in the operating costs and are explained separately.

**Maintenance of MV transformer and switchgear**

In addition to the PV system, large systems also require a transformer station to feed the energy produced directly into the medium-voltage grid. If such a transformer station is available for the PV system, the costs for maintaining the transformer station must also be included in the operating costs. Small and medium-sized systems are connected directly to the low-voltage grid and there are therefore no additional costs for medium-voltage equipment.

**Green roof maintenance**

Green roofs have the potential to cast a lot of shade on the PV system. Compared to roofs without PV, these need to be maintained much more often to avoid such shading losses. For this reason, it is assumed that the costs for green roof maintenance must be offset against the PV systems.

### 3.5.3 Resulting operating cost

**Roof**

The assumptions described above result in the operating costs shown in Figure 15 for the various system types. A more detailed table can be found in the appendix.

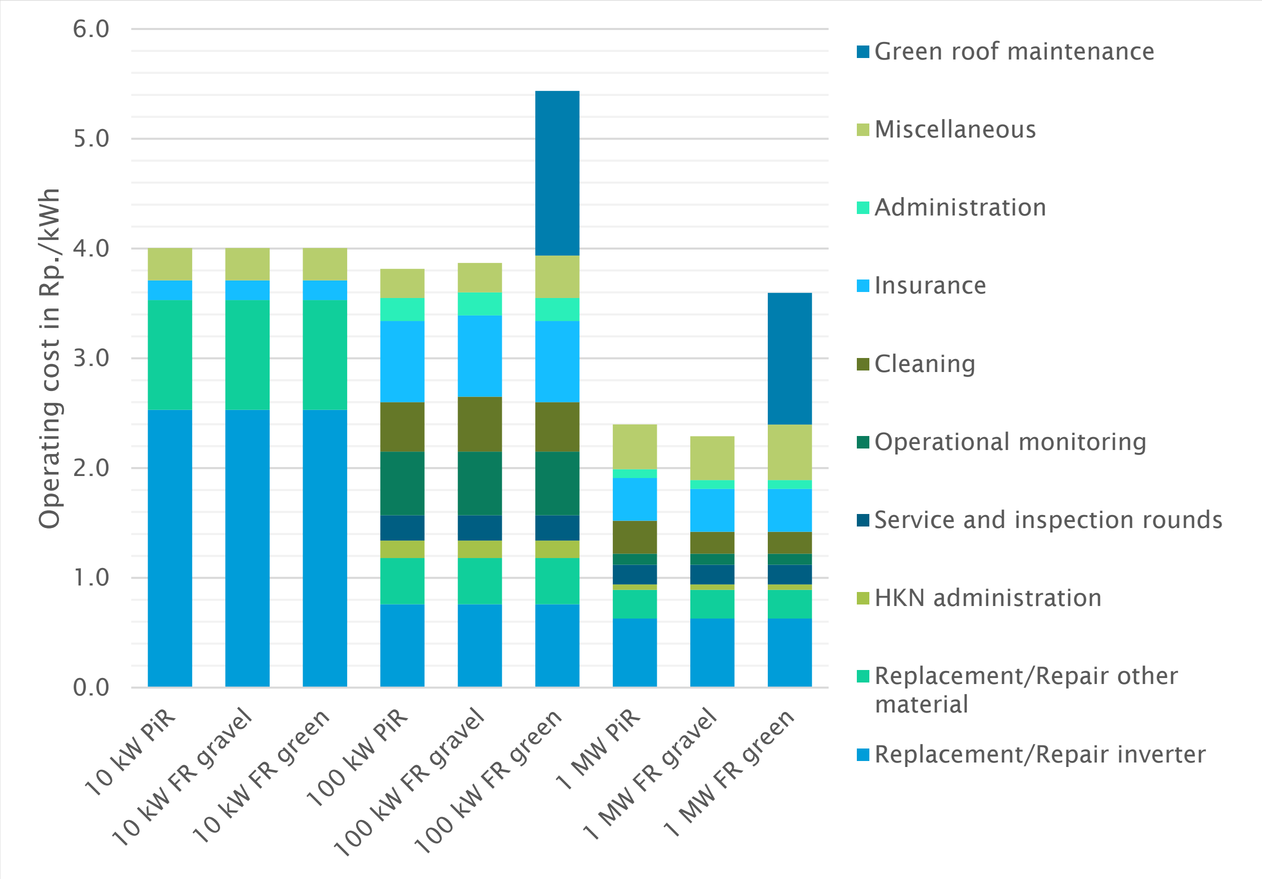


Figure 15: Share of operating costs by category and system type

Certain large installations, particularly in the MW range, are operated by contractors. Roof rents often have to be paid for contract installations. Typical roof rental costs start at around 10 CHF/kW, which corresponds to an annual rent of CHF 10’000 for a 1 MW PV system or 1 Rp./kWh. However, they can also be many times higher. These costs are not included in the above figures.

The costs for uninstalling a complete system are also not included in the operating costs. This is because only a few systems are dismantled. Most systems are replaced. The dismantling costs can be assumed to be 15-30 % of the investment costs of the systems. This corresponds to approx. 1-2 Rp./kWh for 100 kW systems and approx. 0.75-1.5 Rp./kWh for 1 MW systems.

Table 14 shows how operating costs have developed over the last 10 years. It should be noted that the first two studies (2015 and 2018) were conducted by Basler & Hofmann and therefore did not use exactly the same methodology as the present one.

| Type of plant | 2015 | 2018 | 2024 |
|---|---|---|---|
| 10 kW PiR | 3.4 | 3.2 | 4.0 |
| 10 kW FR gravel | 3.6 | 3.2 | 4.0 |
| 10 kW FR green | | | 4.0 |
| 100 kW PiR | 5.1 | 3.6 | 3.8 |
| 100 kW FR gravel | 5.3 | 3.6 | 3.9 |
| 100 kW FR green | 5.8 | 5.1 | 5.5 |
| 1 MW PiR | 2.3 | 2 | 2.4 |
| 1 MW FR gravel | 2.5 | 2 | 2.3 |
| 1 MW FR green | | 3 | 3.6 |

Table 14: Change in operating costs over the last 10 years in Rp./kWh

In general, the operating costs of all system types are higher than in 2018. The biggest changes can be seen in small systems of 10 kW. These are 0.8 Rp./kWh higher, mainly due to higher assumptions for inverter replacement costs. However, green roof maintenance for large systems is also 0.6 Rp./kWh higher.

