Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of the Environment, Transport,
Energy and Communications DETEC

Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Final report dated 08.01.2026

INSOLAGRIN

Agrivoltaic pilot project at Agroscope in Conthey (VS)

Source: ©Insolight 2025

Date: 08.01.2026

Location: Lausanne

Publisher:
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech
CH-3003 Bern
www.bfe.admin.ch

Subsidy recipients:
Insolight SA
Avenue de Longemalle 11, CH-1020 Renens
www.insolight.ch

Romande Energie SA
Rue de Lausanne 53, CH-1110 Morges
www.romande-energie.ch

Agroscope
Route des Eterpys 18, CH-1964 Conthey
www.agroscope.admin.ch

Authors:
Gaël Nardin, Mathieu Ackermann, Mathilde Duchemin (Insolight)
Jocelyn Widmer, André Ançay, Louis Sutter (Agroscope).
Contact: gael.nardin@insolight.ch

SFOE project coordinators:
Stefan Oberholzer, stefan.oberholzer@bfe.admin.ch
Karin Söderström, karin.soederstroem@bfe.admin.ch
Men Wirz, men.wirz@bfe.admin.ch

SFOE contract number: SI/502210-01

Summary

This report summarises the activities and results of the P+D project "Projet pilote agrivoltaïque à l'Agroscope de Conthey (VS)", running from 20.03.2021 to 30.11.2025.

Agrivoltaics refers to the dual use of land for solar energy and agriculture. In the context of climate change, it offers the opportunity to protect crops against excessive solar radiation, rainfall and extreme climatic events, while producing renewable energy. In Switzerland, photovoltaic installations in agricultural zones can be allowed if they do not adversely affect agricultural interests and bring benefits to agricultural production. The objective of the project was to assess the electrical and agricultural productions of an agrivoltaic system designed for berry crops by the company Insolight. Two generations of systems were evaluated, featuring custom semi-transparent solar panels and adjustable light transmission for the crops.

The project aimed at answering the following questions:

- Can the agrivoltaic cover benefit the agricultural production by protecting crops, in a similar way to conventional plastic covers?
- Is there a viable business model beneficial for both the agricultural producer and the solar developer?

The main achievements are:

- Construction and commissioning of the first agrivoltaic installation for berry crops in Switzerland: a 18kWp first-generation featuring prototypal semi-transparent panels
- 5 years of agronomic trials on raspberries and strawberries, electrical and micro-climatic monitoring with three different agrivoltaic systems of first and second generation.
- Evaluation of commercial viability of the solution, for the agricultural producer and the solar developer.

The project showed the limits of the first prototype built at the project beginning in terms of electrical production, light homogeneity and system costs, making it unviable for commercialization as such. On the other hand, a second-generation system design, based on qualified components, provides satisfactory light transmission and specific electrical yield at an economically viable cost. With competitive Capital Expenditure and specific yield, the berry agrivoltaic cover can finance itself through the electricity production, with typical Internal Return on Investment times of 15-20 years.

The protective effect of the agrivoltaic cover was quantified during heat waves, frost nights and a hailstorm, thus demonstrating the potential of agrivoltaics to mitigate the effect of extreme climatic events.

Agronomical results showed varied outcomes, depending on seasons, species, varieties, applied shading, and type of reference zone to which the agrivoltaic cover was compared to. The main conclusions that emerge from the various trials are:

- For raspberries,
  - a benefit in terms of yield, fruit size and production costs compared to open field cultivation, thus satisfying the requirements set by the Swiss legal framework.
  - When compared to two types of plastic covers (multi-span plastic greenhouses and plastic raincovers), yields were in average lower, but in some cases similar under the agrivoltaic cover, and fruit sizes were in average similar or larger. Production costs are estimated to fall in-between those of the two types of reference zones. A viable business case is therefore possible for the producer.

- For strawberries, yields and sugar levels were in general lower than those obtained under plastic tunnels or raincovers, especially for everbearing varieties. Light availability was generally a limiting factor for total and marketable yields, as well as sugar content. For summer strawberries, promising first results in the most luminous second-generation installations were obtained, with yields close to those of the plastic covers, but need further confirmation.

Overall, these results show that the agrivoltaic cover generally fulfills its role of protective structure against severe weather for the berry crops, while producing renewable electricity at a competitive cost. This electricity production is achieved without additional land take than the originally unprotected berry production. The various trial results provide information on which agrivoltaic designs work best and on which varieties are most adapted for cultivation under agrivoltaic covers.

Main findings («Take-Home Messages»)

1. **Agrivoltaics enable dual land use**: In the context of climate change, the project demonstrated that berry crops can be protected while producing renewable electricity, without additional land take—supporting Switzerland's Energy Strategy 2050 goals for solar expansion.
2. **Competitive energy production**: Agrivoltaic systems assessed during the second half of this project achieved a specific yield of ~1,200 kWh/kWp/year at a capital expenditure of ~1.3 CHF/Wp, making it cost-competitive with rooftop photovoltaics and far cheaper than alpine photovoltaics. A significant share of the production (~340 kWh/kWp) was achieved during the winter half-year, supporting the objectives of Switzerland to increase local winter production.
3. **Agronomic viability confirmed**: Raspberry yields were comparable or superior to open field cultivation, proving that the agrivoltaic cover provides benefits to the agricultural production. Over all the trials realized during 5 years, raspberry and strawberry yields were in average lower but in some cases comparable to those of conventional plastic covers, providing information on the varieties that are most adapted for cultivation under agrivoltaic covers.
4. **Scalable solution for climate resilience**: Agrivoltaics offer a pathway to deploy MW-scale solar installations, complementing fragmented rooftop photovoltaics, while mitigating climate risks for crops.

Zusammenfassung

Dieser Bericht fasst die Aktivitäten und Ergebnisse des Forschungs- und Entwicklungsprojekts „Projet pilote agrivoltaïque à l'Agroscope de Conthey (VS)" zusammen, das vom 20.03.2021 bis zum 30.11.2025 lief. Agrivoltaik bezeichnet die gleichzeitige Nutzung von Land für Solarenergie und Landwirtschaft. Im Kontext des Klimawandels bietet sie die Möglichkeit, Nutzpflanzen vor übermäßiger Sonneneinstrahlung, Starkregen und extremen Wetterereignissen zu schützen und gleichzeitig erneuerbare Energie zu erzeugen. In der Schweiz können Photovoltaikanlagen in landwirtschaftlichen Gebieten genehmigt werden, wenn sie die landwirtschaftlichen Interessen nicht beeinträchtigen und der landwirtschaftlichen Produktion Vorteile bringen. Ziel des Projekts war die Strom- und Agrarproduktion eines von der Firma Insolight für Beerenkulturen entwickelten agrivoltaischen Systems zu bewerten. Es wurden zwei Generationen von Systemen evaluiert, die mit maßgeschneiderten halbtransparenten Solarmodulen und einer für die Kulturen einstellbaren Lichtdurchlässigkeit ausgestattet waren.

Das Projekt zielte darauf ab, folgende Fragen zu beantworten:

- Kann die Agrivoltaik-Abdeckung die landwirtschaftliche Produktion durch den Schutz der Nutzpflanzen ähnlich wie herkömmliche Kunststoffabdeckungen fördern?
- Gibt es ein tragfähiges Geschäftsmodell, das sowohl für den landwirtschaftlichen Produzenten als auch für den Solarentwickler vorteilhaft ist?

Die wichtigsten Ergebnisse sind:

- Bau und Inbetriebnahme der ersten Agri-Photovoltaikanlage für Beerenkulturen in der Schweiz: eine 18-kWp-Anlage der ersten Generation mit prototypischen, halbtransparenten Modulen.
- Fünfjährige agronomische Versuchsreihe mit Himbeeren und Erdbeeren, elektrische und mikroklimatische Überwachung mit drei verschiedenen Agri-Photovoltaiksystemen der ersten und zweiten Generation.
- Bewertung der Wirtschaftlichkeit der Lösung für Landwirte und Solarentwickler.

Das Projekt zeigte die Grenzen des Prototyps der ersten Generation, der zu Beginn des Projekts gebaut wurde, hinsichtlich Stromerzeugung, Lichtverteilung und Systemkosten auf, wodurch eine Kommerzialisierung in dieser Form nicht möglich war. Ein System der zweiten Generation hingegen, basierend auf qualifizierten Komponenten, bietet eine zufriedenstellende Lichtdurchlässigkeit und einen spezifischen Stromertrag zu wirtschaftlich tragbaren Kosten. Mit wettbewerbsfähigen Investitionskosten und spezifischen Erträgen kann sich die Agrar-Photovoltaik-Abdeckung durch die Stromerzeugung selbst finanzieren, wobei die typische interne Kapitalrendite bei 15 bis 20 Jahren liegt.

Schutzwirkung der Agri-Photovoltaikabdeckung wurde während Hitzewellen, Frostnächten und einem Hagelsturm quantifiziert und das Potenzial der Agri-Photovoltaik zur Milderung der Auswirkungen extremer Wetterereignisse aufgezeigt.

Die agronomischen Ergebnisse zeigten je nach Jahreszeit, Kulturpflanze, Sorte, angewandter Beschattung und Art der Vergleichsfläche, mit der die Agri-Photovoltaik-Abdeckung verglichen wurde, unterschiedliche Resultate. Die wichtigsten Schlussfolgerungen aus den verschiedenen Versuchen sind:

- Bei Himbeeren ergab sich :
  - Im Vergleich zum Freilandanbau ein Vorteil hinsichtlich Ertrags, Fruchtgröße und Produktionskosten, wodurch die Anforderungen des Schweizer Rechtsrahmens erfüllt werden.

  - Im Vergleich zu zwei Typen von Kunststoffabdeckungen (mehrfeldrige Kunststoffgewächshäuser und Kunststoff-Regenabdeckungen) waren die Erträge unter der agrivoltaischen Abdeckung im Durchschnitt geringer, in einigen Fällen jedoch ähnlich, und die Fruchtgrößen waren im Durchschnitt ähnlich oder größer. Die Produktionskosten der Agri-Photovoltaik-Anlagen zwischen denen der beiden Vergleichsflächen. Für den Erzeuger ist daher ein rentables Geschäftsmodell möglich.

Bei Erdbeeren waren Ertrag und Zuckergehalt im Allgemeinen niedriger als unter Folientunneln oder -schirmen, insbesondere bei immertragenden Sorten. Die Lichtverfügbarkeit war im Allgemeinen ein begrenzender Faktor für den Gesamt- und den vermarktbaren Ertrag, und Zuckergehalt. Bei Sommererdbeeren wurden vielversprechende erste Ergebnisse in den lichtdurchlässigsten Anlagen der zweiten Generation erzielt, deren Erträge denen der Kunststoffabdeckungen nahekommen, jedoch noch einer weiteren Bestätigung bedürfen.

Insgesamt zeigen diese Ergebnisse, dass die Agri-Photovoltaik-Abdeckung im Allgemeinen ihre Funktion als Witterungsschutz für die Beerenkulturen erfüllt und gleichzeitig erneuerbaren Strom zu wettbewerbsfähigen Kosten erzeugt. Diese Stromerzeugung wird ohne zusätzlichen Flächenbedarf im Vergleich zur ursprünglich ungeschützten Beerenproduktion erreicht. Die verschiedenen Versuchsergebnisse liefern Informationen darüber, welche Agrivoltaik-Konzepte am besten funktionieren und welche Sorten für den Anbau unter Agrivoltaik-Abdeckungen am besten geeignet sind.

Résumé

Ce rapport résume les activités et les résultats du projet de recherche et développement « Projet pilote agrivoltaïque à l'Agroscope de Conthey (VS) », mené du 20 mars 2021 au 30 novembre 2025.

L'agrivoltaïsme désigne la double utilisation des terres pour la production d'énergie solaire et l'agriculture. Dans le contexte du changement climatique, il offre la possibilité de protéger les cultures contre le rayonnement solaire excessif, les fortes pluies et les événements climatiques extrêmes, tout en produisant de l'énergie renouvelable. En Suisse, les installations photovoltaïques dans les zones agricoles peuvent être autorisées si elles ne nuisent pas aux intérêts agricoles et apportent des avantages à la production agricole. L'objectif du projet était d'évaluer les productions électrique et agricole d'un système agrivoltaïque conçu par la société Insolight pour la culture des petits fruits. Deux générations de systèmes ont été évaluées, équipées de panneaux solaires spéciaux semi-transparents et d'un système de transmission de lumière réglable pour les cultures.

Le projet visait à répondre aux questions suivantes :

- La couverture agrivoltaïque peut-elle être bénéfique à la production agricole en protégeant les cultures, à l'instar de tunnels plastiques conventionnels ?
- Existe-t-il un modèle économique viable, avantageux à la fois pour le producteur agricole et le développeur solaire ?

Les principaux résultats sont les suivants :

- Construction et mise en service de la première installation agrivoltaïque pour la culture de petits fruits en Suisse : une installation de première génération de 18 kWc dotée de panneaux semi-transparents prototypes.
- Cinq années d'essais agronomiques sur framboises et fraises, avec un suivi électrique et microclimatique réalisé à l'aide de trois systèmes agrivoltaïques différents de première et deuxième générations.
- Évaluation de la viabilité commerciale de la solution, tant pour le producteur agricole que pour le développeur de projets solaires.

Le projet a mis en évidence les limites du prototype construit au début du projet en termes de production électrique, d'homogénéité lumineuse et de coûts du système, le rendant non commercialisable en l'état. En revanche, la conception d'un système de deuxième génération, basée sur des composants qualifiés, offre une transmission lumineuse et un rendement électrique spécifique satisfaisants à un coût économiquement viable. Avec un coût d'investissement et un rendement spécifique compétitifs, l'abri agrivoltaïque pour baies peut s'autofinancer grâce à la production d'électricité, avec un retour sur investissement interne typique de 15 à 20 ans.

L'effet protecteur de la couverture agrivoltaïque a été quantifié lors de vagues de chaleur, de gels nocturnes et d'un orage de grêle, démontrant ainsi le potentiel de l'agrivoltaïsme pour atténuer les effets des événements climatiques extrêmes.

Les résultats agronomiques ont montré des variations selon les saisons, les espèces, les variétés, l'ombrage appliqué et le type de zone de référence auquel la couverture agrivoltaïque a été comparée. Les principales conclusions des différents essais sont les suivantes :

- Pour les framboises :
  - un avantage en termes de rendement, de calibre des fruits et de coûts de production par rapport à la culture en plein champ, répondant ainsi aux exigences fixées par le cadre juridique suisse

    - Comparés à deux types de couvertures plastiques (serres plastiques multi-chapelles et parapluies), les rendements étaient en moyenne inférieurs, mais dans certains cas similaires sous l'abri agrivoltaïque, et la taille des fruits était en moyenne similaire ou supérieure. Les coûts de production des installations agrivoltaïques se situent entre ceux des deux types de zones de référence. Un modèle économique viable est donc possible pour le producteur.

- Pour les fraises, les rendements et les taux de sucre étaient généralement inférieurs à ceux obtenus sous tunnels ou parapluies plastiques, en particulier pour les variétés remontantes. La disponibilité de la lumière était généralement un facteur limitant pour les rendements totaux et commercialisables ainsi que pour le taux de sucre. Pour les fraises d'été, des premiers résultats prometteurs ont été obtenus sous les installations de deuxième génération les plus lumineuses, avec des rendements proches de ceux des couvertures plastiques.

En résumé, ces résultats montrent que la couverture agrivoltaïque remplit généralement son rôle de structure protectrice contre les événements météorologiques pour les cultures de petits fruits, tout en produisant de l'électricité renouvelable à un coût compétitif. Cette production d'électricité est réalisée sans prélèvement de terres supplémentaires par rapport à la production de baies initialement non protégée. Les différents résultats des essais fournissent des informations sur les designs agrivoltaïques qui fonctionnent le mieux et sur les variétés les mieux adaptées à la culture sous abri agrivoltaïque.

