BENEFITS OF AN AGRIVOLTAIC INSTALLATION IN AN ECOLOGICAL VINEYARD IN SOUTHERN SPAIN

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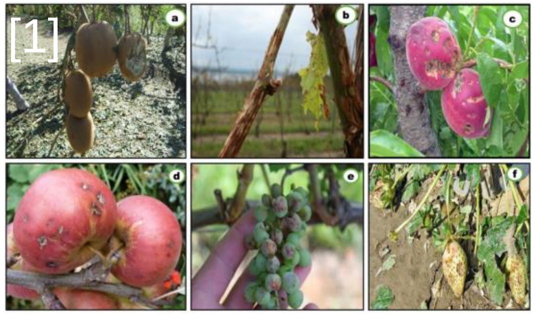
BACKGROUND

Background

Agrivoltaics – Turning challenges into solutions

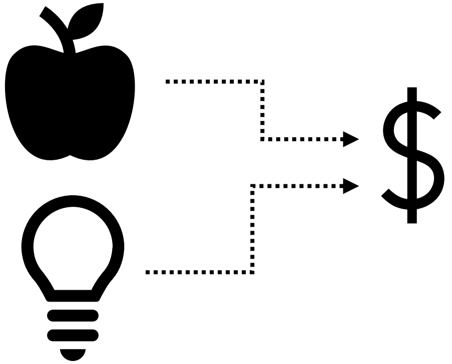
🔴 **Challenge 1: Impact of climate change and crop stress on agriculture.**
✅ Agrivoltaics can enhance resilience and adaptability of agriculture to extreme weather events, heatwaves and droughts.



🔴 **Challenge 2: Energy demand and competition for land**
✅ Agrivoltaics can improve productivity per area, integrating renewable energy generation with farming.


Source: AdobeStock

🔴 **Challenge 3: Rural economic pressure and instability**
✅ Agrivoltaics contributes to reducing the dependence on the grid and leads to an additional source of income for farmers.



[1] Singh Rana et al. (2022), “Management of hailstorms under a changing climate in agriculture: a review”, https://doi.org/10.1007/s10311-022-01502-0

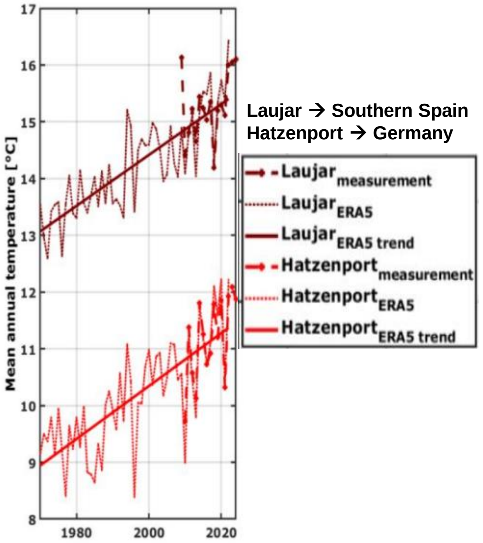
Background

For more information about the topic, check the plenary presentation 4AP.1.2 given by Natalie Hanrieder.

Viticulture & Climate Change

- In 2024, global wine production fell to lowest level since 1961 due to extreme weather events (droughts, heatwaves and hail) in many winemaking regions [1].
- Climate change is reshaping Europe's wine regions
  - Traditional winemaking regions, such as Spain and southern France, are struggling with scarce precipitation and extreme heat.
  - Regions at northern latitudes are becoming more suitable for wine production.
- Since 1970, temperature has risen by ~2.5 ºC in winemaking regions in Germany and Spain [2].
- Some future climate projections by 2100 indicate:
  - Higher average temperatures (↑ 4ºC in some months, particularly in summer).
  - More frequent and intense heat waves in Europe.
  - Higher probabilities of droughts, specially in southern Europe.
- These events may negatively affect crop development, leading to:
  - Heat stress.
  - Water stress.
  - Phenological shifts (earlier budburst and accelerated ripening).

Berries after a heat wave



Historical average annual temperatures in two winemaking locations. Source of data: ERA5. Plot in [2].

[1] https://www.decanter.com/wine-news/global-wine-production-falls-to-lowest-level-since-1961-545528/
[2] Hanrieder et al. (2025), "Agrivoltaic System Potential to Mitigate Effects of Climate Change in Viticulture", under Review in Solar RRL.

Background

Viticulture & Agrivoltaics

- In some vineyards, shading nets have been installed to mitigate and adapt the effects of climate change.