3.5.4 Estimated cost function for small and large installations

As the operating costs depend on the amount of energy produced and the average PV system installed in 2024 in the category up to 30 kW is a 15 kW system, an estimate of the operating costs for systems up to 30 kW is also made. These calculations are based on the costs of the 10 kW system and the estimated costs of a 30 kW system. A cost function for the absolute costs in CHF is determined from these two and the function for the specific costs in Rp./kWh is calculated using the amount of energy produced. The following assumptions are made:

- Investment costs 10 kW system: Costs Planair [1] category 2-10 kW
- Investment costs 30 kW system: Costs Planair [1] category 10-30 kW
- Inverter costs 10 kW system: Average costs of the 2-10 kW and 10-30 kW categories from Planair [1]
- Inverter costs 30 kW system: Average costs of the categories 10-30 kW and 30-100 kW from Planair [1]
- Installation costs 10 kW inverter: Difference between total costs for inverter replacement according to installation companies and inverter costs according to Planair [1]
- Installation costs for 30 kW inverter: Installation costs 10 kW multiplied by 1.2 (assumption based on installation in pairs due to the weight of the inverter)
- Other material costs: Cost function of installation companies
- Insurance costs: Percentage of investment costs

This results in the following cost functions for small systems:

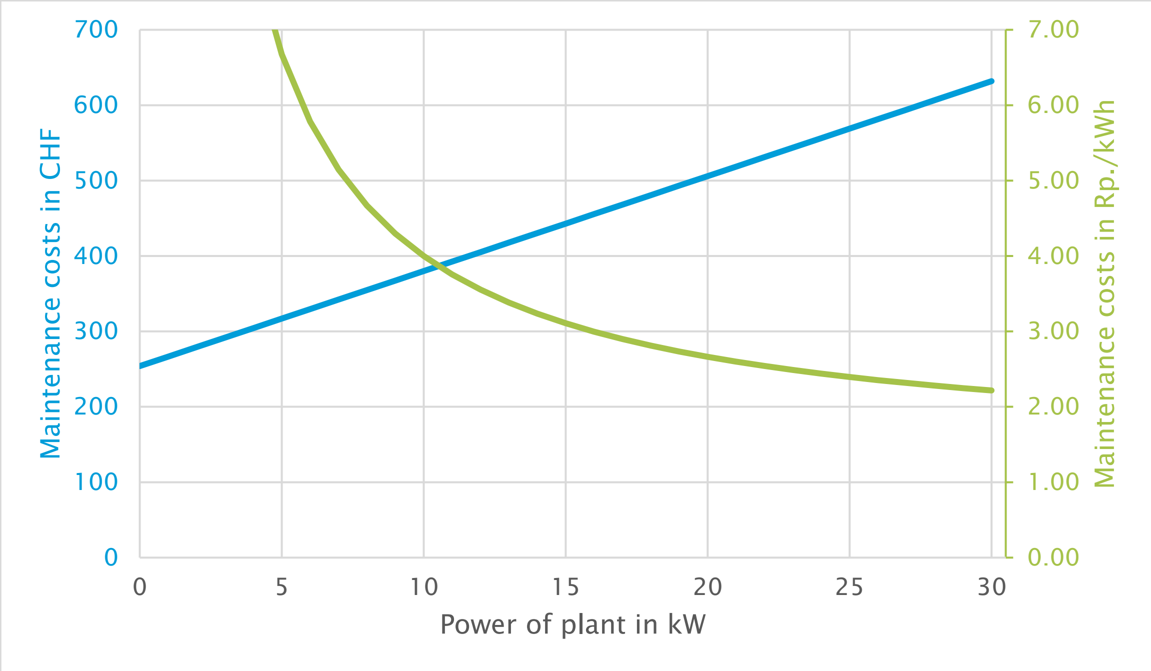


Figure 16: Maintenance cost function for small pv systems until 30 kW

This results in operating costs of approx. 3.1 Rp./kWh for 15 kW systems. For large systems, the following cost function results with the calculated operating costs at 100 and 1000 kW:

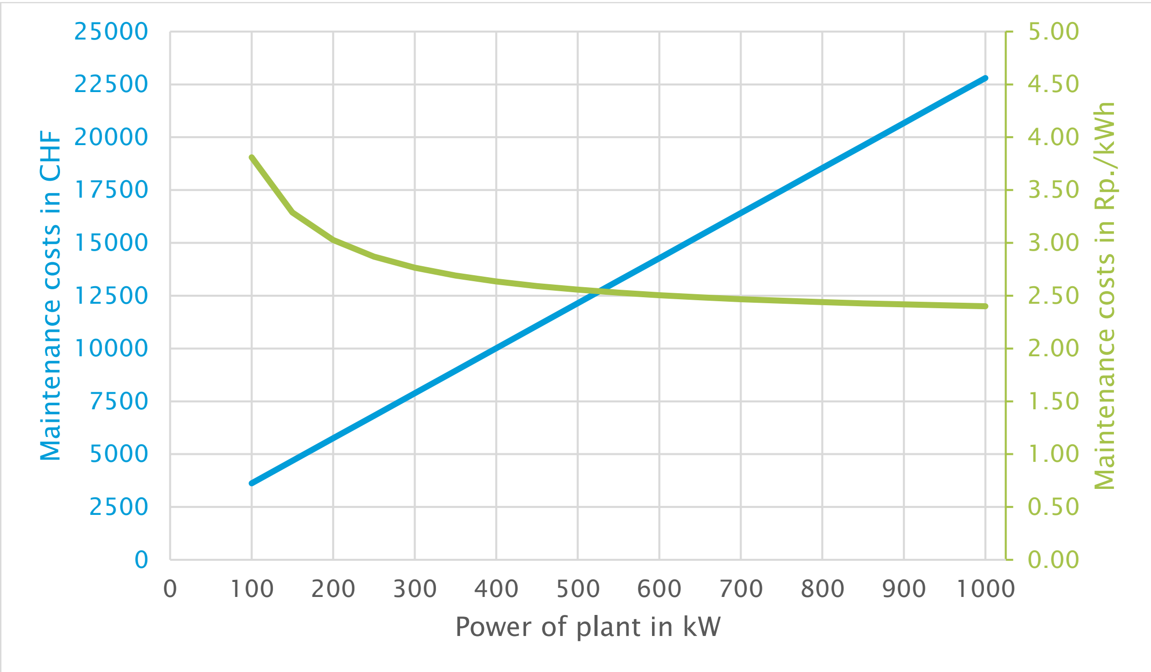


Figure 17: Maintenance cost function for large pv systems from 100 to 1000 kW

### 3.5.5 Further plant types

**Façades**
For façades, it is assumed that the operating costs correspond approximately to those of roof systems. This is based on the assumption that the systems are well ventilated and have been installed in accordance with the specifications. For buildings of medium height (11 metres or more), an additional inspection is required every three years, or every two years for buildings of 30 metres or more [35]. However, this normally also takes place for roof systems and therefore does not lead to increased operating costs. Cleaning will no longer be necessary for these systems due to the vertical installation. The average size of a BIPV façade in Switzerland is about 18 kW (rough estimation). The costs for 10 kW systems are therefore not reduced, as no cleaning costs have already been included in the roof system.

| **Type** | **10 kW** |
|---|---|
| Façade | 4.0 |

Table 15: Operating cost of façade systems in Rp./kWh

**Alpine PV**
It is difficult to estimate the operating costs of alpine PV systems. On the one hand, because there are still hardly any systems with empirical values and, on the other hand, because the conditions in the Alpine region are much tougher and more unpredictable than in midlands. Cost drivers will probably be accessibility in winter (including logistics to bring spare parts to the system) and the ease of maintenance of the system (can individual modules be replaced? How do I get up to the modules?). The operating costs of the Alpine facilities are based on the following assumptions with the help of project developer:

| **Type** | **1 MW** |
|---|---|
| Alpine PV | 5.0 |

Table 16: Operating cost of Alpine PV systems in Rp./kWh

A 1 MW system on rooftops in the midlands has operating costs of around 2.5 Rp./kWh. The chosen assumption therefore corresponds to a doubling of operating costs, although more energy can be generated in Alpine regions with the same size of system. This assumption would correspond to annual costs of around 70'000 CHF in case of an irradiation of 1'450 kWh/kWp.