Contents

Abbreviations

CAPEX:	Capital Expenditure
DLI:	Daily Light Integral
DNI:	Direct Normal Irradiance
E-mode:	Electricity Mode
GEN1:	first-generation agrivoltaic solution developed by Insolight
GEN2:	second-generation agrivoltaic solution developed by Insolight
GHI :	Global Horizontal Irradiance
GII:	Global Inclined Irradiance (aka Global Tilted Irradiance)
LCOE:	Levelized cost of electricity
MLT-mode:	Maximum Light Transmission Mode
PAR:	Photosynthetically Active Radiation (conventionally: AM1.5 filtered to 400-700nm)
PMMA:	Poly(methyl methacrylate)
PPFD:	Photosynthetic Photon Flux Density
PV:	Photovoltaics

1. Introduction

1.1 Context and motivations

Switzerland's Energy Strategy 2050[1] targets the production of 35 TWh/year of electricity from renewable sources (excl. hydro-power) in 2035[2]. With a solar PV production of 6TWh/year in 2024[3], an increase in production capacity of ~2.6TWh/year (~2.2GWp of PV installations) should be deployed every year to meet this target.

Agrivoltaics (Agri-PV) is the combination of agricultural and photovoltaic energy production on the same land[4]. It opens the perspective of mid- to large-scale solar deployments in complement to lower-scale deployments on rooftops and other existing infrastructure, while at the same time fulfilling a role of sustainable protection for the crops in a context of climate change. It is an emerging but growing sector, with 2200 systems (2.8GWp) installed in Europe between 2014 and 2022[5]. Political initiatives to support agrivoltaics are carried in Italy[6], France[7] and Germany[8].

In Switzerland, according to Article 24ter of the Spatial Planning Act (LAT), PV installations in agricultural zones can be allowed if they do not adversely affect agricultural interests and bring benefits to agricultural production or are used for scientific research[9]. A recent study by ZHAW evaluated the total technical potential of agrivoltaics (encompassing open arable land, permanent crops and permanent grassland), within the constraints of Article 24ter and distances to feed-in points of the current electrical grid, to more than 100 TWh/year[10], with 29% of this production achievable during the winter season. In the same study, it was estimated that converting 1-2% of Switzerland's agricultural land could provide 7-8 TWh/year, while still be used for agriculture and benefit from the synergies of agrivoltaics.

In the varied landscape of agricultural production, agrivoltaic solutions optimized to each kind of crops are required[4,10]. Berry crops present an important potential of synergy with agrivoltaics due to their relatively good shade tolerance[11] and the benefits they derive from protection against rainfall, hail, frost and excessive solar radiation, which can damage fruit and reduce marketable yield. In Switzerland, about one-third of strawberries and three-quarters of raspberries are grown under protective structures such as rain covers, plastic tunnels, or greenhouses. When replacing or complementing conventional protective structures such as plastic foils or hail nets, agrivoltaic installations also minimize impact on landscape.

For agrivoltaics to fulfill its promise of a dual use of land, it is key to ensure that agricultural production is preserved. For example, the German DIN specification[12] sets that at least 2/3 of the yields must be preserved. In Switzerland, the Article 24ter LAT requires the agrivoltaic cover to provide a benefit to the

---

[1] https://www.bfe.admin.ch/bfe/en/home/politik/energiestrategie-2050.html

[2] https://aeesuisse.ch/de/news/medienmitteilung-meilenstein-in-der-energiepolitik-parlament-verabschiedet-mantelerlass/

[3] https://www.news.admin.ch/fr/newnsb/iTP15U0PYP57z2h_7EXJO

[4] Asa'a, S. et al. A multidisciplinary view on agrivoltaics: Future of energy and agriculture. Renewable and Sustainable Energy Reviews 200, 114515 (2024).

[5] Roxani *et al*, A. Multidimensional Role of Agrovoltaics in Era of EU Green Deal: Current Status and Analysis of Water–Energy–Food–Land Dependencies. Land 12, 1069 (2023).

[6] "Italy devotes €1.1bn to agrivoltaics, €2bn to energy communities and storage", in PV magazine International (pv-magazine.com)

[7] "Agrivoltaics to shine in France after presidential recognition", in PV magazine International (pv-magazine.com)

[8] https://www.ise.fraunhofer.de/de/presse-und-medien/presseinformationen/2022/forschungsanlage-der-modellregion-agri-photovoltaik-baden-wuerttemberg-von-ministerpraesident-kretschmann-eroeffnet.html

[9] https://www.fedlex.admin.ch/eli/cc/1979/1573_1573_1573/fr#art_24_ter

[10] Anderegg, D., Jäger, M., Strebel, S. & Rohrer, J. Potenzialabschätzungen für Agri-PV in der Schweizer Landwirtschaft. https://doi.org/10.21256/zhaw-2649 (2024)

[11] Hermelink, M. I., Maestrini, B. & de Ruijter, F. J. Berry shade tolerance for agrivoltaics systems: A meta-analysis. Scientia Horticulturae 330, 113062 (2024).

[12] https://www.din.de/de/wdc-beuth:din21:337886742

agricultural production. To achieve that, the agrivoltaic cover must be carefully designed to match the crop needs.

Benefits to agricultural production can take different forms:

- In comparison to open field cultivations
    - increase of production quality or quantity thanks to the rain cover and partial shading provided by the panels
    - stabilization of production thanks to the mitigation of climatic hazards such as hail, spring frost or heat waves
- In comparison to conventional protective structures:
    - Decrease of production costs thanks to financing of the structure and cover by the electricity sales.

To preserve agricultural yields, the PV coverage must be dimensioned cautiously to meet the crop light needs. PV coverage itself is determined by panel density and orientation, as well as cell coverage of the panels. Several approaches are possible on the light-sharing vs crop protection trade-off (Figure 1). (a) Conventional (opaque) PV modules must be spaced enough to meet crop light requirements, thus offering only partial protection against weather. (b) Semi-transparent panels (with partial cell coverage) enable good protection of the crop while providing additional transparency and more homogeneous light distribution, at the expense of higher weight and cost per Wp.

Figure 1: Possible implementation of agrivoltaic systems with spaced conventional modules, semi-transparent modules with partial cell coverage, and conventional modules on dynamic trackers. All photographs © Insolight 2025.

Another category of solution – known as dynamic agrivoltaics – opens the perspective of dynamic sharing, with the real-time adjustment of light transmission. In this case, light transmission can be maximized when the crops need it, and electricity generated when the light is in excess. The most widespread example of dynamic agrivoltaics is implemented with conventional PV modules on 1-axis trackers (Figure 1 (c)). Another category of dynamic agrivoltaic solutions lies in semi-transparent modules with tunable transmission, enabling the combination of dynamic light sharing and crop protection by the panels[13]. Patented by Insolight, semi-transparent tunable modules based on solar concentration (Sec. 2.2.1) were used for the first prototypal installation built in this project. Lastly, the use of semi-transparent modules based on organic or thin film solar cells is also an active topic of research, but so far lack the performance and maturity level for reliable and scalable deployment in commercial contexts.

---

[13] Nardin, G. et al. Industrialization of hybrid Si/III–V and translucent planar micro-tracking modules. Progress in Photovoltaics: Research and Applications 29, 819–834 (2021).

1.2 Project objectives

The objectives of the project were to evaluate the field performance and techno-economic viability of innovative agrivoltaic solutions for berry production, through the construction of the first agrivoltaic installation of Switzerland, and the subsequent monitoring of electricity production, micro-climatic parameters, and agricultural production over 5 years.

The agronomic yield of the crops cultivated below the agrivoltaic installation is compared to the yield of reference crops cultivated under various reference zones, representative of conventional berry production systems.

The initial part of the project focused on the construction and assessment of a first-generation (GEN1) prototype built with THEIA (Translucency and High Efficiency In Agrivoltaics) modules, which enable a real-time control of light transmission at the module level (see Section 2.2.1). The second part of the project focused on the assessment of a second-generation (GEN2) system built at a commercial scale with 6 different configurations of semi-transparent modules dedicated to the production of raspberries and strawberries, and a dynamic shading screen to adjust the light-sharing ratio for crops and boost electricity production in winter (see Figure 11).

The following metrics are compared for the different installations, with related Key Performance Indicators (KPIs) established at the project’s beginning:

- Yield and quality of agricultural production (with respect to conventional production systems).
    - KPI: yield in comparison to conventional plastic covers.
    - Target: no degradation of yields (>100% of reference yield)
- Agricultural production costs for the producer (with respect to conventional production systems)
- Electrical characteristics and performance (power density, specific yield)
    - KPI: yearly energy production per m^2 of panel.
    - Target: >180 kWh/m^2/y
- Projected CAPEX and LCOE of the electricity production.
    - KPI: LCOE (for a deployment capability of 100MWp/y)
    - Target: < 0.1 CHF/kWh

Additionally, a KPI in terms of multiplication potential (MWp of installations planned at the project’s end) was established. Target: 1MWp.

2. Description of the facility

2.1 Overview

The pilot installations designed and deployed in the framework of this project is located on the grounds of the Swiss federal institute of Agronomy (Agroscope) in Conthey (Valais, CH).

Figure 2: Aerial views of the Agroscope center in Conthey and location of the first-generation (GEN1) prototype installation (red square), the second-generation (GEN2) demonstrator (green square) and the GEN2 commercial-scale installation (blue square)..

In the next sections we will describe the properties of the three installations used in this project:

- A first-generation (GEN1) installation, featuring the THEIA prototype modules, constructed in 2021 (Section 2.2).
- A second-generation (GEN2) demonstrator, with semi-transparent panels and additional shading screen (Section 2.3), constructed in 2022. While the construction of that installation was not part of the project activities, the results are included in this report for the sake of completeness.
- A commercial-scale second-generation (GEN2) installation with semi-transparent panels and additional shading screen (Section 2.3), constructed in 2023. While the construction of that installation was not part of the project activities, the agronomic research was supported by the grant.

2.2 First-generation (GEN1) installation

2.2.1 THEIA prototypal modules

The GEN1 installation is based on the innovative photovoltaic modules THEIA, previously developed by Insolight. Thanks to their design made of solar cells and lenses, THEIA modules provide a dynamically adjustable light transmission, as illustrated on Figure 3. In this prototypal version, the modules are composed of a PMMA front plane with embedded optics and a PV backplane with elongated solar cell strips arranged according to a custom layout. Cylindrical lenses on the front plane create a line focus on the backplane (2x concentration factor). The modules include an actuation system, enabling a translational movement of the PV backplane relative to the front plane, adjusting the ratio of direct sunlight focused on the PV cells or transmitted through the gaps between them.

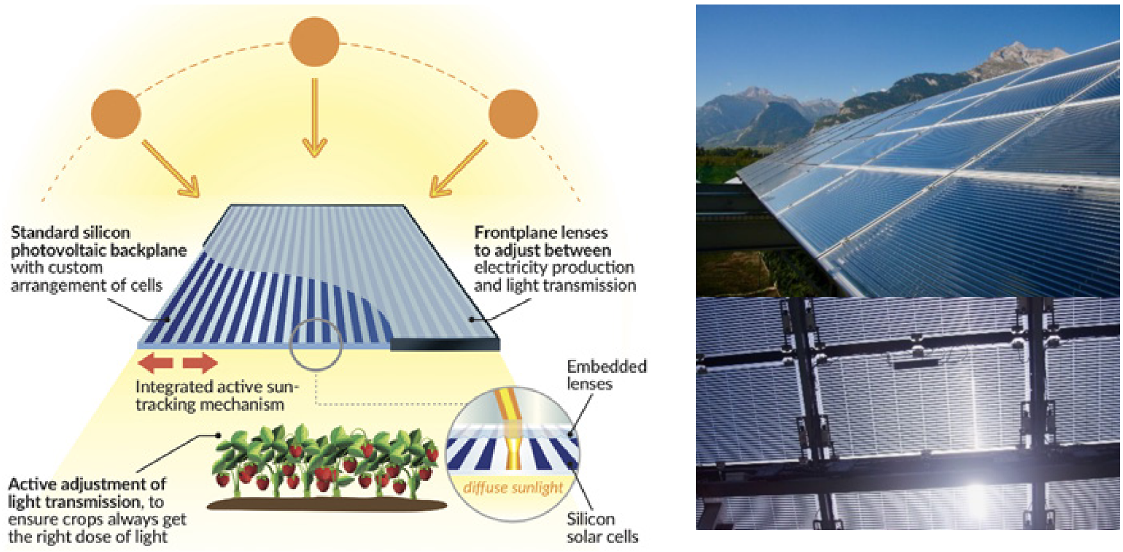
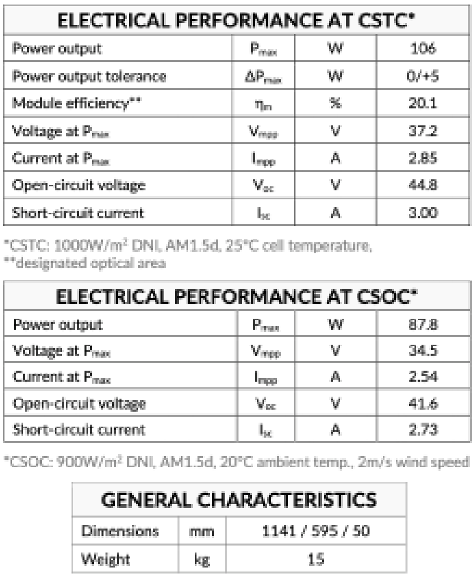


Figure 3: Principle of operation of the THEIA prototypal panels that are used in the first-generation (GEN1) pilot installation.

Light transmission and electricity production can thus be adjusted continuously and instantaneously at any time to match the requirements of the plants growing below. Figure 6 illustrates the minimum and maximum light transmission levels achievable with the THEIA modules, namely E-mode (Electricity mode, 15%) and MLT-mode (Maximum Light Transmission mode, 70%).

Figure 4: close-up pictures of the back side (with striped cSi cells) and front side (PMMA lens array) of the THEIA prototypes.



ELECTRICAL PERFORMANCE AT CSTC*			
Power output	P_{max}	W	106
Power output tolerance	ΔP_{max}	W	0/+5
Module efficiency**	η_m	%	20.1
Voltage at P_{max}	V_{mpp}	V	37.2
Current at P_{max}	I_{mpp}	A	2.85
Open-circuit voltage	V_{oc}	V	44.8
Short-circuit current	I_{sc}	A	3.00

*CSTC: 1000W/m² DNI, AM1.5d, 25°C cell temperature,
**designated optical area

ELECTRICAL PERFORMANCE AT CSOC*			
Power output	P_{max}	W	87.8
Voltage at P_{max}	V_{mpp}	V	34.5
Current at P_{max}	I_{mpp}	A	2.54
Open-circuit voltage	V_{oc}	V	41.6
Short-circuit current	I_{sc}	A	2.73

*CSOC: 900W/m² DNI, AM1.5d, 20°C ambient temp., 2m/s wind speed

GENERAL CHARACTERISTICS		
Dimensions	mm	1141 / 595 / 50
Weight	kg	15

Figure 5: Technical specifications of the THEIA prototypes.