Source: Marigliano et al. [1]


Source: Vinethos


Source: EyouAgro


Source: Wine Business Analytics

- APV systems as a replacement for these shading nets → Simultaneous crop protection and energy generation. Multiple APV installations have been deployed in Europe in the last decade:


Piolenc, France
Source: Sun'Agri


Virgilio, Italy
Source: RemTec


Ihringen, Germany
Picture taken at the Weinbauinstitut Freiburg


Ribera del Duero, Spain
Source: Powerfultree


Laujar de Andarax, Spain
Source: DLR, Cortijo el Cura

This study

[1] Marigliano et al. (2022), https://doi.org/10.3389/fagro.2022.898870
[2] Harvesting the sun, protecting the vines – innovation for sustainable agriculture

Aim of the study

Viticulture & Agrivoltaics

Preserved Crop yield + Energy generation

How do elevated agrivoltaic systems influence vineyard microclimate, crop performance, and energy production in southern Spain?

First results from the southernmost APV installation over a vineyard in Europe.

DESCRIPTION OF THE SYSTEM

Description of the system

- **Pioneering APV project** in Almería, southern Spain, located within an organic vineyard[1]. Installation date: **January 2025**.
- **Overhead PV system** with a checkerboard layout, covering **120 m²** and shading 32 Merlot vines. Planting pattern: 2 m x 2 m spacing (2003). Ground Coverage Ratio – GCR: **38%**.
- System classified as **Category I – Use 1A** under **DIN SPEC 91434 (Germany)**.
- **Eco-friendly foundation** using ground screws to **prevent soil compaction**.
- **PV capacity**: **10.8 kWp** from **18 bifacial modules**. **Inverter** of **10 kWn**.
- **Energy use**: Electricity is used **on-site for self-consumption** by the main winery building.