**Agri PV**
For Agri PV systems, it is assumed that the modules need to be cleaned more frequently. This is due to the dirtier environment caused by cultivation with tractors and other machinery. A cleaning interval of two years is assumed. The other costs do not differ significantly from a roof-mounted system. The remaining assumptions are therefore based on the roof system.

| **Type** | **100 kW** |
|---|---|
| Agri PV | 4.6 |

Table 17: Operating cost of Agri PV systems in Rp./kWh

**Car park PV**
The operating costs of car park PV are in line with those of roof systems. It can be assumed that they need to be cleaned somewhat more frequently than roof systems, but that the effort required for cleaning is less, as accessibility is easy. The same costs as for roof systems are therefore used for the further calculations.

| **Type** | **100 kW** |
|---|---|
| Car park PV | 3.9 |

Table 18: Operating cost of car park PV systems in Rp./kWh

### 3.5.6 Summary

In general, it can be said that the operating costs for roof and façade systems depend heavily on which costs are taken into account at all or at what interval. Costs such as internet subscription fees are incurred even without PV. It also depends on the assumed service life/irradiation/shading and soiling. The type of construction can have a major influence on green roof systems if the growth of plants is favoured and green roof maintenance is more difficult. There are hardly any figures available on operating costs for agrivoltaics and car park PV. However, due to the construction method and location, similar values can be assumed as for roof systems, although the investment costs for agrivoltaics are probably somewhat higher. The operating costs of Alpine PV are completely unknown, as there are no such large systems in operation in the Alps in Switzerland. These are therefore only estimates at present.

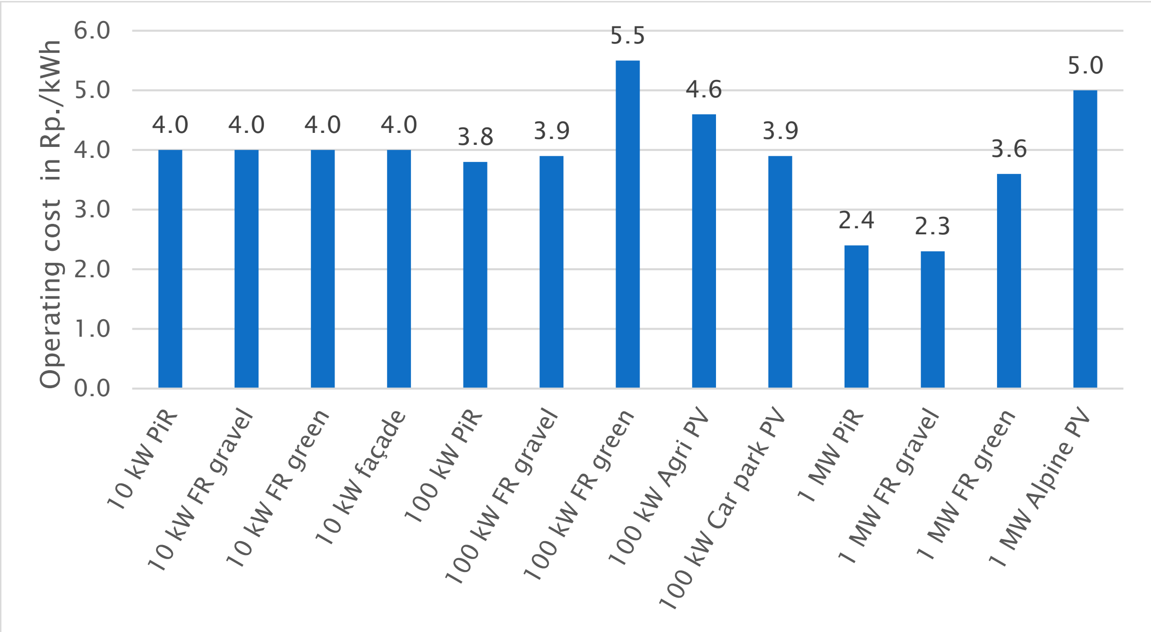


Figure 18: OPEX of the different plant types

### 3.6 Trend of LCOE

To calculate the levelized cost of electricity, the findings from the previous chapter are used for the various types of system. In addition, with the exception of alpine plants, three different locations are considered in each case:

| | |
|---|---|
| Irradiation $G_0$ | Swiss Midlands, location Burgdorf (547 m.a.s.l.): 1'200 kWh/m$^2$<br>Ticino, location Lugano (273 m.a.s.l.): 1'350 kWh/m$^2$<br>Alpine region, location Sedrun (2'057 m.a.s.l.): 1'430 kWh/m$^2$ |
| Irradiation $G_i$ | $G_i = x * G_0$<br>x = 1.05 → Roof, Agri PV and car park PV<br>x = 0.75 → Façade<br>x = 1.15 → Alpine PV |
| CAPEX | According to chapter "Trend of Investment costs" |
| OPEX | According to chapter "Trend of Operating costs" |
| Operating time | 25 years |
| WACC | 2 % |
| Performance ratio | 80 %, for façade 75 % |
| Power | According to the specified plants in chapter 3.5. Roof: The mean value was used for the defined power ranges of roofs:<br>2-10 kW → 6 kW, 10-30 kW → 20 kW, 30-100 kW → 65 kW, 100-300 kW → 200 kW, 300-1'000 kW → 650 kW, >1'000 kW → 1'000 kW |
| Degradation | 0 %[4] |

Table 19: Assumptions for the calculation of the LCOE

In new rooftop PV systems without shadowing, performance ratio reaches values >85 %, thanks to better inverters efficiencies, lower temperature coefficient of the module (in particular for TOPCon and HJT technologies). But because an average plant is to be calculated in each case, the value 0.8 is used as the performance ratio.