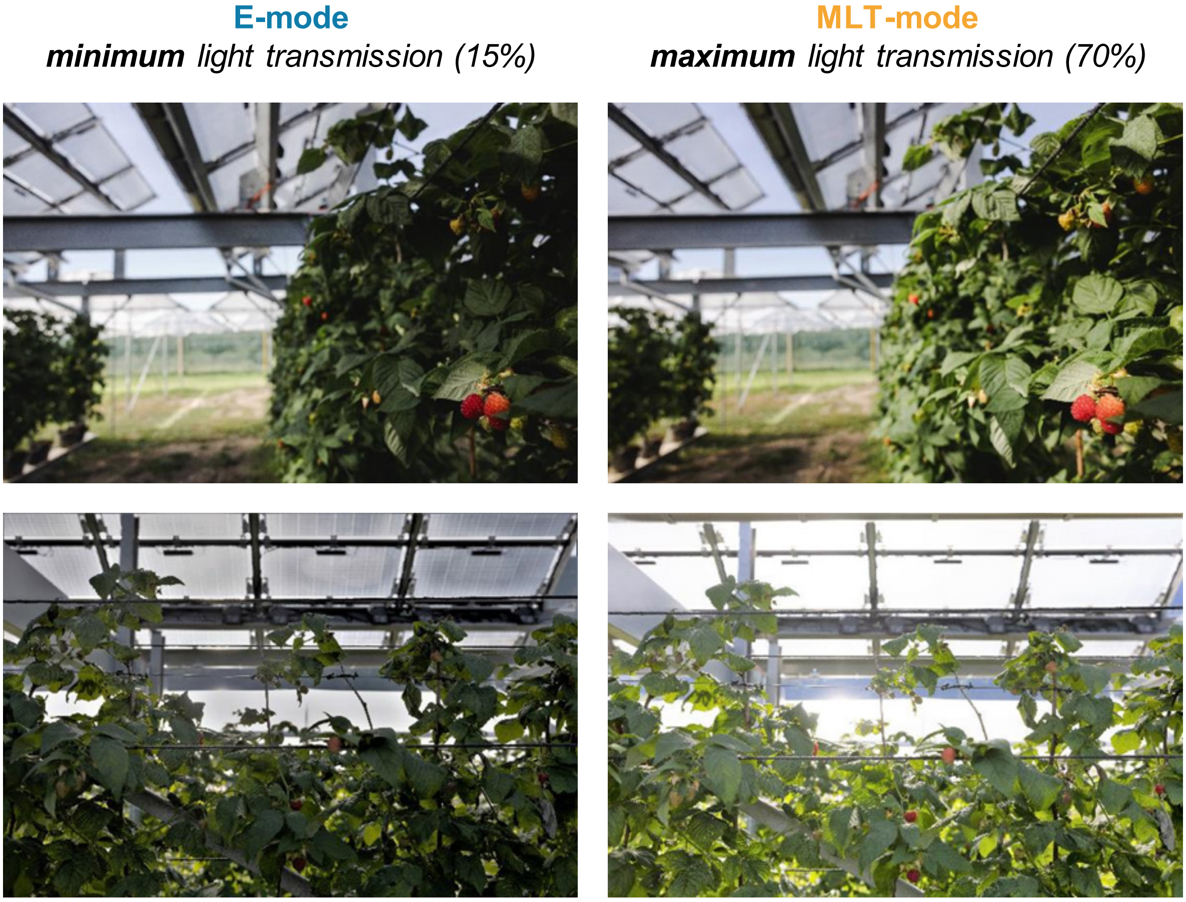


Figure 6: Illustration of the light transmission of the THEIA prototypes on crops in E-mode and MLT-mode, with photographs taken on the GEN1 installation.

THEIA prototypal modules used in the installation have been characterized in concentrator standard test conditions with a quasi-collimated flasher Pasan) at CSEM within the framework of the Innosuisse project ATLAS:

- Modules installed over the raspberries are assembled with monofacial PERC cells backplanes. The median backplane efficiency is 18.8% and module efficiency is 16% (in E-mode).
- Modules installed over the strawberry section are assembled with bifacial IBC cells backplanes. The median backplane efficiency is 19.5%, backplane bi-faciality factor is 83%, and module efficiency is 17.4% (in E-mode). Bi-faciality is particularly beneficial to agrivoltaic systems thanks to high module elevation, overall transparency of the system and relatively good albedo of the vegetation[4].

An example of outdoor measurement of the module efficiency (with respect to GII, without temperature correction) is shown in Figure 7, in a condition where the Direct Inclined Irradiance to Global Inclined Irradiance ratio was 82%.

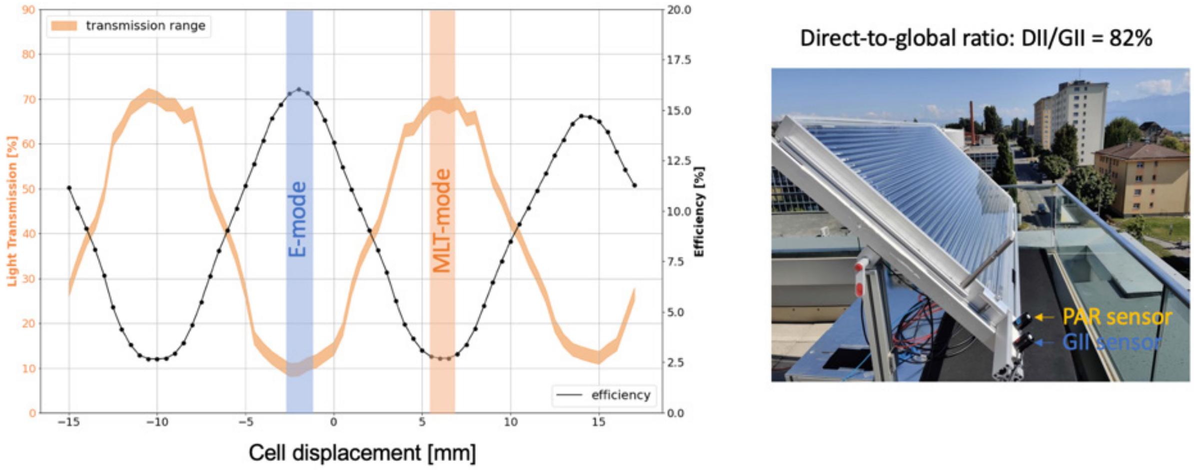


Figure 7: Example of outdoor measurement of PAR transmission and module efficiency (without temperature correction) of a THEIA prototype with respect to GII, as a function of the linear backplane displacement with respect to the optical layer.

A limitation of this design is that the light transmission adjustability only acts on the direct fraction of sunlight. Diffuse light transmission is not controlled, with half of the light being captured by the cells and the other half transmitted, minus optical losses. Transmission of direct light with large incidence angle is also lowered due to optical losses.

2.2.2 Construction of the GEN1 installation.

The design of the structure has been defined by the three project partners - Agroscope, Romande Energie and Insolight - taking into account the requirements of the agricultural production and trying to optimize both crop protection and electricity production. The main parameters of the resulting structure are summarized in Table 1. South-facing (azimuth: 165°) orientation was chosen to optimize electricity production, and a 30° tilt and 3.3 inter-row distance (Ground coverage ratio ~72%) was chosen as a trade-off between inter-row shading losses and crop protection.

Table 1: Main parameters of the agrivoltaic structure.

Layout	4 tables, each with 44 modules on 4 rows
Ground coverage ratio	ca. 72%
Module orientation	tilt: 30°, azimuth: 165°

Figure 8 shows side and front views of the construction. It should be noted that the structure is anchored to the ground with “harpoon” screws, without concrete slabs to preserve the soil and facilitate dismantlement.

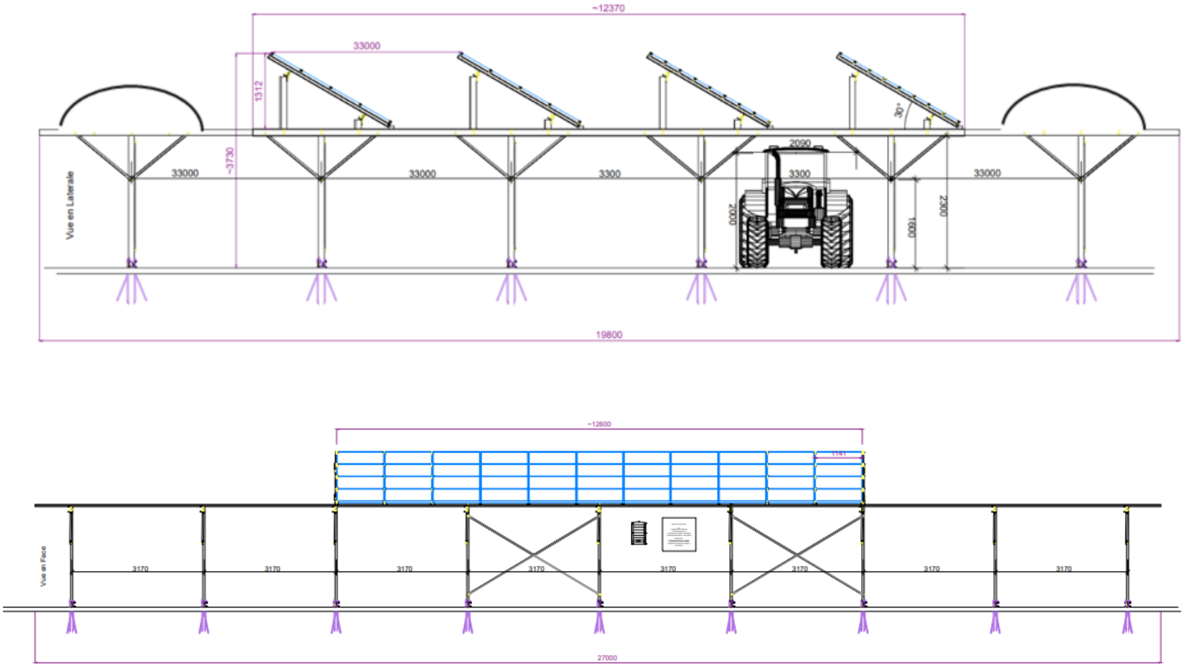


Figure 8: Lateral and front side views of the GEN1 prototypic installation.

Construction started mid-July 2021 and took ca. 3 days.

Due to limited production capacity, modules were deployed in phases, with two batches of PV backplanes from different suppliers:

- **First phase**: 88 modules installed at the end of July 2021.
    - 82 **mono-facial** modules (PERC cells)
    - 6 **bi-facial** modules (IBC cells)
- **Second phase**: 88 **bi-facial** modules (IBC cells) installed at the end of November 2021.

Figure 9: Photographs taken during the GEN1 prototype construction.

THEIA prototypic modules are connected to the grid using one micro-inverter per module (Enphase IQ7 series) and connected for bidirectional communication with a central gateway.

2.3 Semi-transparent modules, GEN2 solution and installations

Based on the learnings of the first two years of the project, which have enabled to establish the performance but also the limitations of the THEIA prototype modules in the field (see Sections 4 and 5), a redesign of Insolight's agrivoltaic solution for berries and has been performed (supported in part by Innosuisse funded project ATLAS – see Section 7). Semi-transparent bi-facial panels have been developed, leveraging the use of conventional-size glass-glass laminates with spaced PERC half-cells. Two levels of transparency have been defined: THEIA-T60 (200W) with 40% of cell coverage, and THEIA-T40 (300W) with 60% cell coverage. The surface that is not covered by cells is made of a transparent diffusive glass-encapsulant-glass laminate. Drawings and a photograph are shown in Figure 10.

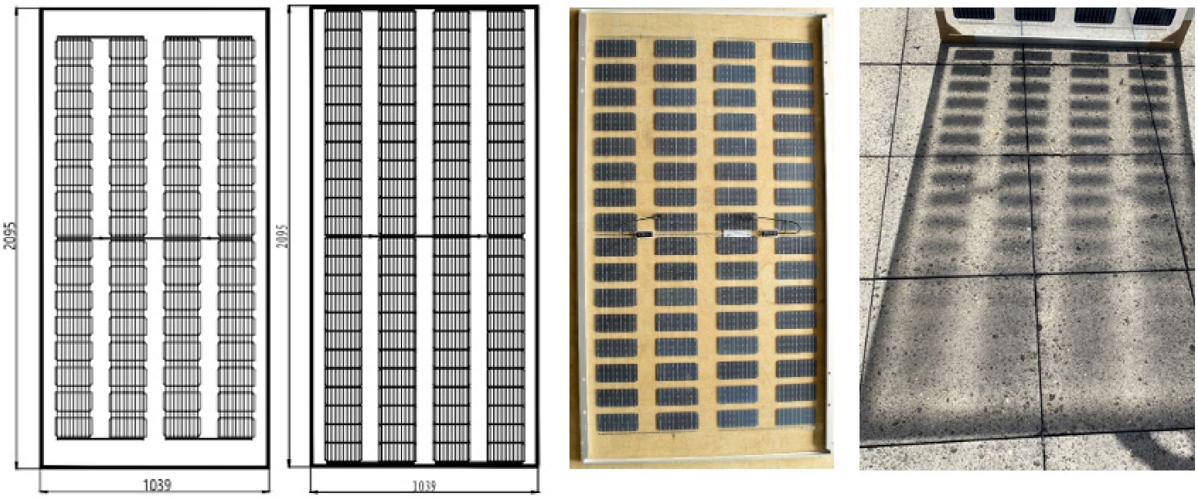


Figure 10: GEN2 THEIA modules. From left to right: (i) Drawing of THEIA-T60 module (ii) Drawing of THEIA-T40 module (iii) Photograph of T60 module (back side) (iv) Photograph of the shadow casted by a T60 module held vertically, to illustrate module diffusivity and homogenization of transmitted light with increasing distance.

With the GEN2 solution, the tuning of transmitted light for micro-climatic control is not done at the module level, but at the system level, using an optional agricultural shading screen with a reflective upper surface positioned under the modules (see Figure 11). The screen can be deployed fully or partially, based on a crop-specific steering algorithm, to optimize microclimatic conditions under the installation, for example in case of a heat wave when direct sunlight can damage fruits and leaves, or to improve worker's comfort. Every time the screen is deployed, it reflects light towards the back side of the bi-facial panels to boost the electricity production. This feature can also be used when there are no crops under the installation to increase electricity production in winter time. In summary, the GEN2 solution retains the protection and dynamic light adjustment features of the prototypal solution, while leveraging on qualified and scalable components.
GEN2 installations are anchored to the ground with rammed profiles, without any concrete, to preserve soil and facilitate dismantlement.

Figure 11: Second-generation (GEN2) agrivoltaic solution, with retracted (left) and deployed (right) shading screen.

Figure 12: Photographs of the projects based on the GEN2 agrivoltaic solution in Conthey. Left: 16kWp GEN2 demonstrator. Right: 265kWp commercial-scale GEN2 installation with dedicated areas optimized for the cultivation of raspberries and strawberries.

The GEN2 demonstrator (16 kWp) is set-up with East-West oriented T60 modules and a 2.3m inter-row distance (840 kWp/ha).

The commercial-scale GEN2 installation (265 kWp) includes a research component in the form of different agrivoltaic modalities. The raspberry part features a 3m inter-row distance and is divided into 4 sub-parts to probe the light-sharing trade-off (see Figure 13):

- (1) East-West oriented T60 modules (640 kWp/ha)
- (2) East-West oriented T40 modules (960 kWp/ha)
- (3) West-only oriented T60 modules (640 kWp/ha)
- (4) West-only oriented T40 modules (960 kWp/ha)

The strawberry part features 4m-wide production sections, in which were installed 2 lines of production per section in 2023, and 3 lines per section in 2024/2025. It is divided into two sub-parts:

- (5) T60 modules (480 kWp/ha)
- (6) T40 modules (720 kWp/ha)

Plastic tarps were drawn between module lines for rainwater management, except on one side of zone 6, which was left without plastic tarps (crops protected by PV modules only) for comparison.

Figure 13: different modalities of the GEN2 commercial-scale agrivoltaic installation in Conthey. From left to right: (i) Raspberry part with East-West (EW) oriented modules. (ii) Raspberry part with West-only (WW) oriented modules. (iii) Strawberry part. Plastic tarps have been added during the year 2024 to close the gaps between modules and protect fruits against rain, except on the westernmost chapel of the strawberry zone to compare agronomic results with/without plastics between the panels.

2.4 Agronomic reference zones

Agronomic reference zones were used as witness for the various agronomic trials. Different reference zones were used, representative of conventional berry production systems in Switzerland (Figure 14). A zone of plastic raincovers was built during the project, adjacent to the prototypal agrivoltaic installation, with 2.3m or 3.3m inter-row. Two other representative reference areas already in place at Agroscope were also used: multi-span plastic greenhouses (high end production tool with active venting and misting system) with 2.2m inter-row distance, and plastic tunnels with 2m inter-row. In addition, an uncovered line was used as an open-field comparison.