[1] Cortijo El Cura-Ecobodega. https://cortijoelcura.com/

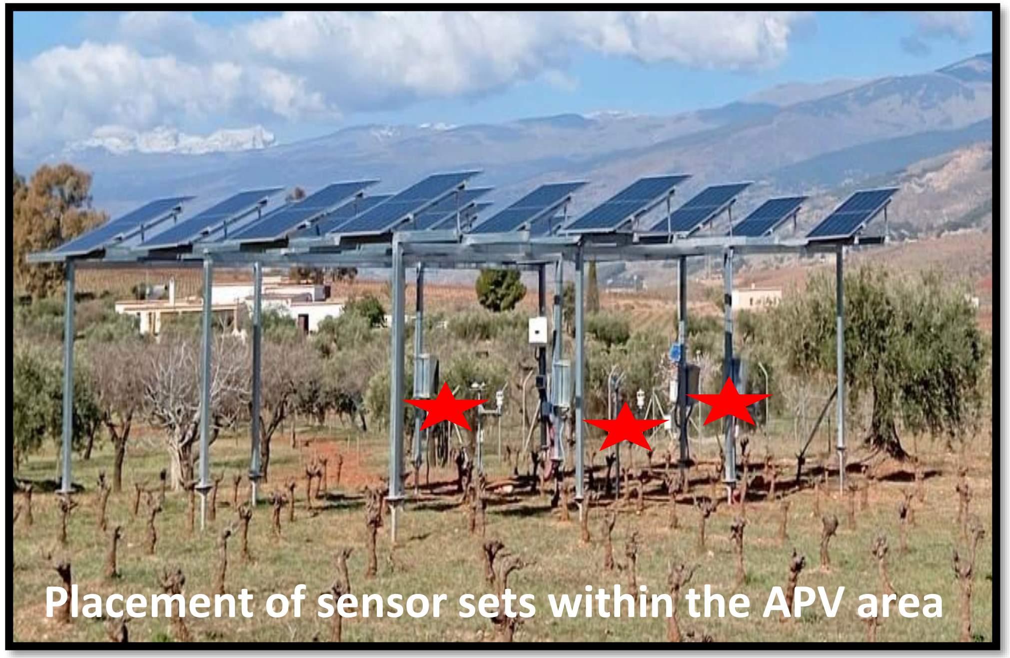
Description of the system

Monitoring system

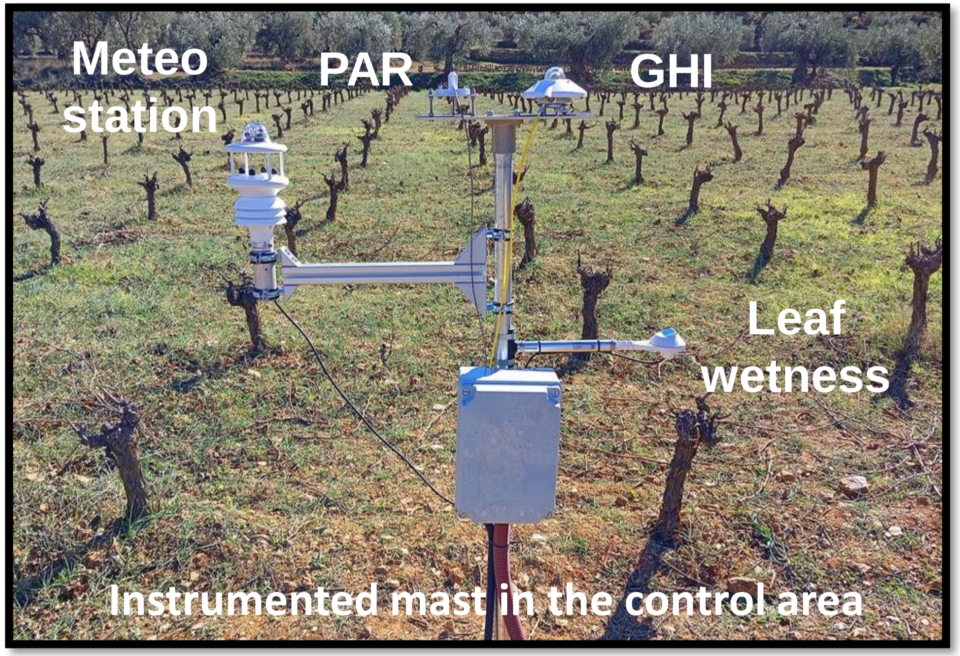
4 measurement zones to assess the impact of shading on microclimate, soil and crop performance:

- Under the PV structure (x3) → APV area
- Control area (no shading)

Category	Parameters Measured
Meteorological	• Air temperature • Relative humidity • Wind speed and direction • Precipitation
Irradiance	• Solar irradiance (PAR, GHI, G_{POA_f}, G_{POA_r})
Soil	• Soil temperature • Soil moisture
Crop	• Leaf wetness • Brix (sugar content) • Physiological traits • Yield quantity and quality