#### 3.6.1 Roof

Table 20 shows the resulting LCOE of the different locations and system sizes. The detailed calculation can be found in the appendix chapter 9.3. The values shown here were calculated from the median of the investment costs.

| **Location** | **2-10 kW** | **10-30 kW** | **30-100 kW** | **100-300 kW** | **300-1'000 kW** | **>1'000 kW** |
|---|---|---|---|---|---|---|
| Midland | 20.0 | 16.1 | 13.3 | 11.5 | 8.3 | 9.1 |
| Ticino | 18.1 | 14.8 | 12.3 | 10.6 | 7.7 | 8.4 |
| Alpine | 17.4 | 14.2 | 11.8 | 10.3 | 7.4 | 8.1 |

Table 20: Calculation of LCOE for different system sizes and locations of rooftop systems in Rp./kWh

#### 3.6.2 Façade

The LCOE for façade systems refer to the outermost photovoltaic layer of the building envelope, as described in the previous chapter. BIPV costs are strongly project-related and affected by construction work factors that cannot be observed or generalised at a macro-scale. Due to a lack of available statistical figures, this report therefore does not calculate percentiles and mean values for LCOE, but merely provides a range. Façade PV systems also often replace alternative façade cladding. Depending on the materialisation, this alternative façade cladding can be more expensive than the photovoltaic

[4] Degradation is not taken into account as it is already integrated in the performance ratio.

modules themselves. In this case, the additional costs for photovoltaics in the façade will be low or even negative. However, this is highly project-specific and includes a hypothetical component, which is why it is not taken into account in this study. The performance ratios of façade photovoltaic systems are reported to be slightly lower than those of rooftop PV systems due more frequent partial shading situations. Therefore, LCOE can vary greatly.

LCOE depends on the productivity of the system and for a façade, even if it faces South and is not shaded by adjacent buildings and by the building itself, the differences can be significant between locations. For example, a vertical façade in Sedrun (Yf = 1’173 kWh/kW) has 15 % more energy compared to Lugano (Yf = 1’020 kWh/kW) and 39 % more energy than in Burgdorf (841 kWh/kW). The calculation of the LCOE with the median data for CAPEX is shown below.

| Location | 10 kW |
|---|---|
| Midland | 29.0 |
| Ticino | 26.3 |
| Alpine | 25.0 |

Table 21: Calculation of LCOE for different locations of façade systems in Rp./kWh

### 3.6.3 Alpine PV

According to the study "Harnessing solar power in the Alps: A study on the financial viability of mountain PV systems", the electricity generation costs for alpine PV systems are highly dependent on the investment costs. They range from 9.7 Rp./kWh at 2’231 CHF/kW to 16.2 Rp./kWh at 4’182 CHF/kW [6]. For the calculation, installations with an Internal Rate of Return (IRR) of more than 5.23 % were considered and subsidies were not taken into account. In the case of an average system with 3’800 CHF/kW, this would correspond to an LCOE of 14.9 Rp./kWh.

However, this report does not use the results of study [6]. Instead, the costs and energy yields published by the project planners of the large-scale alpine plants of the SolarExpress (EnG Art. 71a) are used to calculate the LCOE. At 19.8 Rp./kWh, these are significantly higher than the costs mentioned above. However, it should be noted that the calculated LCOE also has very large uncertainties due to the widely varying investment costs.

| Location | 1 MW |
|---|---|
| Alpine | 19.8 |

Table 22: Calculation of LCOE for Alpine PV systems in Rp./kWh

### 3.6.4 Agri PV

Markus Markstaler put the production costs of agrivoltaic systems for speciality crops at 14 Rp./kWh [9]. The ZHAW, on the other hand, estimates it at 8.4 Rp./kWh. It should be noted that the ZHAW assumes significantly lower investment costs for Agri PV systems (1’818 CHF/kW incl. grid connection line) and that the operating costs are also assumed to be relatively low at 1.36 Rp./kWh [8]. The calculation (median) from the information in the previous chapters shows the following LCOE for Agri PV systems:

| Location | 100 kW |
|---|---|
| Midland | 14.8 |
| Ticino | 13.6 |
| Alpine | 13.1 |

Table 23: Calculation of LCOE for different system sizes and locations of Agri PV systems in Rp./kWh

### 3.6.5 Car park PV

According to the study "Solarstrom auf Parkplatzüberdachungen" [10], the Courgenay solar park has production costs of 18 Rp./kWh. This system covers a vehicle warehouse of a car logistics company. The following LCOEs result from the assumptions (median) made in this study:

| Location | 100 kW |
|---|---|
| Midland | 15.8 |
| Ticino | 14.5 |
| Alpine | 13.9 |

Table 24: Calculation of LCOE for different system sizes and locations of car park PV systems in Rp./kWh

### 3.6.6 Summary

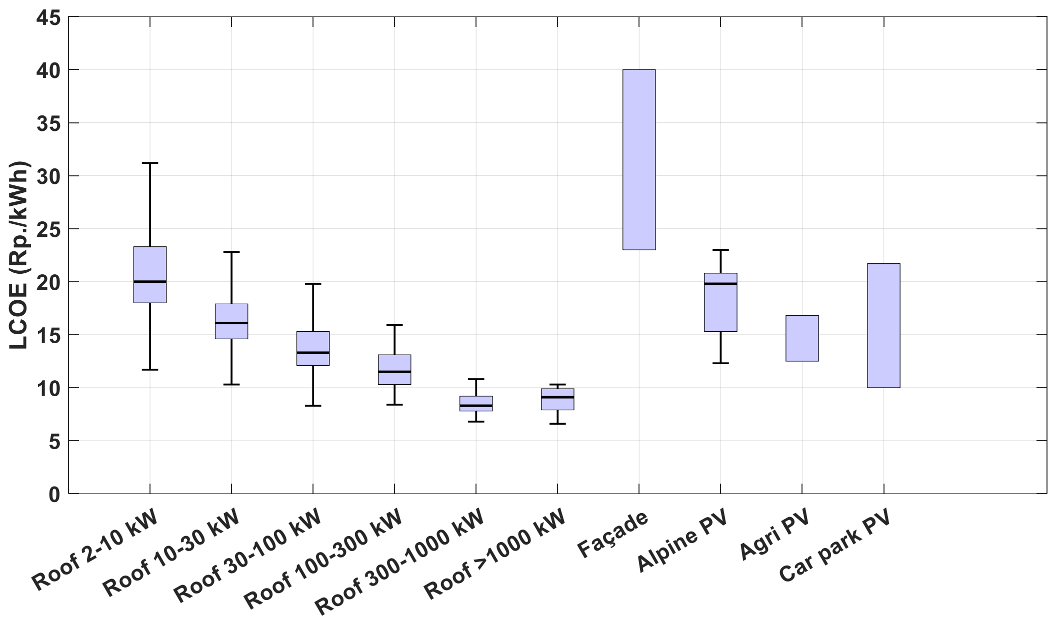


Figure 19: LCOE of the different plant types in midlands

The graph above compares the LCOE of the various plants in midlands. The LCOE for alpine plants is an exception. This is calculated for the Sedrun site. It can be seen that the production costs of façade systems are the highest, but also have the largest range. This is because, on the one hand, the irradiation on these surfaces is lower and, on the other hand, the costs for such systems are high compared to the others. Furthermore, car park PV and alpine PV also show a rather large dispersion. It should again be noted that the systems with box plots are statistically determined values. The bars are based on limited data and should therefore be treated with caution. It is also assumed here that the actual range of production costs is greater for Agri PV, as significantly cheaper but also more expensive systems can be realised.