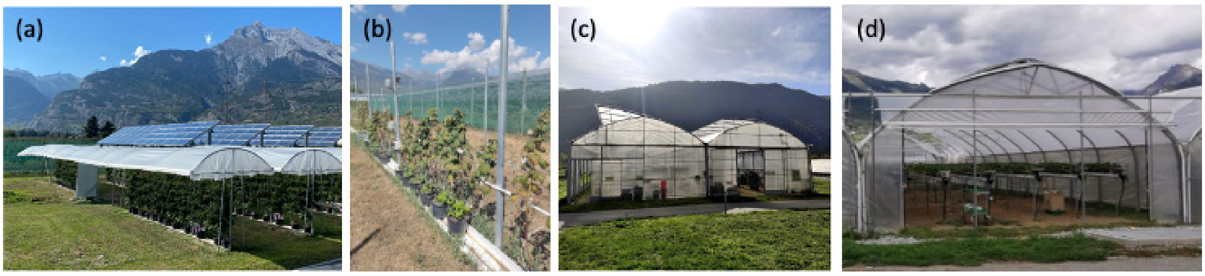


Figure 14: Photographs of the reference zones used throughout the project. (a) Plastic raincovers, used for raspberries and strawberries ; (b) uncovered area (open field) ; (c) Multi-span plastic greenhouses used for raspberries ; (d) Plastic tunnels used for strawberries.

3. Procedures and methodology

3.1 Climatic monitoring

A series of climatic sensors has been deployed on-site. They are used for two purposes: (1) Log meteorological data to provide inputs for our simulation toolbox, and compare PV output and light transmission to theoretical predictions; (2) Provide inputs for the light management algorithm that steers the installation. The sensors deployed include irradiance sensors: Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), Global Inclined Irradiance (GII – aka Global Tilted Irradiance GTI), and Photosynthetically Active Radiation (PAR – solar radiation filtered to 400-700nm); air temperature and relative humidity sensors, leaf temperature sensors. The sensors that are critical to evaluate the micro-climatic conditions of plant growth are deployed under the panels (test zone) and in the reference zones. Example photographs of sensors are shown in Figure 15.

Figure 15: Climatic monitoring equipment deployed on site: Direct and diffuse irradiance sensor (left) ; Photosynthetically Active Radiation (PAR) sensor (middle) ; Temperature and relative humidity sensor (right)

3.2 Data acquisition and exploitation

For the GEN1 installation, the operating current and voltage of every panel is probed independently. For GEN2 systems, electrical data is collected at the string level from the inverters. This data, along with data from irradiance, PAR, temperature, and relative humidity sensors is collected and saved on a database, which can be accessed and visualized from a web interface (Figure 16) or using an Application Programming Interface (API) for custom analysis.

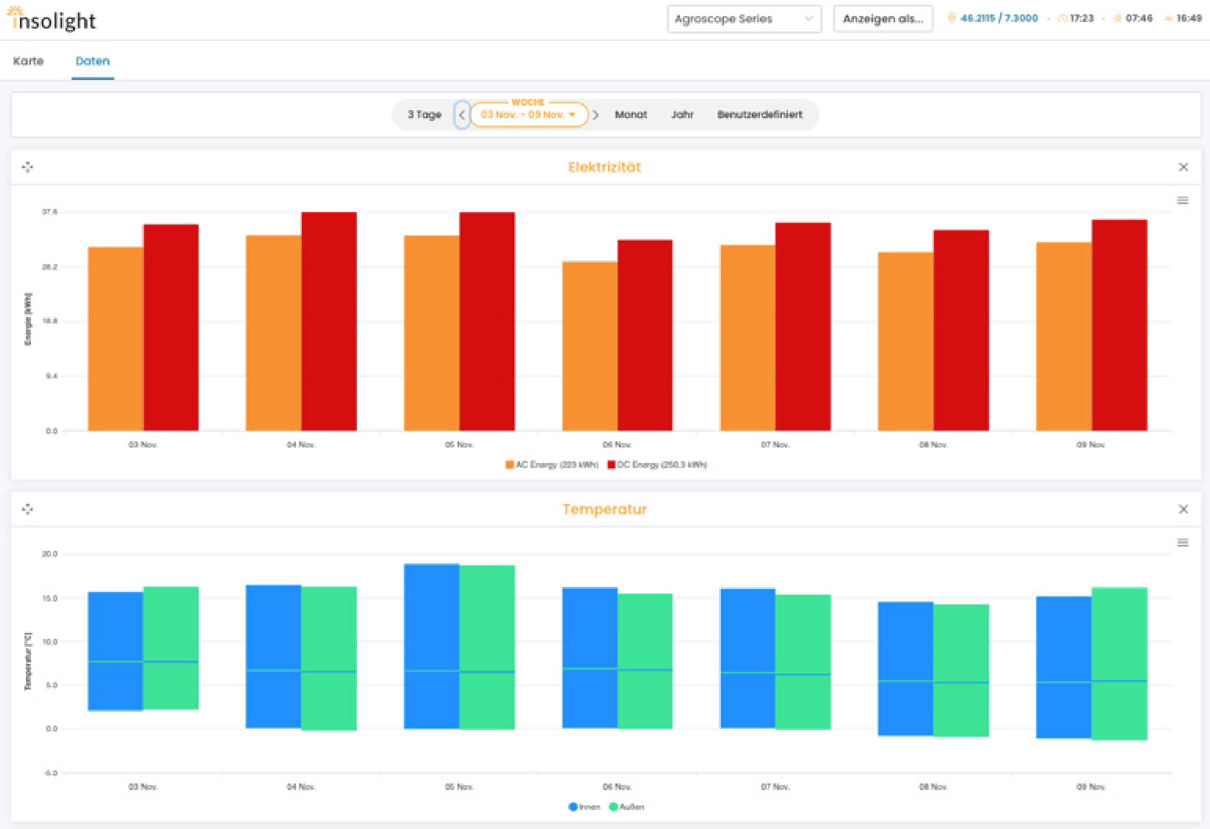


Figure 16: Screenshot example of the web interface developed by Insolight for data visualization.

3.3 Steering and light management algorithmics

During the project, a Light Management Algorithm (LMA) has been designed to consider micro-climatic needs of the crops. The basic functions are to provide the right amount of light to the crop and protect them from excess irradiance and temperature. The LMA tunes the panel transmission or screen deployment between Electricity mode (E-mode), Maximum Light Transmission mode (MLT-mode) and intermediate modes, based on the feedback from light and temperature sensors, to produce electricity with excess sunlight. Crop specific input parameters have been defined in collaboration with Agroscope and are expressed in terms of a target of Daily Light Integral (DLI), and limits of PAR Photon Flux Density (PPFD) and air temperature.

3.4 Photovoltaic and light transmission simulation toolbox

A simulation toolbox has been developed by Insolight to predict photovoltaic electricity generation and light transmission. Prediction of electricity generation and light transmission through the THEIA panels is based on a ray-tracing modelling and a separation of irradiance in its direct and diffuse components. The simulation also considers inter-row shading in winter. Example of PV production and light transmission over typical days are shown for the GEN1 installation in Figure 17, with a good agreement between measurements and simulations. A slight excess of PV production (associated to a lack of light transmission) in MLT-mode can be noted between 9h-10h and has been attributed to light scattering in the optical layer for the angle of incidence prevailing at this hour. On the GEN1 prototypic installation, average measured transmission is lowered by 30% due to the shade of structural elements.

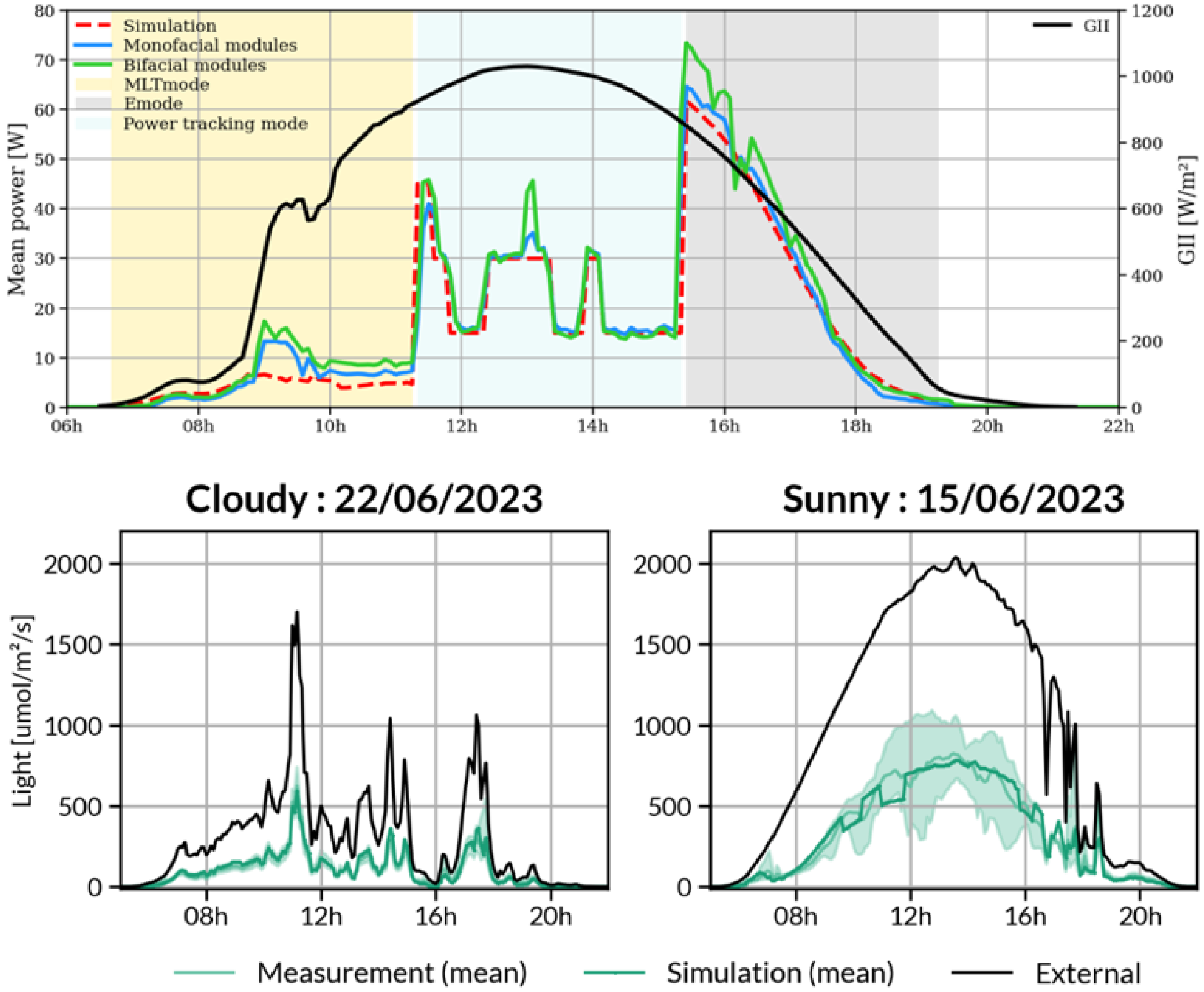


Figure 17: Examples of comparison between simulation and mean power output per module on August 8, 2021 (top) and light transmission on a cloudy day and a sunny day on GEN1 installation with THEIA module prototypes. Simulation did not include bi-faciality, hence the better agreement with the power output of mono-facial modules. The min/max range of PAR light measured under the panels shows the effect of local shadows.

Figure 18 and Figure 19 show the good agreement of the simulation results with electricity produced by and light transmitted through the GEN2 demonstrator, respectively.

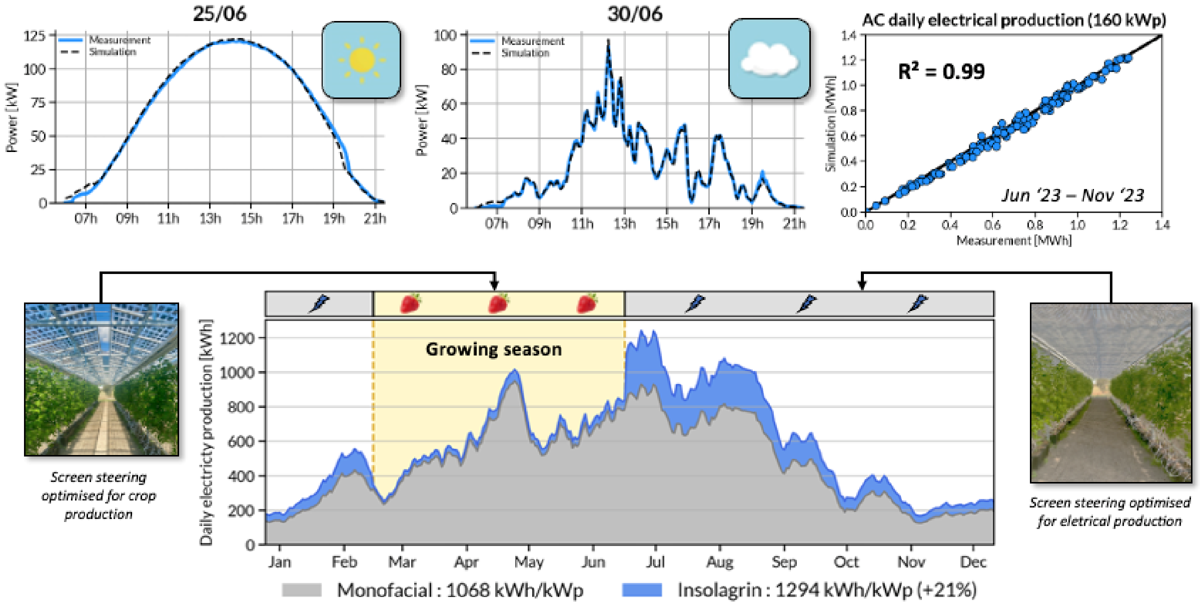


Figure 18: Top: comparison of simulated vs measured AC electrical production on the GEN2 demonstrator. Bottom: Simulation exemplifying the bi-facial boost generated by the reflective shading screen which can be fully deployed out of the agricultural season. Bi-facial gain combined with the screen usage provides a boost of electricity production of ~20% compared to a monofacial installation.

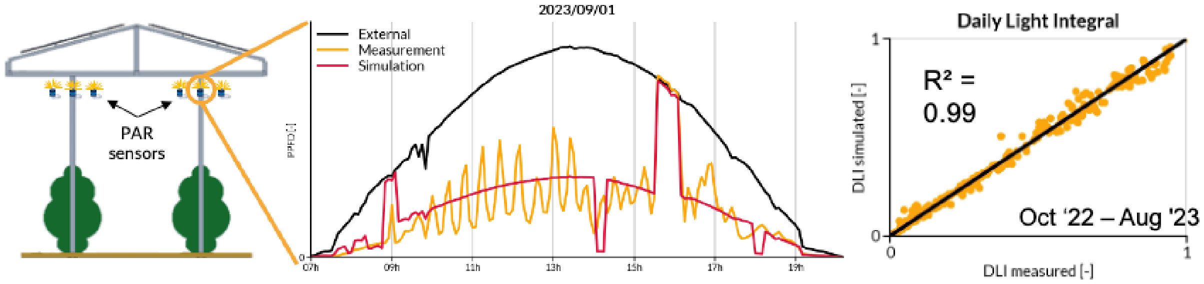


Figure 19: Comparison of simulated vs measured light transmission on the GEN2 demonstrator.

The simulation toolbox enables the simulation of installation performance using typical meteorological year data, satellite data or onsite measurements. Thus, it can be used to simulate the effect of installation geometries and steering strategies in arbitrary locations.

3.5 Agricultural procedures and monitoring

Raspberries:

- In the GEN1 installation, pre-cultivated (also called “long canes”) raspberry plants were used. Plants were cultivated in so-called spatial repetitions, which had a length of six meters (twelve pots) in 2021/2022 and 2m (4 pots) in 2023. Pots had a volume of 10 L and a professional substrate (ökohum GmbH) was used (with a medium nutrient level, high pH and nutrient buffering due to adequate humus content and very good water absorption and storage, raw material: bark humus, peat (<40%), coconut, rice husks, pumice sand). In total 3 spatial repetitions per system were used.

- In the GEN2, commercial-scale installation, a local producer managed the overall raspberry production. In each zone, 4 blocks of 6 pots were set up and are monitored by Agroscope to carry out agronomic measurements. The plant types and varieties were chosen by the producer: Tulameen and Vajolet long canes in 2023, and bare-root plants of raspberry variety ‘Paris’ (Primocane-type genotype) in 2024. The planting density is 3 plants per linear meter, in 10-litre round pots and filled with a professional raspberry substrate.