Placement of sensor sets within the APV area



Instrumented mast in the control area

RESULTS

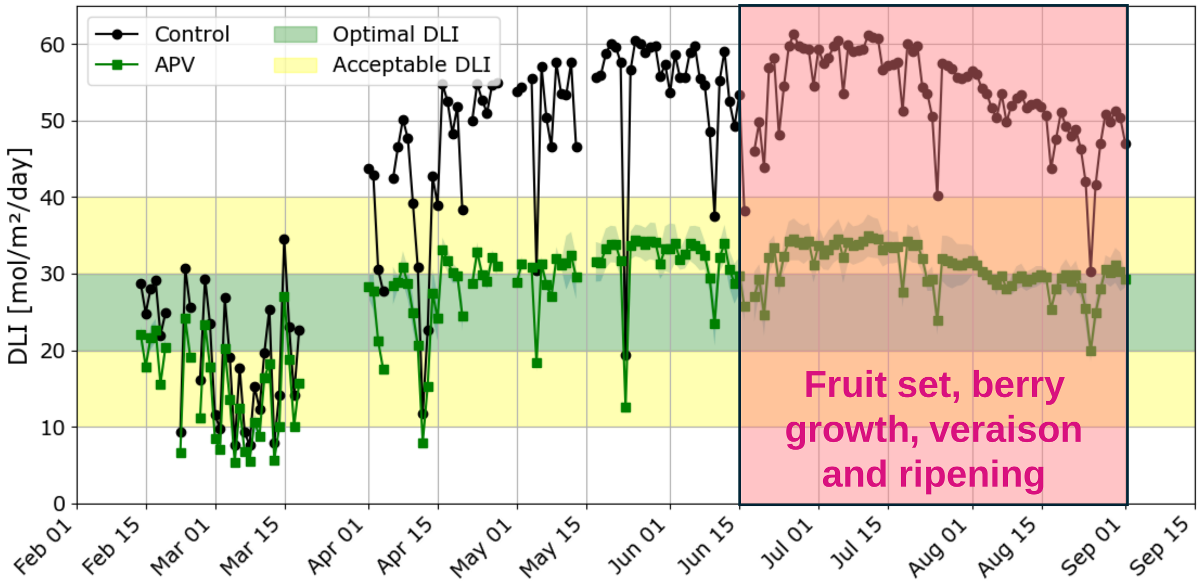
Results

Microclimate: Radiation – DLI

- PAR (DLI) was monitored with EKO ML-020P PAR sensors at 1.5 m height.
- In APV zone, excessive DLI values are partially mitigated.
- Optimal DLI for grapevines: 20–30 mol m^{-2} d^{-1} (stage & weather dependent) [1].
- DLI > 20 mol m^{-2} d^{-1} in both APV and control zones, except on very cloudy days.
- During berry growth–ripening, DLI in APV zone stayed within the acceptable range, ~40% lower than control.

DLI evolution during the crop cycle

$$DLI = \int PPFD\ (PAR)\ dt$$



[1] Photone Growth Light Meter, “Light Requirements for Plants”. https://growlightmeter.com/light-requirements-for-plants/