# 4 Discussion

With the rapid advancements in PV technology, both the efficiency (reaching 25 % module efficiency) and lifespan of modules are improving, as evidenced by the extension of warranty periods. However, these developments can sometimes progress quickly, with the primary focus often on reducing costs per power (not energy yield) rather than considering long-term performance. As a result, it has been observed that the degradation rate and even the failure rate of newly introduced technologies such as TOPCon or HJT have increased only in some cases. To prevent such unexpected rapid degradation and failures, new technological developments should be approached with caution and all necessary tests must be performed. Above all, the most critical indicator is the performance of the modules under actual operating conditions.

The share of winter electricity differs on the one hand mainly due to the location (midlands or alpine region) and on the other hand due to the typical inclination of the modules. For this reason, façade systems generate a higher proportion of electricity in winter. A winter electricity share of approx. 25 % can be expected for roof systems up to a share of 43 % for alpine systems. For individual alpine systems, a winter electricity share of up to 53 % is currently assumed.

Prices for mature PV systems are not expected to change significantly in the next 5 years. As modules are currently unsustainably cheap, they are more likely to become more expensive again. This could compensate for possible efficiency gains. Most of the rest of PV system costs (especially labour costs) are linked to the general economic development rather than major developments in the PV market.

Operating costs are also not expected to change significantly in the coming years. The higher module efficiency and associated higher energy production and lower operating costs will probably be offset by higher costs for materials, services and insurance.

In general, it should be noted that the available results are subject to very large uncertainties, especially for new technologies and systems such as agrivoltaics or alpine PV systems. On the one hand, this is due to the small amount of data available for certain types of installation and, on the other hand, due to the wide scope for making assumptions.

# 5 List of illustrations

# 6 List of tables

# 7 Glossar

| Abbreviation | Description |
|---|---|
| ABC | All-Back-Contact |
| BAPV | Building-applied PV |
| BC | Back Contact |
| BFE | Bundesamt für Energie |
| BFH | Berner Fachhochschule |
| BIPV | Building-integrated PV |
| BOM | Bill-of-materials |
| CalEnCo | California Energy Commission |
| CAPEX | Capital Expenditure |
| EIV | Einmalvergütung |
| EnG | Energiegesetz (Energy Act) |
| EVS | Einspeisevergütungssystem |
| FR | Flat roof |
| GO | Guarantees of origin |
| GUSTAVO | Cantons Genève, Uri, Schwyz, Ticino, Appenzell Innerrhoden, Valais, Obwalden |
| HJT | Heterojunction |
| HKN | Herkunftsnachweis |
| HPBC | Hybrid Passivated Back Contact |
| IEA PVPS | International Energy Agency Photovoltaic Power Systems Programme |
| IRR | Internal Rate of Return |
| ISE | Fraunhofer Institute for Solar Energy Systems |
| ITRPV | International Technology Roadmap for Photovoltaic |
| MKF | Mehrkostenfinanzierung |
| MV | Medium-voltage |
| OPEX | Operational Expenditure |
| OST | Ostschweizer Fachhochschule |
| PERC | Passivated Emitter and Rear Cell |
| PiR | Pitched roof |
| PLR | Performance Loss Rate |
| PR | Performance ratio |
| STC | Standard test conditions |
| SUPSI | Scuola universitaria professionale della Svizzera italiana |
| UV | Ultraviolet |
| VAT | Value added tax |
| WACC | Weighted Average Cost of Capital |
| ZHAW | Zürcher Hochschule für Angewandte Wissenschaften |

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# 9 Appendix

## 9.1 Winter electricity share Alpine PV

| PV plant name | Specific winter yield [kWh/kWp] | Winter percentage [%] |
|---|---|---|
| Albigna Solar | 610 | 50 |
| Alpin Solar Ybrig | 667 | 50 |
| AlpinSolar | 750 | 50 |
| Bernina Solar | 533 | 37 |
| Gibidum Solar | 720 | 45 |
| Gondosolar | 541 | 39 |
| Grengiols Solar | 696 | 43 |
| Grindelwald Gemschberg | 648 | 42 |
| Grindelwald Oberjoch | 599 | 40 |
| Lago di Lei | 554 | 50 |
| Madrisasolar | 667 | 43 |
| MontSol | 542 | 38 |
| NalpSolar | 505 | 38 |
| Nandro Solar | 782 | 45 |
| Oberaar Staumauer | 394 | 40 |
| Ovra Solara Camplauns | 733 | 50 |
| Ovra Solara Magriel | 600 | 37 |
| Parco Solare Alpino Duragno | 761 | 53 |
| Prafleuri | 608 | 45 |
| PV Alpin Parsenn | 587 | 40 |
| PVA Hohsaas | 676 | 43 |
| Räterichsboden Stausee | 408 | 40 |
| Schattenhalb Tschingel Ost | 668 | 42 |
| Schattenhalb Tschingel West | 668 | 42 |
| Scuol Solar | 637 | 44 |
| Sedrun Solar | 696 | 45 |
| Solar Alpin Disentis | 850 | 51 |
| Solar Alpin Käserstatt | 638 | 45 |
| Solaranlage Schwandfäl | 686 | 45 |
| Solaranlage Vorab | 567 | 40 |
| Solarkraftwerk Samedan | 609 | 47 |
| Solarprojekt Morgeten | 646 | 45 |
| **Average** | **642** | **43.5** |

## 9.2 Trend of operating costs

### 9.2.1 Results

| | | 10 kW PiR | 10 kW FR gravel | 10 kW FR green | 100 kW PiR | 100 kW FR gravel | 100 kW FR green | 1 MW PiR | 1 MW FR gravel | 1 MW FR green |
|---|---|---|---|---|---|---|---|---|---|---|
| Replacement/Repair inverter | Replacement/Repair inverter | 2.53 | 2.53 | 2.53 | 0.76 | 0.76 | 0.76 | 0.63 | 0.63 | 0.63 |
| | Replacement/Repair other material | 1.00 | 1.00 | 1.00 | 0.42 | 0.42 | 0.42 | 0.26 | 0.26 | 0.26 |
| Meter and grid costs, GO | GO administration | 0.00 | 0.00 | 0.00 | 0.16 | 0.16 | 0.16 | 0.05 | 0.05 | 0.05 |
| Service and inspection rounds | Service and inspection rounds | 0.00 | 0.00 | 0.00 | 0.23 | 0.23 | 0.23 | 0.18 | 0.18 | 0.18 |
| Operational monitoring | Monitoring | 0.00 | 0.00 | 0.00 | 0.29 | 0.29 | 0.29 | 0.05 | 0.05 | 0.05 |
| | Subscription fees | 0.00 | 0.00 | 0.00 | 0.08 | 0.08 | 0.08 | 0.02 | 0.02 | 0.02 |
| | Device replacement | 0.00 | 0.00 | 0.00 | 0.21 | 0.21 | 0.21 | 0.03 | 0.03 | 0.03 |
| Cleaning | Cleaning | 0.00 | 0.00 | 0.00 | 0.45 | 0.50 | 0.45 | 0.30 | 0.20 | 0.20 |
| Insurance | Liability | 0.00 | 0.00 | 0.00 | 0.63 | 0.63 | 0.63 | 0.32 | 0.32 | 0.32 |
| | Natural hazards | 0.18 | 0.18 | 0.18 | 0.11 | 0.11 | 0.11 | 0.07 | 0.07 | 0.07 |
| Administration | Administration | 0.00 | 0.00 | 0.00 | 0.21 | 0.21 | 0.21 | 0.08 | 0.08 | 0.08 |
| Miscellaneous | VAT. | 0.29 | 0.29 | 0.29 | 0.26 | 0.27 | 0.39 | 0.17 | 0.16 | 0.26 |
| | Maintenance of MV transformer and switchgear | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.24 | 0.24 |
| Green roof maintenance | Green roof maintenance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 0.00 | 0.00 | 1.20 |