Strawberries:

- For strawberries in the GEN1 installation, tray-plants of the everbearing variety ‘Karima’ were arranged in blocks of 6m and consisted of eight pots, each containing 4 strawberry trayplants (8 plants per linear meter). The pots had a volume of 8 L filled with a professional strawberry substrate (raw material: bark humus, bark compost, wood fiber, wood chips, rice husks, sheep wool, perlite (ökohum GmbH, Erdbeersubstrat 865)). In total 3 spatial repetitions per system were used.
- In the GEN2 demonstrator, tray-plants of the season varieties ‘Flair’ and ‘Joly’ were planted in the same conditions as for the ‘Karima’, but with 10 plants per linear meter (5 plants / pot) and 4 repetitions per system and variety (3 in the plastic tunnel).
- In the GEN2, commercial scale installation, waiting bed of the summer variety ‘Joly’ were planted in 1-meter growing bag and filled with a professional strawberry substrate Promix Mychorize + Bacillus from Premier Tech Ltd. The planting density is 8 plants per linear meter. In each zone, 4 blocks of 16 plants have been set up and are being monitored to carry out agronomic measurements.

The following trials have been conducted under the GEN1 system within the project:

Species	Variety	Type	Dates	Reference zones
Raspberries	Vajolet	Long-cane, summer variety	26.07.2021 – 12.11.2021 (late season due to set-up availability)	Raincovers, Plastic greenhouse (1 repetition)
Raspberries	Vajolet	Long-cane, summer variety	29.04.2022 – 02.08.2022	Raincovers, Plastic greenhouse
Raspberries	Glen-Ample	Long cane, summer variety	03.08.2022 – 04.11.2022 (late season due to set-up availability)	Raincovers
Strawberries	Karima	Everbearing	29.04.2022 – 26.10.2022	Raincovers
Raspberries	Clarita	Long-cane, Autumn variety	13.04.2023 – 28.07.2023	Plastic greenhouse, open field
Raspberries	Kwanza	Long-cane, Autumn variety	13.04.2023 – 28.07.2023	Plastic greenhouse, open field

Table 2: Agronomic trials conducted within the project under the GEN1 prototypal system.

The following trials have been conducted under the GEN2 demonstrator:

Species	Variety	Type	Dates	Reference zones
Raspberries	Glen-Ample	Long cane, Summer variety	03.08.2022 – 07.11.2022 (late season due to set-up availability)	Raincovers
Raspberries	Vajolet	Long-cane, Summer variety	21.04.2023 – 28.07.2023	Raincovers, Plastic tunnel, open field
Raspberries	Tulameen	Long-cane, Summer variety	04.05.2023 – 18.08.2023	Raincovers, Plastic tunnel, open field
Strawberries	Flair	Summer variety	11.05.2023 – 14.07.2023	Raincovers, Plastic tunnel
Strawberries	Joly	Summer variety	11.05.2023 – 12.07.2023	Raincovers, Plastic tunnel

Table 3: Agronomic trials conducted under the GEN2 demonstrator.

The following trials have been conducted under the commercial-scale GEN2 system:

Species	Variety	Type	Dates	Reference zones
Raspberries	Vajolet	Long-cane, Summer variety	04.07.2023 – 11.10.2023 (late season due to set-up availability, shading screen activated on 09.09.2023)	Plastic tunnel, open field

Raspberries	Tulameen	Long-cane, Summer variety	04.07.2023 – 27.10.2023 (late season due to set-up availability, shading screen activated on 09.09.2023)	Plastic tunnel, open field
Strawberries	Flair	Summer variety	25.07.2023 – 15.09.2023 (late season due to set-up availability, shading screen activated on 09.09.2023)	Plastic greenhouse
Strawberries	Joly	Summer variety	25.07.2023 – 15.09.2023 (late season due to set-up availability, shading screen activated on 09.09.2023)	Plastic greenhouse
Raspberries	Paris	Plug plants, Autumn variety	11.04.2024 – 27.10.2024	NA
Strawberries	Joly	Summer variety	13.06.2024 – 02.08.2024	Uncovered line at edge of GEN2 installation
Raspberries	Paris	Plug plants, Autumn variety	2024 – 03.10.2025	Open field
Strawberries	Joly	Summer variety	2024 – 23.06.2025	Raincovers

Table 4: Agronomic trials conducted within the project under the commercial-scale GEN2 system.

Unfortunately, due to a last-minute delay in its construction (ramming machine broken), the control zone that was planned adjacent to the commercial-scale GEN2 installation (a conventional production zone made of 4 rows of plastic raincovers) was not ready for the 2024 planting. The trial still took place to establish a first reference point, compare the various agrivoltaic modalities between each other, and evaluate the compatibility of the infrastructure with commercial berry production practices. For the strawberries, the westernmost row at the very edge of the installation, which is not covered by plastics nor solar panels, served as an uncovered control line (Figure 21).

In 2025, a control zone for the raspberries (open field) and strawberries (plastic raincovers) was established next to the commercial-scale installation as planned. The plants of 2024 were re-used in 2025 for a second year, after wintering under the agrivoltaic installation. The plants were brought to the reference zone in March before the vegetative growth of the 2025 season.

Figure 20: Selected photographs of the trials in agrivoltaic GEN1 prototypal installation and reference zones.

Figure 21: Selected photographs of the trials in the GEN2 commercial-scale agrivoltaic installation dedicated to raspberries (top) and strawberries (bottom). Bottom right: westernmost line at the edge of the strawberry installation, serving as an uncovered control for the 2024 season.

3.5.1 Fruit yield and weight

Fruits were harvested and weighed 3 times per week. The fruit weight was first extrapolated at each harvest date, then calculated as a weighted average using the amount of marketable yield harvested at each picking date as the weighting factor.

For statistical comparisons, a t-test was used when two cropping systems were evaluated. When more than two systems were compared, a one-way ANOVA followed by a Holm post-hoc test for pairwise comparison was performed.

3.5.2 Fruit quality

After harvest, fruits were classified into marketable and non-marketable malformed and discolored fruits (fruits affected by disease and pests), as performed by Swiss producers.

During the harvesting period, sugar content (in Brix°), acidity (in g/L) and firmness of the fruits (g/mm^2 or g/cm^2) were analyzed at regular intervals. Note that berry firmness is a numerical expression whether berry is considered rather hard or soft. For each trial and depending on the number of treatments analyzed, Student's T-tests or ANOVA tests were performed if the conditions of application were met. Otherwise, non-parametric tests (Wilcoxon or Kruskal-Wallis) were performed. In the case of comparisons of three or more systems, post-hoc analyses were conducted using a Tukey test and adjusting the p-value according to Holm.

3.5.3 Pests and diseases

Plants were checked for pests and diseases once per week.

3.5.4 Irrigation and drainage management

During the whole growth cycle, raspberries were constantly irrigated through two drip irrigation tubes per plant pot. Measurements of the irrigation and drainage water quantity were carried out at regular intervals over the whole growth cycle.

4. Results

4.1 Light management

Example of light management on typical days are shown in Figure 22 for the GEN1 installation, and Figure 23 for the GEN2 demonstrator.

Figure 22 shows that the steering algorithm was able to achieve its targets on the GEN1 installation: (1) The installation activated a light limitation mode between 12h and 14h to prevent the PPFD to go beyond the set limit. (2) The installation activated a protection mode between 14h and 15h when the air temperature reached the set limit (temperature graph not shown). (3) The installation turned into E-mode when the algorithm estimated that the DLI target would be reached by end-of-day.

Figure 23 shows the steering of the reflective shading screen to protect crops from direct radiation when temperature was above 30°C between 13h00 and 17h00, and its protective effect on measured leaf temperature.

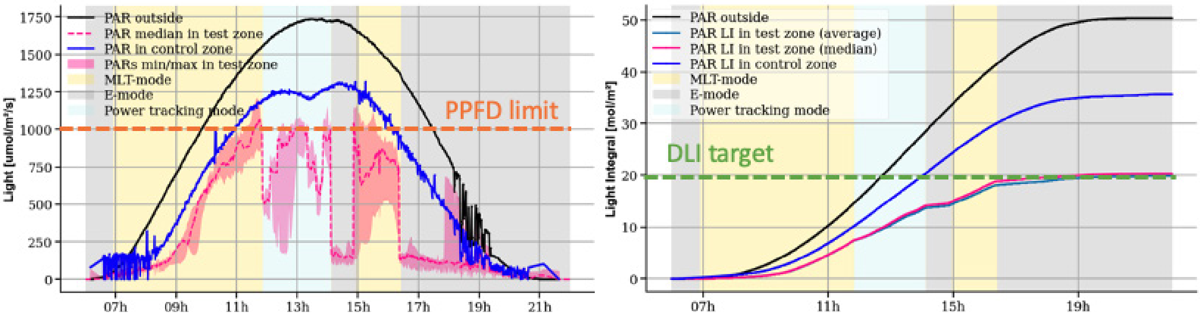


Figure 22: Example of light management under the GEN1 installation on a summer day. Left: PAR Photon Flux Density (PPFD) is steered to never overcome the PPFD limit parameter. Right: Accumulated light integral is steered to reach the Daily Light Integral (DLI) target parameter. At the same time, PPFD and DLI outside and in the control zone exceed the limit and target, respectively.

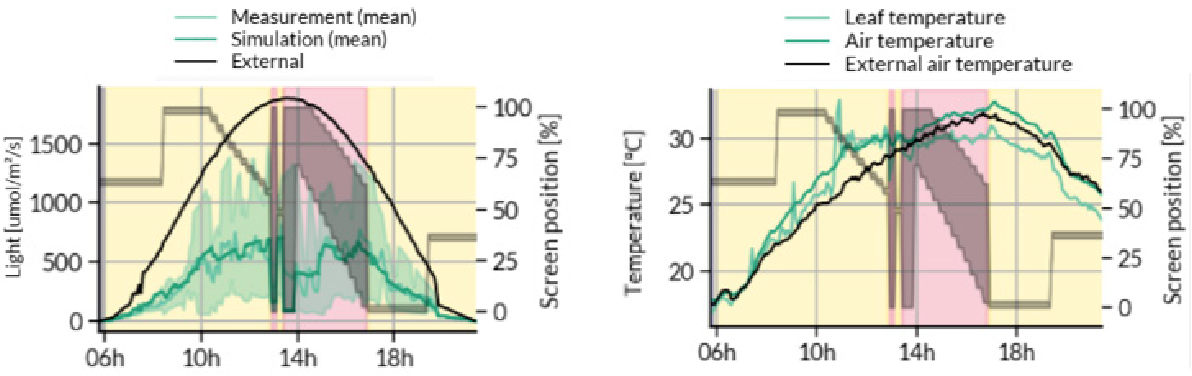


Figure 23: Example of light management under the GEN2 installation on a summer day. Deployment of the protective shading screen is shown by the grayed area. The screen deploys fully or partially to protect crop from direct radiation when internal air temperature exceeds threshold (red background). Left: Screen deployment superimposed to external (black) and internal (green) PPFD. Right: temperature measurements superimposed to external (black) and internal (green) temperature.

The temperature limit to close the shading screen was set to 30°C for the raspberries, and 35°C for strawberries, which tolerate higher temperatures. However, in 2024-2025 the screen temperature protection feature was disabled in the raspberry zones to not favor the emergence of drosophilae.

4.2 Light availability

Light availability in the multi-span plastic greenhouse was measured to an average of between 62% and 67% of the outdoor radiation. Light availability under the raincovers was measured to an average of 67% of the outdoor radiation for the trials of 2021-2022, and between 72% and 80% in 2023 (different plastics were used).

Under the prototypal agrivoltaic system, the light availability varied as a function of the applied light management strategy, with averages between 30 and 40%.

As discussed in Section 2.2.1, a limitation of the THEIA panels prototypes arises in case of highly diffuse light conditions (e.g. overcast days). In this case, the transparency of the panels can't be controlled, and averages around 30% transmission, in conditions where light availability is generally a limiting factor for photosynthesis.

Additionally, it was observed during the Strawberry trial (Karima 2022) that the position of the pots under the agrivoltaic cover was sub-optimal in terms of light distribution. Indeed, most of the leaves were directly shaded by the rain collection gutters for a large part of the season without benefitting from the light regulation by the THEIA panels, while the fruits were hanging in full sun (Figure 24). Poor light homogeneity is also a generic limitation of south-facing solar panels such as in the GEN1 installation, which led to the choice of East-West facing panels for GEN2 installations.

Figure 24: Photograph from the strawberry trial (02.08.2022), showing the light distribution on the plants, due to a sub-optimal positioning of the pots (rain gutter shading on the leaves, no shading on fruits).

The light availability under the new commercial-scale installation varies between the modalities (T40 or T60 modules) and whether the gaps between the modules are filled with plastic for rain protection during harvest. The raspberry zone transmits between 27% (T40 with plastics) and 45% (T60 without plastics) of the DLI, while the strawberry zones transmit between 36% (T40 with plastics) and 53% (T60 without plastics) of the DLI. Transmission is also reduced when the screen is deployed to protect crops against extreme temperature or irradiance. The low coverage of the strawberry zone makes it the most luminous agrivoltaic installation tested on strawberries to date, to the authors' knowledge.

4.3 Impact on temperature

We didn't measure any significant air temperature difference between under the small GEN1 prototype and GEN2 demonstrator, the plastic raincover zone, and the uncovered zone. This is attributed to the small size of the agrivoltaic and raincover zones, where edge effects minimize impact on local air temperature despite different amounts of solar radiations transmitted by the covers.

On the other hand, temperature in the closed multi-span plastic greenhouses was significantly higher than in the other zones by 3°C. In addition, in the plastic greenhouses, an active system of venting and misting was applied whenever the temperature was above 25°C during the harvest season.

In the GEN2 commercial-scale installation, measurements performed during summer 2023 showed that the air temperature under the commercial-scale installation remained close to air temperature, while reaching temperatures up to 5-6°C higher under a plastic tunnel (see Figure 25).

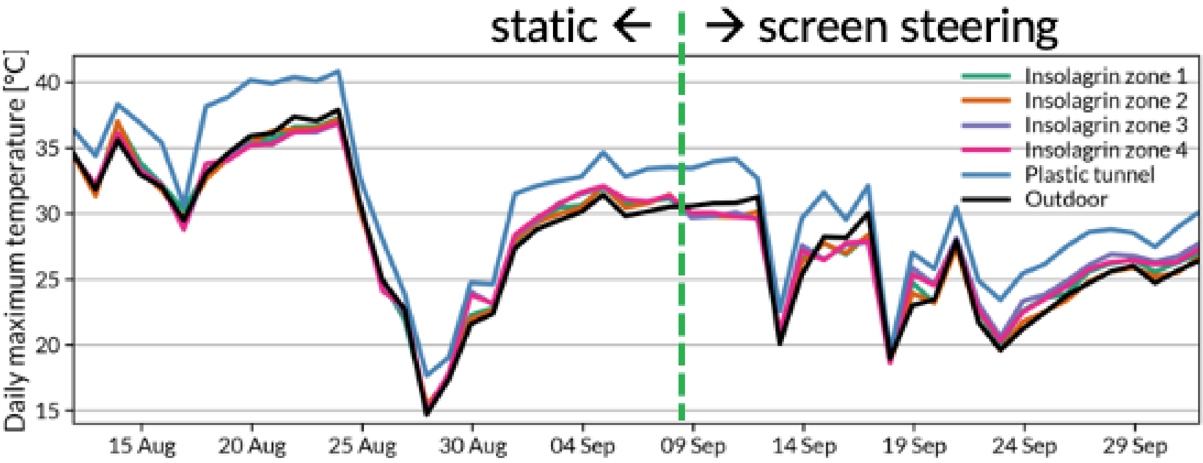


Figure 25: Maximal air temperature recorded during summer 2023 under the 4 raspberry zones of the commercial-scale GEN2 installation, and compared to a plastic tunnel. The shading screen was commissioned on Sept. 9th.. Before that date the screen was retracted and not moving. After Sept 9th the screen was steered according to the LMA to protect crops from direct radiation in case of high temperatures.