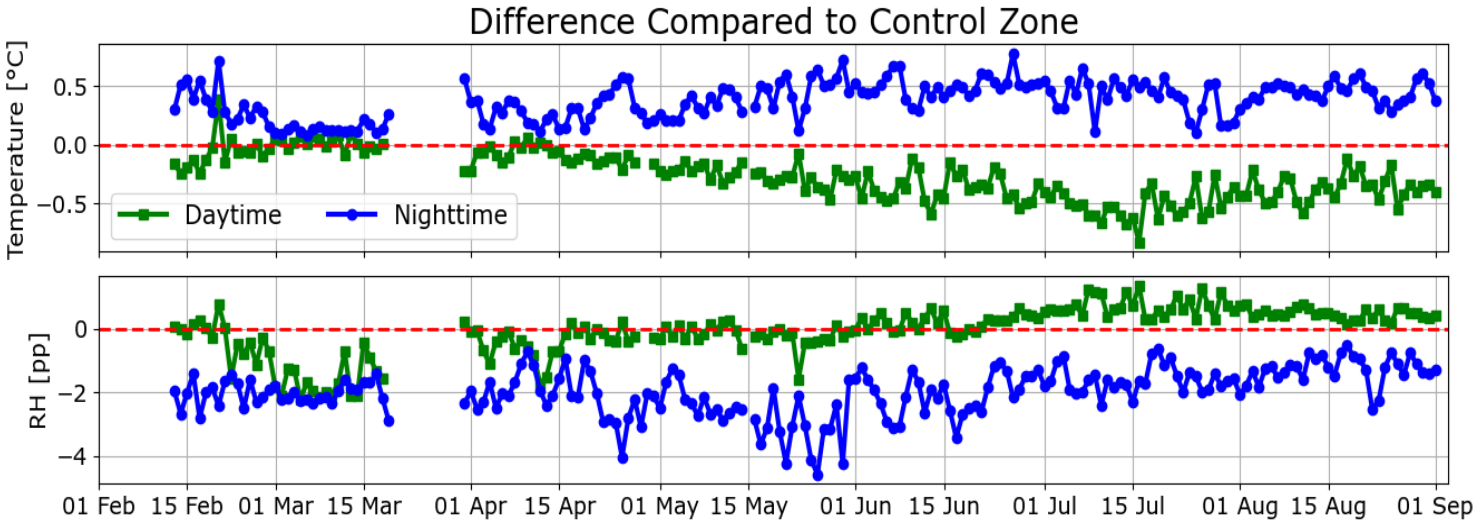
Results

Microclimate: Air Temperature, RH and soil moisture

Microclimate Effects in the APV Zone

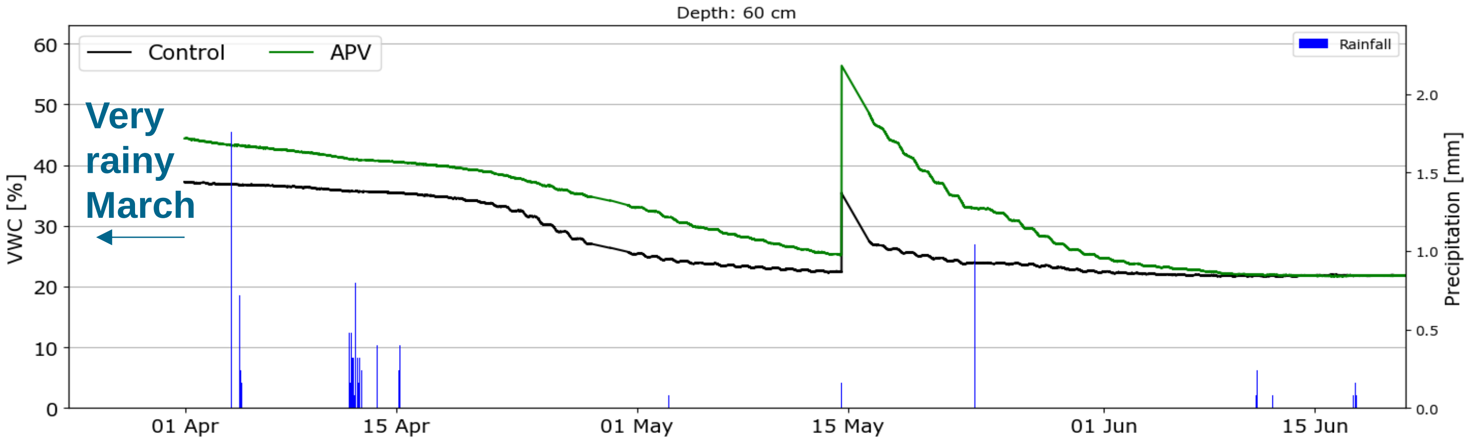
😊 **Daytime:**
⬇️ Temperature up to **–0.5 °C**
➖ Relative Humidity **similar**

🌙 **Nighttime:**
⬆️ Temperature **+0.6 °C**
⬇️ Relative Humidity up to **–4 pp**



Soil moisture

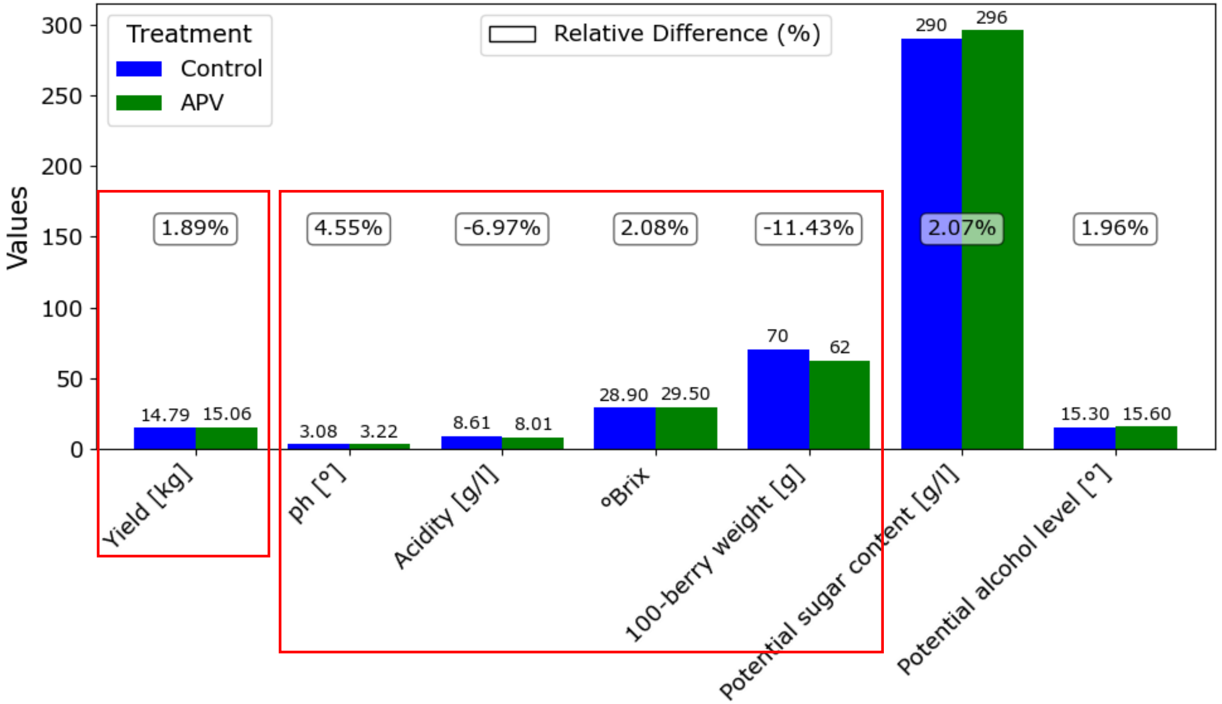
- Measurements of volumetric water content (VWC) at different depths.
- Extended soil moisture retention in the APV area → lower evapotranspiration.