### 9.2.2 Categories

**Natural hazard**

In 19 out of 26 cantons, it is compulsory to take out insurance for natural hazards with the buildings insurance. The premium structure depends on the canton and can vary greatly. There are fixed rates, but there are also rates that are based on the structure of the building and risk factors. The following is an extract from various cantons. The premium is based on the insured value of the building.

| Canton | Approach [‰] |
|---|---|
| Baselland | 0.26 – 0.62 |
| Baselstadt | 0.25 – 1.2 |
| Bern | 0.34 – 0.66 |
| Freiburg | 0.42 – 0.62 |
| Graubünden | 0.26 – 0.56 |
| Luzern | 0.55 |
| Neuenburg | 0.42 – 0.91 |
| Schaffhausen | 0.16 – 0.94 |
| Solothurn | 0.44 - 0.55 |
| St.Gallen | 0.35 – 0.73 |
| Thurgau | 0.33 – 0.96 |
| Zug | 0.6 |
| Zürich | 0.29 |

### 9.3 Calculation LCOE

Calculation method with fictitious example:

| | |
|---|---|
| Investment cost (BW): | 190’000 CHF |
| Operating cost (O&M): | 3 % of the CAPEX |
| WACC (z): | 2 % |
| Operating time (T): | 25 years |
| Production: | 210’000 kWh |

Annuity:

$$ANF = BW \cdot \frac{(1+z)^T \cdot z}{(1+z)^T - 1} = 190'000 \cdot \frac{(1+0.02)^{25} \cdot 0.02}{(1+0.02)^{25} - 1} = 9'731.88$$

O&M = BW * 0.03 = 190’000 * 0.03 = 5’700

ANF + O&M = 9’731.88 + 5’700 = 15’431.88

LCOE:

$$LCOE = \frac{15'431.88\ CHF}{210'000\ kWh} = 0.073\ \frac{CHF}{kWh}$$

| Assumptions | |
|---|---|
| WACC | 0.02 |
| Operating time [a] | 25 |
| Factor $G_0$ --> $G_i$ roof, Agri PV, Car park PV | 1.05 |
| Factor $G_0$ --> $G_i$ Façade | 0.75 |
| Factor $G_0$ --> $G_i$ Alpine PV | 1.15 |
| Irradiation Midland/Burgdorf [kWh/m$^2$] | 1’200 |
| Irradiation Ticino/Lugano [kWh/m$^2$] | 1’350 |
| Irradiation Alpin/Sedrun [kWh/m$^2$] | 1’430 |
| PR | 0.8 |
| Degeneration | 0.0 |

## Calculation

Min-values

| | Roof | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2-10 kW Midland** | **10-30 kW Midland** | **30-100 kW Midland** | **100-300 kW Midland** | **300-1000kW Midland** | **>1000 kW Midland** | **2-10 kW Ticino** | **10-30 kW Ticino** | **30-100 kW Ticino** | **100-300 kW Ticino** | **300-1000kW Ticino** | **>1000 kW Ticino** | **2-10 kW Alpine** | **10-30 kW Alpine** | **30-100 kW Alpine** | **100-300 kW Alpine** | **300-1000kW Alpine** | **>1000 kW Alpine** |
| Spec. Cost [CHF/kWp] | 1525 | 1235 | 878 | 915 | 861 | 831 | 1525 | 1235 | 878 | 915 | 861 | 831 | 1525 | 1235 | 878 | 915 | 861 | 831 |
| CAPEX [CHF] | 9150 | 24700 | 57070 | 183000 | 559650 | 831000 | 9150 | 24700 | 57070 | 183000 | 559650 | 831000 | 9150 | 24700 | 57070 | 183000 | 559650 | 831000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 |
| OPEX abs [CHF/a] | 241.92 | 806.4 | 2489.76 | 7660.8 | 15724.8 | 24192 | 272.16 | 907.2 | 2800.98 | 8618.4 | 17690.4 | 27216 | 288.288 | 960.96 | 2966.964 | 9129.12 | 18738.72 | 28828.8 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 1260 | 1260 | 1260 | 1260 | 1260 | 1260 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 |
| PR | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6048 | 20160 | 65520 | 201600 | 655200 | 1008000 | 6804 | 22680 | 73710 | 226800 | 737100 | 1134000 | 7207.2 | 24024 | 78078 | 240240 | 780780 | 1201200 |
| | | | | | | | | | | | | | | | | | | |
| LCOE | 0.117 | 0.103 | 0.083 | 0.084 | 0.068 | 0.066 | 0.109 | 0.096 | 0.078 | 0.079 | 0.063 | 0.062 | 0.105 | 0.093 | 0.075 | 0.077 | 0.061 | 0.059 |

| | Fassade | | | AlpinePV | AgriPV | | | Car Park PV | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **10kW Midland** | **10kW Ticino** | **10kW Alpine** | **1MW Alpine** | **100kW Midland** | **100kW Ticino** | **100kW Alpine** | **100kW Midland** | **100kW Ticino** | **100kW Alpine** |
| Spec. Cost [CHF/kWp] | 2500 | 2500 | 2500 | 1880 | 1550 | 1550 | 1550 | 1200 | 1200 | 1200 |
| CAPEX [CHF] | 25000 | 25000 | 25000 | 1880000 | 155000 | 155000 | 155000 | 120000 | 120000 | 120000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.04 | 0.05 | 0.046 | 0.046 | 0.046 | 0.039 | 0.039 | 0.039 |
| OPEX abs [CHF/a] | 270 | 303.75 | 321.75 | 65780 | 4636.8 | 5216.4 | 5525.52 | 3931.2 | 4422.6 | 4684.68 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 900 | 1012.5 | 1072.5 | 1644.5 | 1260 | 1417.5 | 1501.5 | 1260 | 1417.5 | 1501.5 |
| PR | 0.75 | 0.75 | 0.75 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 10 | 10 | 10 | 1000 | 100 | 100 | 100 | 100 | 100 | 100 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6750 | 7593.75 | 8043.75 | 1315600 | 100800 | 113400 | 120120 | 100800 | 113400 | 120120 |
| | | | | | | | | | | |
| LCOE | 0.230 | 0.209 | 0.199 | 0.123 | 0.125 | 0.116 | 0.112 | 0.100 | 0.093 | 0.090 |