In winter and spring, observations and measurements of night temperatures were also performed under the GEN2 commercial-scale installation to assess the capability of agrivoltaic installation to mitigate frost damages. While air temperature is not particularly affected by the cover during night, the temperature of ground and plants can be strongly influenced by infrared radiation exchanges, especially during clear sky nights, when leaf temperature can drop well below air temperature. The protective effect provided by the solar panels can be clearly seen with the frost pattern on the ground, while the ground under the agrivoltaic installation remains unfrozen. Infrared camera pictures taken in the same morning provide an estimate of ground temperature difference of 4°C in favor of the agrivoltaic cover compared to outside (Figure 26).

Figure 26: Visible light and infrared photographs of the GEN2 commercial scale agrivoltaic installation during winter 2023/2024. The ground is visibly frozen outside the installation while the ground under the installation remains protected. A difference of ground temperature of 4°C between outside and inside is measured.

To quantify the effect of the agrivoltaic cover on leaves we installed radiation frost sensors (Apogee SF-110) that mimic leaves outside and inside the commercial-scale GEN2 installation (Figure 27). The minimal temperature recorded every night during winter and spring 2024 is shown on the bottom part of the figure, with leaf temperature being systematically warmer under the agrivoltaic, especially during the coldest nights. An example of temperature profile is shown for the night of April 18-19 (Figure 27 top right) when raspberries were already planted: the temperature dropped to nearly -3°C outside but remained close to 0°C under the agrivoltaic cover.

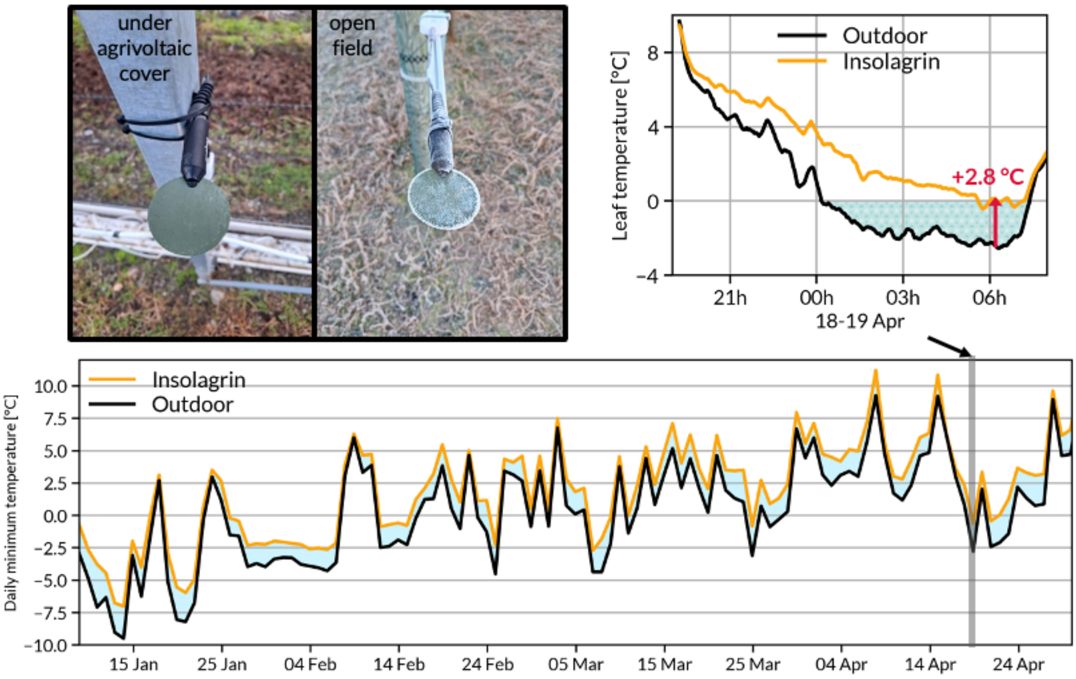


Figure 27: *Top left*: Photographs of radiation frost sensors (Apogee SF-110) installed outside and inside the agrivoltaic installation. *Bottom*: Minimal leaf temperatures recorded every night during the 2024 winter and spring under the agrivoltaic cover (orange line) and outside (black line). *Top right*: Example of leaf temperature curve on the night of April 18-19 April under the agrivoltaic cover (orange line) and outside (black line).

4.4 Hail protection

A hailstorm hit the area and severely damaged all the orchards of the nearby plots on 24.07.2023[14]. The agrivoltaic installation withstood the storm without any damage. An estimate of damage assessment (estimated number of broken twigs) on the raspberry canes that had been planted on 04.07 brought the following results: 0% damage in the plastic tunnel area, 10-20% damage in the open field area, 0-10% damage in zones 1-2 (East-West oriented panels) of the GEN2 commercial-scale installation, 0% damage in zones 3-4 (West-only oriented panels) of the GEN2 commercial-scale installation. The agrivoltaic cover, when properly designed, is thus an efficient way of protecting crops against hail damages, similarly to conventional covers.

Figure 28: Photograph of hail damages on young raspberry plants in the open field area after the hailstorm of 24.07.2023.

4.5 Agronomic results

The agronomic results of obtained with raspberries and strawberries are listed in Table 5 and Table 6, respectively.

Trial	Zone	Total yield (g/cane)	Marketable yield (g/cane)	Fruit size (g/fruit)	Sugar content (°Brix)	Acidity (g/L)	Firmness (g/mm^{2})
Vajolet Fall 2021	Agrivoltaic GEN1	754	678	5.9	9.6^{a}	15.9^{a}	19.2^{a}
	Plastic raincover	909	837	6.2	10.1^{a}	16.3^{a}	19.0^{a}
	Plastic greenhouse	735*	667*	5.3*	N/A	N/A	N/A
Vajolet Summer 2022	Agrivoltaic GEN1	747	564^{a}	5.0^{a}	10.6^{a}	17.8^{a}	30.2^{a}
	Plastic raincover	1022	844	5.6^{a}	11.5^{a}	17.4^{a}	33.1^{a}
	Plastic greenhouse	637	535^{a}	5.1^{a}	9.6*	16.0*	33.1*
Glen-Ample Fall 2022	Agrivoltaic GEN2 demonstrator	526	369^{a}	6.0^{a}	8.5^{a}	18.4^{a}	26.1^{a}
	Plastic raincover A	753^{a}	568^{a}	5.9^{a}	9.0^{ab}	18.4^{a}	24.6^{a}
	Agrivoltaic GEN1	689^{a}	457^{a}	5.6^{a}	9.0^{b}	19.8^{b}	24.3^{a}
	Plastic raincover B	824^{a}	550^{a}	5.9^{a}	9.5^{b}	19.6^{b}	23.8^{a}

---

[14] https://www.rts.ch/info/regions/valais/14197832-un-episode-de-grele-et-des-dommages-importants-pour-les-cultures-valaisannes.html

Clarita Summer 2023	Agrivoltaic GEN1	642^{a}	621^{a}	5.2	8.5	16.7^{a}	41.3^{a}
	Plastic greenhouse	650^{a}	622^{a}	4.1^{a}	10.0^{a}	16.4^{a}	37.0^{a}
	Open field	556^{a}	526^{a}	4.1^{a}	9.8^{a}	15.5^{a}	36.2^{a}
Kwanza Summer 2023	Agrivoltaic GEN1	605	556	4.7	9.2^{a}	18.0^{a}	40.7^{a}
	Plastic greenhouse	723	691	3.8^{a}	10.0^{b}	18.0^{a}	40.2^{a}
	Open field	528	479	4.0^{a}	9.9^{ab}	16.7^{a}	35.1^{a}
Vajolet Summer 2023	Agrivoltaic GEN2 demonstrator	869^{a}	837^{a}	5^{ab}	8.5^{a}	15.4^{a}	29.1^{a}
	Plastic greenhouse	1248^{b}	1230	5.7^{c}	9.8^{a}	16.7^{a}	35.6^{a}
	Open field	772^{a}	749^{a}	4.5^{a}	9.5^{a}	16.4^{a}	30.5^{a}
	Plastic raincover	1167^{b}	1133	5.2^{bc}	9.3^{a}	15.5^{a}	32.3^{a}
Tulameen Summer 2023	Agrivoltaic GEN2 demonstrator	716	617	4.1	10.7^{a}	23.1^{a}	22.8^{a}
	Plastic greenhouse	870	801	3.4^{a}	9.8^{a}	22.3^{a}	25.1^{a}
	Open field	480	425	3.1^{a}	10.8^{a}	21.6^{a}	25.0^{a}
	Plastic raincover	1048	933	3.8	10.8^{a}	23.4^{a}	26.5^{a}
Vajolet Fall 2023	Agrivoltaic GEN2 EW-T60	512*	430*	4.5*	8.8^{a}	18.7^{a}	28.9^{a}
	Agrivoltaic GEN2 EW-T40	547*	390*	3.8*	7.8^{a}	18.3^{a}	28.6^{a}
	Agrivoltaic GEN2 WW-T60	480^{a}	376^{a}	3.9^{a}	8.8^{a}	17.7^{a}	23.9^{a}
	Agrivoltaic GEN2 WW-T40	486^{a}	381^{a}	4.2^{a}	8.2^{a}	19.1^{a}	26.5^{a}
	Plastic tunnel	684	515	4^{a}	9.0^{a}	17.3^{a}	24.6^{a}
	Open field	460^{a}	381^{a}	3.7^{a}	9.6^{a}	16.5^{a}	22.9^{a}
Tulameen Fall 2023	Agrivoltaic GEN2 EW-T60	574^{a}	533^{a}	3.4^{a}	10.6^{ab}	25.0^{ab}	21.7^{a}
	Agrivoltaic GEN2 EW-T40	545^{a}	510^{a}	3.2^{a}	10.2^{a}	25.7^{a}	21.4^{a}
	Agrivoltaic GEN2 WW-T60	586^{a}	537^{a}	3.3^{a}	10.8^{b}	26.2^{ab}	20.4^{a}
	Agrivoltaic GEN2 WW-T40	535^{a}	494^{a}	3.6^{a}	10.6^{ab}	25.8^{a}	20.4^{a}
	Plastic tunnel	740^{a}	685^{a}	3.4^{a}	10.5^{ab}	28.5^{ab}	21.0^{a}
	Open field	609^{a}	548^{a}	3.1^{a}	11.5	28.7^{b}	22.1^{a}
Paris Summer 2024	Agrivoltaic GEN2 EW-T60	285^{a}	251^{a}	4.1^{a}	11.4^{a}	23.1^{a}	25.3^{a}
	Agrivoltaic GEN2 EW-T40	199^{a}	183^{a}	4.1^{a}	10.9^{a}	23.3^{a}	23.3^{a}
	Agrivoltaic GEN2 WW-T60	191^{a}	171^{a}	4.0^{a}	11.4^{a}	23.5^{a}	24.9^{a}
	Agrivoltaic GEN2 WW-T40	218^{a}	172^{a}	4.0^{a}	11.0^{a}	23.5^{a}	24.9^{a}
Paris Summer 2025	Agrivoltaic GEN2 EW-T60	269^{a}	241^{a}	3.9^{a}	12.8^{a}	24.3^{a}	30.6^{a}
	Agrivoltaic GEN2 EW-T40	245^{a}	221^{a}	3.9^{a}	12.7^{a}	24.9^{a}	28.5^{a}
	Agrivoltaic GEN2 WW-T60	266^{a}	233^{a}	3.7^{a}	12.5^{a}	24.8^{a}	31.2^{a}
	Agrivoltaic GEN2 WW-T40	287^{a}	236^{a}	4.0^{a}	12.6^{a}	24.7^{a}	31.3^{a}
	Open field	126	97	3.4^{a}	12.6^{a}	24.1^{a}	NA

Table 5: Summary of agronomic results for raspberries. Results that have the same superscript letter indicate that the difference between them is not statistically significative. (*) statistical significance could not be determined due to insufficient sampling.

Trial	Zone	Total yield (g/plant)	Marketable yield (g/plant)	Fruit size (g/fruit)	Sugar content (°Brix)	Acidity (g/L)	Firmness (g/cm^{2})
Karima Summer 2022	Agrivoltaic GEN1	622	442	14.3^{a}	6.7	7.8^{a}	73.8^{a}
	Plastic rain-cover	1245	956	15.4^{a}	7.3	7.6^{a}	73.1^{a}
Flair Summer 2023	Agrivoltaic GEN2 demonstrator	225^{a}	186^{a}	13.1^{a}	8.3^{a}	8.7^{a}	73.1^{a}
	Plastic tunnel	205^{a}	162^{a}	11.2^{a}	10.6	9.6^{a}	74.0^{a}
	Plastic rain-cover	311	277	13.7^{a}	8.7^{a}	9.3^{a}	71.5^{a}
Joly Summer 2023	Agrivoltaic GEN2 demonstrator	147^{a}	130^{a}	13.3^{a}	8.3	10.1^{a}	63.8^{a}
	Plastic tunnel	152^{a}	126^{a}	12.7^{ab}	10.5	11.0	68.8^{a}
	Plastic rain-cover	215	197	14.8^{b}	9.3	9.8^{a}	65.9^{a}
Flair Fall 2023	Agrivoltaic GEN2 T60	158^{a}	72^{a}	12.5^{a}	7.1^{a}	9.8^{a}	58.8^{a}
	Agrivoltaic GEN2 T40	143^{a}	67^{a}	12.4^{a}	6.9^{a}	10.0^{a}	60.0^{a}
	Plastic tunnel	199	95^{a}	13.1^{a}	7.8	10.0^{a}	72.7^{a}
Joly Fall 2023	Agrivoltaic GEN2 T60	125	96	13.9^{a}	7.2^{a}	9.9^{a}	50.8^{a}
	Agrivoltaic GEN2 T40	103	78	13.5^{a}	7.2^{a}	9.9^{a}	54.0^{a}
	Plastic tunnel	190	154	13.8^{a}	8.0	10.1^{a}	60.7^{a}
Joly Summer 2024	Agrivoltaic GEN2 T60 + plastic foils	162^{a}	43^{a}	10.5^{a}	6.7	9.9^{a}	58.8^{a}
	Agrivoltaic GEN2 T40 + plastic foils	142^{a}	48^{a}	12.2^{ab}	6.2	9.9^{a}	57.3^{a}
	Agrivoltaic GEN2 T60	152^{a}	43^{a}	12.7^{b}	7.2^{a}	10.4^{a}	63.3^{ab}
	Edge line (no cover)	152^{a}	77	11.8^{ab}	7.3^{a}	11.1	65.3^{b}
Joly Summer 2025	Agrivoltaic GEN2 T40 + plastic foils	310^{a}	130^{a}	20.3^{a}	7.2^{a}	7.7^{a}	66.3
	Agrivoltaic GEN2T60 + plastic foils	355^{ab}	174^{ab}	18.7^{ab}	7.6^{a}	8.1^{a}	69.8^{a}

	Agrivoltaic GEN2 T60	397^{b}	232^{bc}	20.1^{a}	8.3^{b}	8.8^{b}	71.0^{a}
	Plastic rain-cover (Ex PV)	437^{b}	281^{c}	16.0^{b}	8.7^{b}	9.3^{bc}	70.9^{a}
	Plastic rain-cover (Ex no cover)	389^{ab}	256^{c}	17.3^{b}	8.8^{b}	9.7^{c}	72.1^{a}

Table 6: Summary of agronomic results for strawberries. Results that have the same superscript letter indicate that the difference between them is not statistically significative. (*) statistical significance could not be determined due to insufficient sampling.

In the next two subsections, we discuss the results for raspberries and strawberries. We use a conservative approach that takes all results into account, including those from the sub-optimal GEN1 system or with late planting dates, to derive trends for the different types of covers, species and plant types.

4.5.1 Raspberry agronomic results: discussion

From the results summarized in

Table 5, the following trends can be derived:

- When compared to open field, the raspberry yields were similar (no statistically significant difference) of better under the agrivoltaic cover (especially in the 2025 year with more than 2x better yield). Over all trials from the Conthey site, commercial yields were in average 40% better and fruit size 14% larger compared to open field. The agrivoltaic installation thus fulfilled its role of weather protection.
- There are significant differences in yields and fruit sizes between the two different kinds of plastic covers used as reference zones (plastic raincovers, and multi-span plastic greenhouses). In trials where both control zones were used, yields were in most cases better under plastic raincovers than in all the other systems. A possible explanation of the better performance of the raincover compared to other systems may be due to its small size, which limits the impact of heat, contrarily to large or closed plastic covers[15]. Marketable yields under plastic raincovers were in average 25% better than under agrivoltaic systems, with negligible difference (1%) in fruit size.

- Overall, the agrivoltaic system achieves yields close to those of multi span plastic greehouses. Over the 6 trials where plastic greenhouses were used as a control, 3 had similar commercial yields (no statistically significant difference and 3 had a lower yield, with an overall average difference per plant of 8% and 11% for total and marketable yields in favor of the plastic greenhouse. Fruit sizes are either larger or similar (+11% in average) for the raspberries cultivated under the agrivoltaic system in comparison to the plastic greenhouse. This result is important, as harvesting costs are lower for larger fruits (per kg of harvested fruits).

---

[15] The plastic raincovers feature a very high transparency (67-80%), which is an advantage for photosynthesis when temperatures are low or moderate. However, in large-scale installations, a high transparency also impacts the microclimate as solar radiation heats the air, which can inhibit photosynthesis or even damage the crops. In the present small-scale experiment, the plastic raincovers are distributed all around the agrivoltaic zone, and thus especially prone to edge effects, which prevent the modification of air temperature, thus only keeping the positive effect of the high transparency and not its disadvantages. The results obtained in the small raincover zones may thus not be representative of what would be obtained in commercial-scale area of plastic raincover. In contrast, the agrivoltaic system transparency is in average much lower (30-50%), limiting increases of air temperature independently of the system size.

The economic returns for the producer can thus potentially be larger, even in the case of a similar or lower commercial yield.

- Quality analyses show in general no statistically significant difference between the modalities, except in three of the eleven trials where a lower sugar content was measured in the agrivoltaic zone in comparison to one or the other reference zone.

4.5.2 Strawberry agronomic results: discussion

As seen inTable 6, agronomic results from the everbearing Karima variety under the GEN1 system in 2022 show significantly lower yield and sugar content under the agrivoltaic system compared to the plastic raincovers. The conclusions may be impacted by effects specific to this trial: (1) edge effects favourably impacting the reference plastic raincovers, as discussed for the raspberries[15] ; (2) the setting of the pots under the agrivoltaic cover in this trial was sub-optimal, as the leaves were directly shaded by the rain collection gutters for a large part of the season, without benefitting from the light regulation by the THEIA panels (Figure 24). Nevertheless, we can infer from this experiment that the prototypal system is not well adapted for the cultivation of strawberries, and that it is important to design a specific agrivoltaic system for each kind of crop. These results, combined with results from other Insolight sites also suggest that in general everbearing strawberries suffer more from the shading created by the panels than summer varieties, and are therefore not recommended for cultivation in agrivoltaic system at the current stage of knowledge..

The 2023-2025 trials on summer strawberries (Flair and Joly) showed various outcomes:

- The 2023 trial with varieties Joly and Flair in the GEN2 demonstrator system showed slightly better yields (no statistically significant difference) compared to conventional plastic tunnels, and lower yields compared to plastic raincovers (with the same possible edge effects for the small area of raincovers that have been discussed for the raspberries13). An irrigation issue in the plastic tunnels during the season may also have negatively impacted the results in this zone.
- The 2023 fall trial with varieties Joly and Flair in the GEN2 commercial-scale installation showed lower yields than the conventional plastic tunnels (but statistically significant for the Joly only). This result is however to be taken carefully as the planting dates were late and the dynamic shading screen of the agrivoltaic installation was only activated in September, thus casting extra shade on the crops during the first month of the trial. Overall yields were really low, even in the reference zone: 100-150g/plant instead of the 250-300g normally expected.
- The last 2025 trial on Joly strawberries under the GEN2 commercial-scale installation compared to a raincover area shows a gradient of yields from the most shaded zone (Agrivoltaics T40 + plastic foils) to the most luminous zone (raincovers), suggesting that light availability is a limiting factor. This gradient may have been amplified by a stronger powdery mildew pressure under the most shaded zones. Promisingly, sugar content and yields for the most luminous agrivoltaic zone (T60 without additional plastic tarps) are close (-4% total yield and -14% marketable yield in average, but without being statistically significant) from the control zone. Edge effects may also have influenced the results of the reference zone (see footnote[15]) and of the T60 without additional plastic tarps.

From these observations, the following conclusions can be made:

- Light availability is a limiting factor for strawberry production on substrates, in particular for everbearing varieties such as Karima. Everbearing strawberries generally suffer significant yield losses under agrivoltaic covers.
- Agrivoltaic installations need to be optimized with a low PV coverage to maintain comparable yields and sugar content to conventional plastic raincovers. Promising results have been obtained with the most luminous agrivoltaic designs, with comparable sugar content and yields

per plant (no statistically significant difference) in comparison to plastic raincovers, although these results may have been influenced by edge effects and need to be repeated for confirmation. The comparison to open field has not been made for strawberries, as strawberries on substrates are always covered.

The higher sensitivity of strawberries compared to other berries to light limitation is consistent with the available literature[16].

4.6 Photovoltaic energy production

4.6.1 PV production – GEN1 prototypal system

Figure 29 and Figure 30 shows the daily electrical power output per unit of active module area of mono-facial, respectively bi-facial modules since their installation, and compare it with their simulation. The agreement between actual output and simulation is generally good, except for a slight under-estimation of the energy production in MLT-mode, especially for bi-facial modules, due to the light scattering effect mentioned in section 3.4 and to the contribution of bi-faciality. Overall, the PV production of mono-facial modules was ~7% higher and bi-facial 20% higher than the simulated outcome.

As can be seen, IBC bi-facial cells provide a significant boost (+13.6 %) compared to the mono-facial PERC cells.

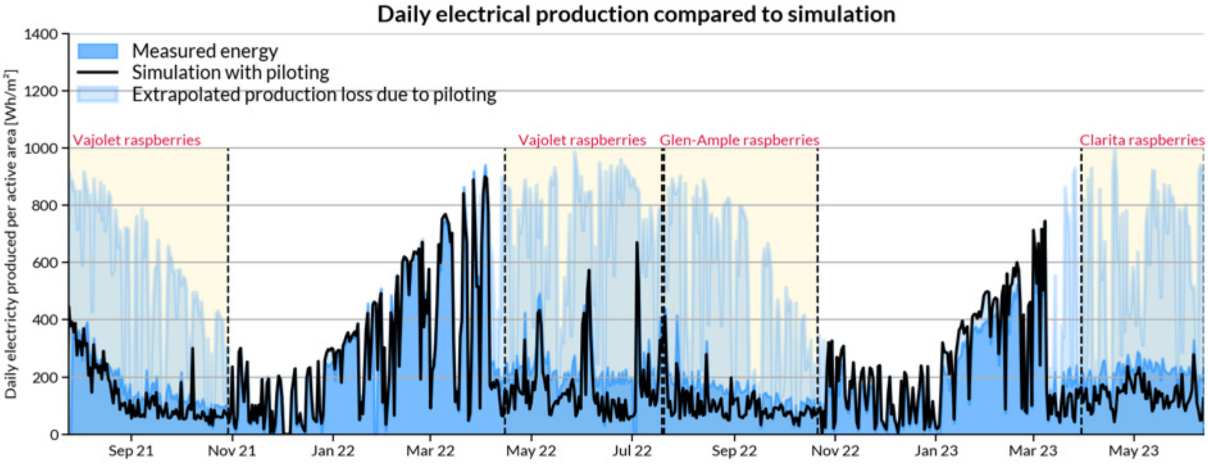


Figure 29: Daily electrical production of the GEN1 installation with mono-facial THEIA prototypes (energy generated per unit of active area) until June 2023. The black line is the simulated output based on irradiance data measured on-site. During the agronomical trials, represented by the yellow areas, the panels were steered to meet the agricultural targets of light needs. Light blue area represents the electricity production sacrificed to meet the crop light needs.

---

[16] Hermelink, M. I., Maestrini, B. & de Ruijter, F. J. Berry shade tolerance for agrivoltaics systems: A meta-analysis. Scientia Horticulturae 330, 113062 (2024).

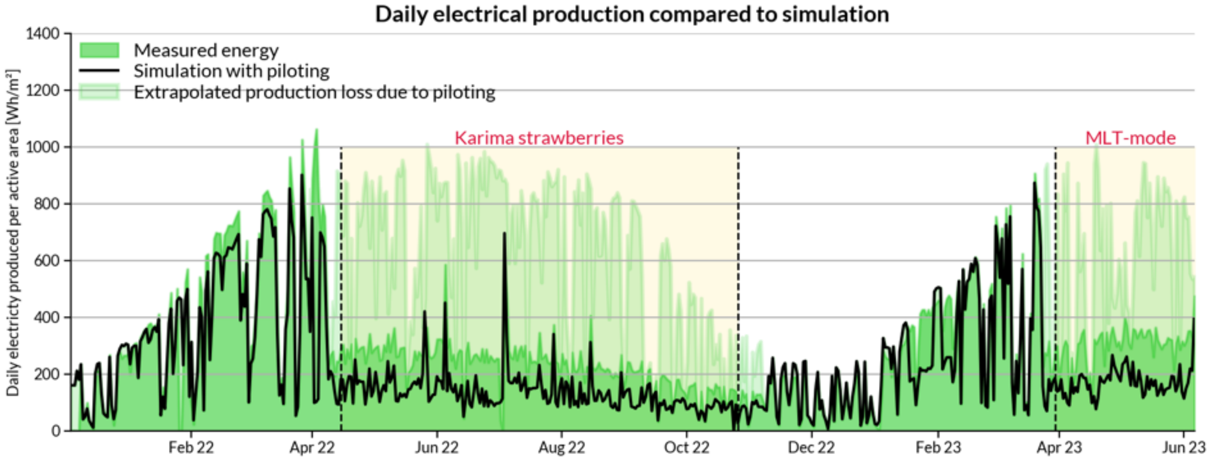


Figure 30. Daily electrical production of the GEN1 installation with bi-facial THEIA prototypes (energy generated per unit of active area), until June 2023. The black line is the simulated output based on irradiance data measured on-site. During the agronomical trials, represented by the yellow areas the panels were steered to meet the agricultural targets of light needs. Light green area represents the electricity production sacrificed to meet the crop light needs.

As we have full data on the year 2022, we will compare the energy production during this year with the KPIs. As the modules made with IBC bi-facial cells provide a significant improvement, we extrapolate the result for an installation made of these modules. Based on the good agreement between actual PV energy production and simulations, especially when modules are in E-mode, we use the simulation toolbox to extrapolate the production of an installation for three different scenarios.

- Scenario 1: actual steering of 2022 (with two agronomic trials from mid-April to mid-November –representative of the production schedule of many producers)
- Scenario 2: 1 agricultural cycle of 3 months (3 to 3.5 months are representative of a summer cycle for producers performing staged plantations).
- Scenario 3: No agricultural cycle, full E-mode (limit case).

Figure 31 shows the cumulated energy output per unit of active area for the bi-facial installation, for the different scenarios mentioned above.

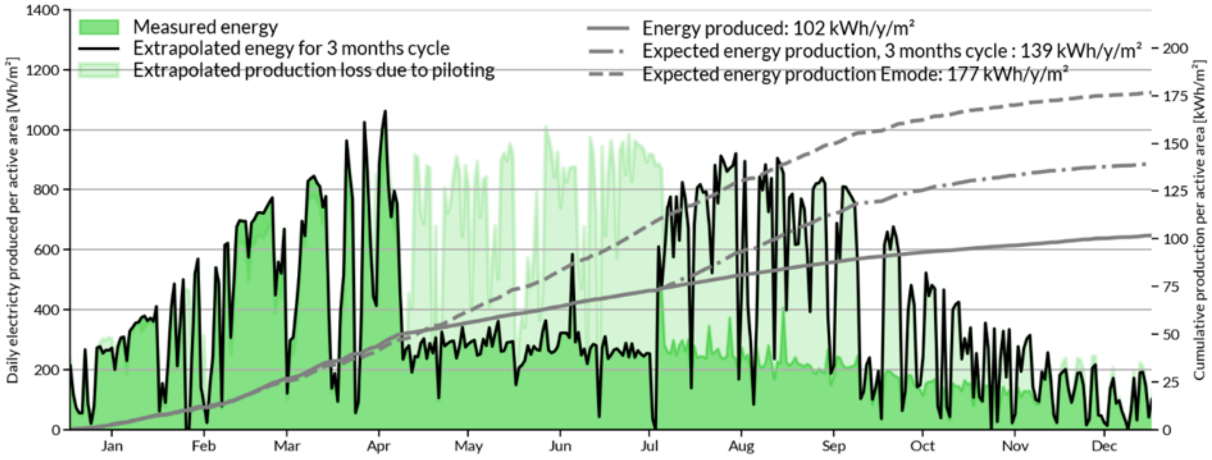


Figure 31: Daily and cumulated production per unit of active module area of the GEN1 installation with bi-facial THEIA prototypes for the different scenarios in 2022. Full grey line is the measured cumulated energy (actual steering of 2022 with two agronomic trials), the dash-dot line is the extrapolated cumulated energy for only 1 agronomical cycle of 3 months (realistic) and the dash line is the extrapolated cumulated energy if no agronomical cycle, so modules would be in full E-mode (limit case).

Results and corresponding specific yield are summarized in Table 7.

	Yearly production per module active area	Specific yield
Scenario 1: actual steering (2 agronomic trials in 2022)	102.0 kWh/m^2	534.1 kWh/kWp/yr
Scenario 2: 1 agronomical cycle of 3 months. (extrapolated)	139.3 kWh/m^2	729.4 kWh/kWp/yr
Scenario 3: Full E-mode (extrapolated)	176.6 kWh/m^2	924.8 kWh/kWp/yr

Table 7: PV production of the GEN1 installation in 2022 and extrapolations for other scenarios.

The annual production of this GEN1 prototypal system would therefore stand between 534 kWh/kWp and 729 kWh/kWp, depending on if 1 or 2 agricultural production cycles are performed.

With an installation density (for this prototype) of 109 Wp/m2 of ground area, the yearly production per ground area is thus between 58 kWh/m^2 and 79 kWh/m^2, or 580-790 MWh/ha.

Specific yields for GEN1 THEIA modules are about 25% lower than what was planned at the beginning of the project for this prototypal technology and fall short, even if steered in Full-E-mode during the whole year, to the KPI target of >180 kWh/m2 of panel surface set for these concentrator modules. Good agreement with the simulation tools developed during the project allows us to attribute this difference to (1) optical losses within the lens plate, especially at high angle of incidence ; (2) larger-than-originally expected fraction of diffuse light, on which the lens array doesn't have a steering power ; (3) additional shading due to structural elements whose cross section is dimensioned to support the weight of the GEN1 THEIA prototypes.

4.6.1 PV production – GEN2 demonstrator

The PV production of the GEN2 solution is assessed using a 16kWp GEN2 demonstrator that was connected to the grid in Fall 2022. The large 265kWp installation was only connected to the grid during 2025 and does not provide enough data for a yearly yield calculation. Figure 32 shows the monthly AC production of the 16kWp GEN2 installation for three full years, compared to its expected production simulated for a typical meteorological year (TMY). An average specific yield of 1217 kWh/kWp/year is measured. This is significantly higher than the average of rooftop photovoltaic production (around 970 kWh/kWp/year[10]), primarily thanks to the elevated geometry and bi-facial production. The yearly production potential per surface of ground area is obtained by multiplying the specific yield with the installation capacity. It reaches 1019 MWh/ha for the geometry of the GEN2 demonstrator, 1171 MWh/ha (781 MWh/ha) for the raspberry part with T60 (T40) modules of the GEN2 commercial-scale installation, and 871 MWh/ha (581 MWh/ha) for the strawberry part with T40 (T60) modules. Production of the GEN2 demonstrator during some of the winter months is lowered due to snow cover on the panels (around 30 days in total over the three years), due to the clamping system used in the demonstrator that prevents the snow to slide off the panels. In newer GEN2 installations such as the commercial-scale system, the clamping has been modified so that the snow slides off the modules, usually within a few hours. Even with the few days of snow cover, the winter production of the GEN2 demonstrator was very significant, with an average of 336 kWh/kWp produced in average over the winter half-year (01.10 to 31.03) (27.6% of the yearly production, and 28% more than average rooftop photovoltaics[10]).