1. Quartil (25 %)

| | Roof | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2-10 kW Midland** | **10-30 kW Midland** | **30-100 kW Midland** | **100-300 kW Midland** | **300-1000kW Midland** | **>1000 kW Midland** | **2-10 kW Ticino** | **10-30 kW Ticino** | **30-100 kW Ticino** | **100-300 kW Ticino** | **300-1000kW Ticino** | **>1000 kW Ticino** | **2-10 kW Alpine** | **10-30 kW Alpine** | **30-100 kW Alpine** | **100-300 kW Alpine** | **300-1000kW Alpine** | **>1000 kW Alpine** |
| Spec. Cost [CHF/kWp] | 2746 | 2089 | 1635 | 1286 | 1055 | 1088 | 2746 | 2089 | 1635 | 1286 | 1055 | 1088 | 2746 | 2089 | 1635 | 1286 | 1055 | 1088 |
| CAPEX [CHF] | 16476 | 41780 | 106275 | 257200 | 685750 | 1088000 | 16476 | 41780 | 106275 | 257200 | 685750 | 1088000 | 16476 | 41780 | 106275 | 257200 | 685750 | 1088000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 |
| OPEX abs [CHF/a] | 241.92 | 806.4 | 2489.76 | 7660.8 | 15724.8 | 24192 | 272.16 | 907.2 | 2800.98 | 8618.4 | 17690.4 | 27216 | 288.288 | 960.96 | 2966.964 | 9129.12 | 18738.72 | 28828.8 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 1260 | 1260 | 1260 | 1260 | 1260 | 1260 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 |
| PR | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6048 | 20160 | 65520 | 201600 | 655200 | 1008000 | 6804 | 22680 | 73710 | 226800 | 737100 | 1134000 | 7207.2 | 24024 | 78078 | 240240 | 780780 | 1201200 |
| | | | | | | | | | | | | | | | | | | |
| LCOE | 0.180 | 0.146 | 0.121 | 0.103 | 0.078 | 0.079 | 0.164 | 0.134 | 0.112 | 0.096 | 0.072 | 0.073 | 0.157 | 0.129 | 0.108 | 0.093 | 0.069 | 0.070 |

| | **AlpinePV** |
|---|---|
| | **1MW Alpine** |
| Spec. Cost [CHF/kWp] | 2640 |
| CAPEX [CHF] | 2640000 |
| OPEX rel [CHF/kWh] | 0.05 |
| OPEX abs [CHF/a] | 65780 |
| Operating time [a] | 25 |
| WACC | 0.02 |
| Irradiation [kWh/m2] | 1644.5 |
| PR | 0.8 |
| Power [kW] | 1000 |
| Degeneration | 0 |
| Energy Yield [kWh/a] | 1315600 |
| | |
| LCOE | 0.153 |

Median:

| | Roof | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2-10 kW Midland** | **10-30 kW Midland** | **30-100 kW Midland** | **100-300 kW Midland** | **300-1000kW Midland** | **>1000 kW Midland** | **2-10 kW Ticino** | **10-30 kW Ticino** | **30-100 kW Ticino** | **100-300 kW Ticino** | **300-1000kW Ticino** | **>1000 kW Ticino** | **2-10 kW Alpine** | **10-30 kW Alpine** | **30-100 kW Alpine** | **100-300 kW Alpine** | **300-1000kW Alpine** | **>1000 kW Alpine** |
| Spec. Cost [CHF/kWp] | 3141 | 2384 | 1879 | 1513 | 1163 | 1326 | 3141 | 2384 | 1879 | 1513 | 1163 | 1326 | 3141 | 2384 | 1879 | 1513 | 1163 | 1326 |
| CAPEX [CHF] | 18846 | 47680 | 122135 | 302600 | 755950 | 1326000 | 18846 | 47680 | 122135 | 302600 | 755950 | 1326000 | 18846 | 47680 | 122135 | 302600 | 755950 | 1326000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 |
| OPEX abs [CHF/a] | 241.92 | 806.4 | 2489.76 | 7660.8 | 15724.8 | 24192 | 272.16 | 907.2 | 2800.98 | 8618.4 | 17690.4 | 27216 | 288.288 | 960.96 | 2966.964 | 9129.12 | 18738.72 | 28828.8 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 1260 | 1260 | 1260 | 1260 | 1260 | 1260 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 |
| PR | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6048 | 20160 | 65520 | 201600 | 655200 | 1008000 | 6804 | 22680 | 73710 | 226800 | 737100 | 1134000 | 7207.2 | 24024 | 78078 | 240240 | 780780 | 1201200 |
| | | | | | | | | | | | | | | | | | | |
| LCOE | 0.200 | 0.161 | 0.133 | 0.115 | 0.083 | 0.091 | 0.182 | 0.148 | 0.123 | 0.106 | 0.077 | 0.084 | 0.174 | 0.142 | 0.118 | 0.103 | 0.074 | 0.081 |

| | Fassade | | | AlpinePV | AgriPV | | | Car Park PV | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **10kW Midland** | **10kW Ticino** | **10kW Alpine** | **1MW Alpine** | **100kW Midland** | **100kW Ticino** | **100kW Alpine** | **100kW Midland** | **100kW Ticino** | **100kW Alpine** |
| Spec. Cost [CHF/kWp] | 3300 | 3300 | 3300 | 3800 | 2000 | 2000 | 2000 | 2350 | 2350 | 2350 |
| CAPEX [CHF] | 33000 | 33000 | 33000 | 3800000 | 200000 | 200000 | 200000 | 235000 | 235000 | 235000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.04 | 0.05 | 0.046 | 0.046 | 0.046 | 0.039 | 0.039 | 0.039 |
| OPEX abs [CHF/a] | 270 | 303.75 | 321.75 | 65780 | 4636.8 | 5216.4 | 5525.52 | 3931.2 | 4422.6 | 4684.68 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 900 | 1012.5 | 1072.5 | 1644.5 | 1260 | 1417.5 | 1501.5 | 1260 | 1417.5 | 1501.5 |
| PR | 0.75 | 0.75 | 0.75 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 10 | 10 | 10 | 1000 | 100 | 100 | 100 | 100 | 100 | 100 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6750 | 7593.75 | 8043.75 | 1315600 | 100800 | 113400 | 120120 | 100800 | 113400 | 120120 |
| | | | | | | | | | | |
| LCOE | 0.290 | 0.263 | 0.250 | 0.198 | 0.148 | 0.136 | 0.131 | 0.158 | 0.145 | 0.139 |