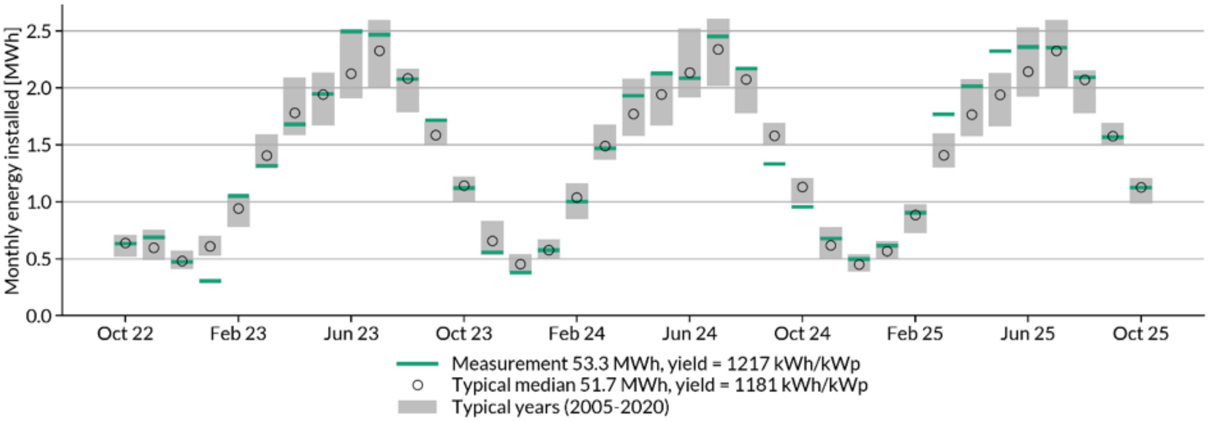


Figure 32 : Monthly PV production (AC) of the GEN2 demonstrator (16kWp installed, of which 14.4kWp were stringed for grid injection) from Oct. 2022 to Oct. 2025.

5. Discussion: economic viability

5.1 Agricultural returns

As detailed in Section 4.5, marketable yields under the GEN1 prototypal dynamic agrivoltaic system were in general comparable to those obtained under a multi-span plastic greenhouse, lower than those obtained under plastic raincovers (result that may in part be due to the small size of the raincover area[15]), and better than those obtained in an open field reference zone. Fruit sizes were also in several cases larger under the agrivoltaic system compared to the other zones, which advantageously impacts harvesting costs and margins. To establish agricultural returns, we perform a calculation of production costs per kg of berries in the agrivoltaic, plastic and open field areas using the Reseau-lution calculator[17]. The agrivoltaic cover is considered free of charge for the producer as it is financed by electricity returns (see Section 5.2). Various business models exist for financing the agrivoltaic infrastructure by third parties without costs to be borne by the producer. In some cases, a monthly rent or an initial lump sum can even be paid to the farmer to finance other production infrastructure. We determine the impact on marketable yield and fruit size using a conservative approach, averaging all the results obtained from the Conthey site (including the sub-optimal GEN1 prototype with strong shading). We consider the case of long cane raspberries with one summer cultivation cycle. Plantation densities are considered the same for the agrivoltaic areas and raincovers, as the raincovers were installed with the same inter-row distance as the agrivoltaic cover to which they were compared to. For comparison to open field or plastic greenhouses, we consider denser plantation in the reference zones (2.5m inter-row) than under the agrivoltaic cover (3m inter-row).

5.1.1 Raspberries: agrivoltaic cover vs open field

For the comparison of agricultural returns when using the agrivoltaic cover in comparison to an open field cultivation, the conclusion is straightforward: with an agrivoltaic cover, the producer increases its marketable yield per plant by 40% in average, and fruit size by 14%. The benefit brought to the agricultural production compared to open field is therefore demonstrated. These benefits on agricultural production comes at no cost for the producer, as the agrivoltaic cover is financed by the electricity production. With the increased yield per plant and fruit size (and thus reduced operational costs for harvest), we estimatea reduction of production costs of CHF 3.40/kg thanks to the agrivoltaic cover.

5.1.2 Raspberries: agrivoltaic cover vs plastic raincovers or greenhouses

To compare agricultural returns in comparison to plastic covers, we conservatively consider the average of all results from the Conthey site (including the sub-optimal GEN1 prototype). Due to the large spread of results, we separate results in two cases to establish a comparison range: (1) Comparison to the average of all trials performed vs small areas of plastic raincovers (which may have benefitted from edge effects[15]). Investment costs for the raincover are estimated to be CHF 140’000/ha. (2) Comparison to the average of all trials performed vs multi-span plastic greenhouses. Investment costs for the greenhouse are estimated to CHF 350’000/ha. Using the Reseau-lution calculator**Fehler! Textmarke nicht definiert.** for these two scenarios, we find that production costs under the Agri-PV cover lie in between the production costs of the two kind of plastic covers (-0.22 CHF/kg compared to the multi-span greenhouses, + 1.91 CHF/kg more expensive compared to the small area of raincovers).

5.2 Electrical returns

It was shown in Section 4.8 that electrical production with the GEN1 system is about 25% lower than what was planned at the project beginning for this prototypal technology. In addition to that, several

---

[17] https://reseau-lution.agridea.ch

challenges linked to the reliability and industrialization of the THEIA prototypes with integrated micro-tracking technology made us review our predictions of production costs (not detailed in this report), bringing the Levelized Cost of Electricity (LCOE) to ~0.4CHF/kWh for a production capacity of 100 MWp/yr. THEIA modules such as those tested in this prototypal installation are thus non-competitive for the agrivoltaic market, even when bringing benefits to the agricultural production. These challenges in terms of industrialization and competitiveness have led Insolight to develop the second generation (GEN2) of agrivoltaic solution, retaining its important features but leveraging on qualified components from the PV and agricultural industry.

GEN2 systems generate a specific yield of ~1200 kWh/kWp/yr (Based on 3-year average measured in Conthey – see Figure 32). Capital expenditure for large-scale agrivoltaic berry installations is 1.3 CHF/Wp (based on actual costs of 1MW- or 1ha-scale projects currently in construction in Switzerland, including Bill of System costs). This price is very competitive compared to alpine solar PV (typ. 4-6 CHF/Wp [18, 19]) and rooftop PV (typ.1.5 – 3 CHF/Wp, depending on system size[20]). Moreover, agrivoltaics enable utility-scale (multi-MW) deployments that can well complement the more fragmented rooftop market. There is no cost reference for Ground-Mounted PV to compare with, as Ground mounted PV is not permitted in Switzerland on agricultural land and does not enable a continuation of agricultural activities on the land.

5.3 Overall economic viability

With a competitive Capital Expenditure and specific yield, the berry agrivoltaic cover can finance itself through the electricity production, with typical Internal Return on Investment times of 15-20 years. The business case is attractive enough for a third-party investor to pay for the agrivoltaic system and provide it for free to the agricultural producer. In some cases, a monthly rent or an initial lump sum can even be paid to the berry producer to finance other production infrastructure, such as a fertigation system, at the project beginning. Co-investing models also exist where the agricultural producer invests in whole or part of the agrivoltaic infrastructure to share the risks and benefits of the electricity production sales.

From the perspective of the berry producer, the agrivoltaic cover provides a free protection system for the crops and better yields than uncovered cultivation, dramatically lowering its production costs. Production costs are comparable to common types of plastic covers.

The agrivoltaic installation is thus economically viable for both the producer and the investor and enables generation of renewable electricity while maintaining agricultural activities.

---

[18] https://www.pv-magazine.com/2025/01/17/construction-begins-on-12-mw-swiss-alpine-pv-project/
[19] https://www.srf.ch/news/wirtschaft/teurer-strom-aus-den-bergen-hohe-kosten-bremsen-den-solarexpress
[20] https://www.suisseenergie.ch/tools/calculateur-solaire/

6. Conclusions and perspectives

The completion of this 4-year project provides a first reference for agrivoltaics on berry crops. During the project, the first berry agrivoltaic system of Switzerland was built in 2021: a functional 18kWp dynamic agrivoltaic installation of first generation (GEN1), featuring THEIA prototypal modules. From 2021 to 2023, electrical monitoring and agronomic trials showed that the system can protect crops while producing solar energy. The GEN1 architecture however showed its limits, with low specific yields (500-900 kWh/kWp) and limited overall light transmission for the crops, especially in diffuse light conditions, as well as unviable economics due to the complex nature of the THEIA prototypes.

Two second generation (GEN2) agrivoltaic systems were additionally evaluated during the project: a 16 kWp demonstrator built in 2022 and a 265 kWp commercial-scale installation in 2023, featuring semi-transparent panels and a mobile shading screen. However, as mentioned in Section 4.1, the screen was barely used in the commercial scale agrivoltaic installations and thus did not significantly influence the agronomic results. The added value of the shading screen for berry production in Switzerland remains therefore questionable and would need further comparative trials to be quantified. With a specific yield of ~1200 kWh/kWp/year (of which nearly 340 kWh/kWp is produced during the winter half-year, and economically viable CAPEX of ~1.3 CHF/Wp, this agrivoltaic solution is cost-competitive and a good complement to the rooftop surfaces for renewable energy generation.

Between 2021 and 2025, 6 varieties of raspberries (with two types of plants) and 3 varieties of strawberries were evaluated in agronomic trials comparing the main agronomic indicators (total yield, commercial yield, fruit size, and quality factors) between the GEN1 and GEN2 agrivoltaic installations with open field as well as various types of plastic covers.

Milder climate during heat waves and spring frost events, and protection against hail have been demonstrated during the project, showing the benefits provided by the agrivoltaic cover to mitigate effects of climatic hazards.

The main agronomic results are, for the raspberries, a benefit in terms of yield, fruit size and production costs compared to open field cultivation. As such, the agrivoltaic cover comply with the requirements set by Article 24ter al.2a of the Spatial Planning Act (LAT). When compared to two types of plastic covers, yields were in average smaller, but similar in some cases to the agrivoltaic cover. Production costs under the agrivoltaic installations were in-between those of the two types of reference zones. Quality differences were mostly not statistically different overall, although a lower sugar content was recorded in three of the eleven trials.

For strawberries, yields and sugar levels were in general lower than those obtained under plastic tunnels or raincovers, especially for everbearing varieties. Light availability was generally a limiting factor for total and marketable yields as well as sugar content. For summer strawberries, promising preliminary results in the most luminous second-generation installations were obtained but need further confirmation.

In the comparison to conventional covers, areas of some of the reference zones (plastic raincovers) were only available in limited size during the project, thus limiting potentially adverse heat effects on agronomic results thanks to edge effects. Trials with comparison to larger areas of raincovers, representative of a commercial production, would thus be needed to observe the full benefits of the agrivoltaic cover in comparison to this type of cover.

Based on the results above, we conclude that in general the agrivoltaic cover fulfills its role as a protective structure for the raspberry crops, while producing renewable electricity at a competitive cost, without additional land take than the originally unprotected berry production. For strawberries, the results show that everbearing strawberries are too sensitive to light reduction, while promising results for summer strawberries need further confirmation.

The project provided first reference points at the experimental and commercial scale to Insolight, and a basis to inform the development of two generations of agrivoltaic solutions as well as associated monitoring and modelling tools. These tools were subsequently used to design agrivoltaic solutions for other locations and type of crops. With currently more than 2.3 MWp of agrivoltaic projects built to date (of which 1.5MWp are in Switzerland), 3MWp in construction in Switzerland (over blueberries, cherries and grapes), and nearly 300 MWp in development (of which 30 MWp are in Switzerland), the KPI target of 1MWp of projects planned at the project end has thus been largely attained. Solutions designed for other crops and locations do not always rely on the configurations tested during this project, as every use case has its requirements in terms of transparency and protection needs. In particular, the added value of a reflective shading screen, as tested within the GEN2 implementations of this project, remains to be confirmed for berry crops in Switzerland.

Further research may help identify additional varieties and plant types that tolerate or benefit from the additional shading generated by the solar panels, optimize practical aspects such as the management of rainwater or pest and diseases, and quantify the added value of optional dynamic elements such as the shading screen. Another outlook is the field assessment of agrivoltaic systems designed for other climates, crops and agricultural practices (orchards, arable and forage crops, grazing or biodiversity areas).

7. National and international cooperation

In parallel to this project and leveraging on its GEN1 infrastructure, Agroscope and Insolight have applied and obtained, in collaboration with CSEM (Neuchâtel), an Innosuisse funding (ATLAS project - 55307.1 IP-EE) for 2021-2024 to support the development of the GEN2 system assessed in 2023-2025. Additionally, the ATLAS project enabled the development of metrology tools for the measurement of PV efficiency and light transmission of semi-transparent solar modules. Advanced agronomic measurements such as carbon assimilation, leaf temperature and area or sap flow were also implemented to feed crop models and provide finer understanding of how microclimatic conditions impact the yield of various varieties of raspberries and strawberries.

8. Publications

Scientific and technical publications, contributions to conferences:

- Oral presentation: “PV Modules with Dynamic Control of Transmitted Light for Agri-photovoltaics” – *Intersolar 2021, Münich, 07.10.2021*
- Invited oral presentation: “Une solution suisse pour l’agrivoltaïque dynamique” – *4. Nationale Gewächshaustagung, online, 23.10.2021*
- Invited oral presentation: “Une solution au service des cultures” – *Conférence INES Agrivoltaïsme, Gréoux-les-Bains, 30.11.2021*
- Oral presentation: “Agrivoltaïsme en Suisse ? Potentiel et solution insolagrin” – *PV Tagung 2022, Bern, 30.03.2022*
- Invited oral presentation: “insolagrin: a semi-transparent solution for dynamic agrivoltaics” – *1st International Integrated-PV Workshop, online, 7-8.04.2022*
- Oral presentation: “insolagrin : a Solution for Dynamic Agrivoltaics” – *Agrivoltaics 2022, Piacenza, 15-17.06.2022*
- Oral presentation: “Agrivoltaics in Switzerland? – Potential and insolagrin solution”, ZHAW Fachtagung Agro-photovoltaik: Agro-Photovoltaik in der Schweizer Landwirtschaft, Wädenswil, 14.07.2022
- Oral presentation: “Dynamic agrivoltaics with berry crops” – *31st International Horticultural Congress, Angers, 14-20.08.2022*
- Oral presentation: “First results from insolagrin, a novel solution for dynamic agrivoltaics” – *8th World Conference on Photovoltaic Energy Conversion (WCPEC-8), Milano, 26-30.09.2022*
- A public event on agrivoltaics has been organized by Agroscope in Martigny and Conthey on 4.11.2022, with the attendance of 70 participants from Switzerland and European countries.
- Invited oral presentation: “insolagrin: a semi-transparent solution for dynamic agrivoltaics” – *2nd International Integrated-PV Workshop, online, 28.03.2023*
- Oral presentation: “Dynamic agrivoltaics with raspberry crops: field trial results” – *Agrivoltaics 2023, Korea, 12-14.04.2023*
- Oral presentation: “Field results and simulation of a new generation dynamic agrivoltaic solution” – *40th European Photovoltaic Solar Energy Conference and Exhibition (EU-PVSEC), 18-22 Sept 2023, Lisbon*
- Oral presentation: “Heat stress and frost mitigation in a commercial-scale dynamic agrivoltaic system” -- 5th World Conference on Agrivoltaics (Agrivoltaics 2024), Denver, USA, June 13th, 2024.
- Invited oral presentation: “Mitigation of heat stress and frost in agrivoltaic installations” -- *INNOVATION, EXPERIMENTATION AND SUSTAINABILITY FOR AGRIVOLTAIC SYSTEMS DESIGN, Naples, Italy, October 21st, 2024*
- Invited oral presentation: “Developing APV-Projects for Vegetal Agriculture: Key Learnings” -- *3rd Agrivoltaics Europe -- Vienna, Austria, November 5th-7th, 2024.*
- Invited oral presentation: “Light and Temperature Management in Agrivoltaic Systems” -- *Optica Advanced Photonics Congress, Marseille, France, July 13-17, 2025*
- Light Thresholds and Shading Effects on Strawberry and Raspberry Yields and Quality under Agrivoltaics Systems in Switzerland. J. Widmer *et al.* Accepted for publication.