3. Quartil

| | Roof | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2-10 kW Midland** | **10-30 kW Midland** | **30-100 kW Midland** | **100-300 kW Midland** | **300-1000kW Midland** | **>1000 kW Midland** | **2-10 kW Ticino** | **10-30 kW Ticino** | **30-100 kW Ticino** | **100-300 kW Ticino** | **300-1000kW Ticino** | **>1000 kW Ticino** | **2-10 kW Alpine** | **10-30 kW Alpine** | **30-100 kW Alpine** | **100-300 kW Alpine** | **300-1000kW Alpine** | **>1000 kW Alpine** |
| Spec. Cost [CHF/kWp] | 3800 | 2738 | 2264 | 1822 | 1340 | 1473 | 3800 | 2738 | 2264 | 1822 | 1340 | 1473 | 3800 | 2738 | 2264 | 1822 | 1340 | 1473 |
| CAPEX [CHF] | 22800 | 54760 | 147160 | 364400 | 871000 | 1473000 | 22800 | 54760 | 147160 | 364400 | 871000 | 1473000 | 22800 | 54760 | 147160 | 364400 | 871000 | 1473000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 |
| OPEX abs [CHF/a] | 241.92 | 806.4 | 2489.76 | 7660.8 | 15724.8 | 24192 | 272.16 | 907.2 | 2800.98 | 8618.4 | 17690.4 | 27216 | 288.288 | 960.96 | 2966.964 | 9129.12 | 18738.72 | 28828.8 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 1260 | 1260 | 1260 | 1260 | 1260 | 1260 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 |
| PR | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6048 | 20160 | 65520 | 201600 | 655200 | 1008000 | 6804 | 22680 | 73710 | 226800 | 737100 | 1134000 | 7207.2 | 24024 | 78078 | 240240 | 780780 | 1201200 |
| | | | | | | | | | | | | | | | | | | |
| LCOE | 0.233 | 0.179 | 0.153 | 0.131 | 0.092 | 0.099 | 0.212 | 0.164 | 0.140 | 0.120 | 0.085 | 0.091 | 0.202 | 0.157 | 0.135 | 0.116 | 0.081 | 0.087 |

| | **AlpinePV** |
|---|---|
| | 4050 |
| Spec. Cost [CHF/kWp] | 4050000 |
| CAPEX [CHF] | 0.05 |
| OPEX rel [CHF/kWh] | 65780 |
| OPEX abs [CHF/a] | 25 |
| Operating time [a] | 0.02 |
| WACC | 1644.5 |
| Irradiation [kWh/m2] | 0.8 |
| PR | 1000 |
| Power [kW] | 0 |
| Degeneration | 1315600 |
| Energy Yield [kWh/a] | |
| | 0.208 |
| LCOE | 4050 |

Max values

| | Roof | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2-10 kW Midland** | **10-30 kW Midland** | **30-100 kW Midland** | **100-300 kW Midland** | **300-1000kW Midland** | **>1000 kW Midland** | **2-10 kW Ticino** | **10-30 kW Ticino** | **30-100 kW Ticino** | **100-300 kW Ticino** | **300-1000kW Ticino** | **>1000 kW Ticino** | **2-10 kW Alpine** | **10-30 kW Alpine** | **30-100 kW Alpine** | **100-300 kW Alpine** | **300-1000kW Alpine** | **>1000 kW Alpine** |
| Spec. Cost [CHF/kWp] | 5352 | 3705 | 3147 | 2382 | 1647 | 1559 | 5352 | 3705 | 3147 | 2382 | 1647 | 1559 | 5352 | 3705 | 3147 | 2382 | 1647 | 1559 |
| CAPEX [CHF] | 32112 | 74100 | 204555 | 476400 | 1070550 | 1559000 | 32112 | 74100 | 204555 | 476400 | 1070550 | 1559000 | 32112 | 74100 | 204555 | 476400 | 1070550 | 1559000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 | 0.04 | 0.04 | 0.038 | 0.038 | 0.024 | 0.024 |
| OPEX abs [CHF/a] | 241.92 | 806.4 | 2489.76 | 7660.8 | 15724.8 | 24192 | 272.16 | 907.2 | 2800.98 | 8618.4 | 17690.4 | 27216 | 288.288 | 960.96 | 2966.964 | 9129.12 | 18738.72 | 28828.8 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 1260 | 1260 | 1260 | 1260 | 1260 | 1260 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1417.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 | 1501.5 |
| PR | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 | 6 | 20 | 65 | 200 | 650 | 1000 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6048 | 20160 | 65520 | 201600 | 655200 | 1008000 | 6804 | 22680 | 73710 | 226800 | 737100 | 1134000 | 7207.2 | 24024 | 78078 | 240240 | 780780 | 1201200 |
| | | | | | | | | | | | | | | | | | | |
| LCOE | 0.312 | 0.228 | 0.198 | 0.159 | 0.108 | 0.103 | 0.282 | 0.207 | 0.180 | 0.146 | 0.098 | 0.094 | 0.268 | 0.198 | 0.172 | 0.140 | 0.094 | 0.090 |

| | Fassade | | | AlpinePV | AgriPV | | | Car Park PV | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **10kW Midland** | **10kW Ticino** | **10kW Alpine** | **1MW Alpine** | **100kW Midland** | **100kW Ticino** | **100kW Alpine** | **100kW Midland** | **100kW Ticino** | **100kW Alpine** |
| Spec. Cost [CHF/kWp] | 4750 | 4750 | 4750 | 4630 | 2400 | 2400 | 2400 | 3500 | 3500 | 3500 |
| CAPEX [CHF] | 47500 | 47500 | 47500 | 4630000 | 240000 | 240000 | 240000 | 350000 | 350000 | 350000 |
| OPEX rel [CHF/kWh] | 0.04 | 0.04 | 0.04 | 0.05 | 0.046 | 0.046 | 0.046 | 0.039 | 0.039 | 0.039 |
| OPEX abs [CHF/a] | 270 | 303.75 | 321.75 | 65780 | 4636.8 | 5216.4 | 5525.52 | 3931.2 | 4422.6 | 4684.68 |
| Operating time [a] | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| WACC | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Irradiation [kWh/m2] | 900 | 1012.5 | 1072.5 | 1644.5 | 1260 | 1417.5 | 1501.5 | 1260 | 1417.5 | 1501.5 |
| PR | 0.75 | 0.75 | 0.75 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Power [kW] | 10 | 10 | 10 | 1000 | 100 | 100 | 100 | 100 | 100 | 100 |
| Degeneration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Energy Yield [kWh/a] | 6750 | 7593.75 | 8043.75 | 1315600 | 100800 | 113400 | 120120 | 100800 | 113400 | 120120 |
| | | | | | | | | | | |
| LCOE | 0.400 | 0.360 | 0.342 | 0.230 | 0.168 | 0.154 | 0.148 | 0.217 | 0.197 | 0.188 |

# 10Version

| Version | Date | Description | Author |
|---|---|---|---|
| 1.0 | 13.02.2025 | Create report | Ebrar Özkalay<br>Domenico Chianese<br>Mauro Caccivio<br>Matthias Hügi<br>Christof Bucher |
| 1.1 | 23.05.2025 | Adjustments according discussion with Wieland Hintz | Ebrar Özkalay<br>Domenico Chianese<br>Mauro Caccivio<br>Matthias Hügi<br>Christof Bucher |
| 1.2 | 09.01.2026 | Expansion with summaries and factsheet | Mauro Caccivio<br>Matthias Hügi |