Results

Crop yield

- 28 plants were harvested in each zone.
- As expected due to the relatively small size of the system:
  - **No differences were observed during the crop cycle**. All phenological stages had the same start and end dates in both areas.
  - **Yield** → Slightly positive impact in the APV area (~2% higher), aspect that should be further analyzed in upcoming years.
- **Smaller grapes** in the APV area, but with slightly **higher sugar content**, **lower acidity** and **higher pH** than the grapes in the control zone.
- **More advanced technical maturity in the APV area** despite reduced light.

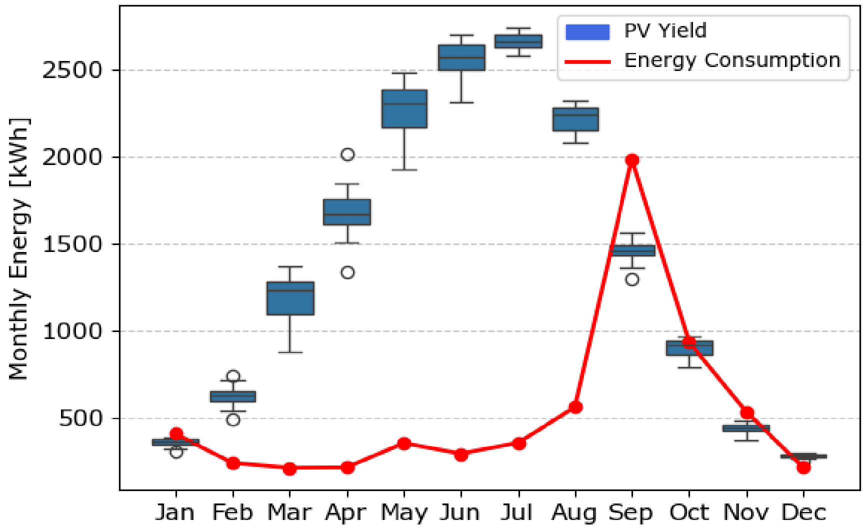


Results

Energy yield

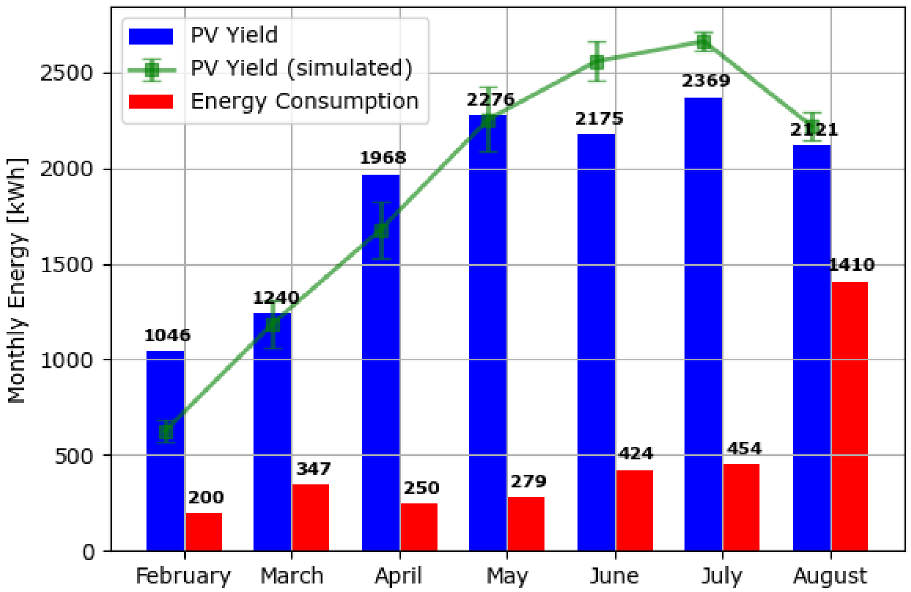
Simulations

- **PV yield**: 16400 ± 280 kWh/year (2.6 × winery demand); based on 15 years of weather data (2009 – 2024).
- **Consumption profile**: energy use is concentrated post-harvest, peaking between end August – October.



Actual data (2025)

- The APV installation has reduced grid dependence by **60%** since February.
- PV yield in line with the simulations, with the exceptions of:
  - February → Better performance (sunnier than normal)
  - Summer → Underperformance (higher thermal and soiling losses than expected)



CONCLUSIONS

Conclusions

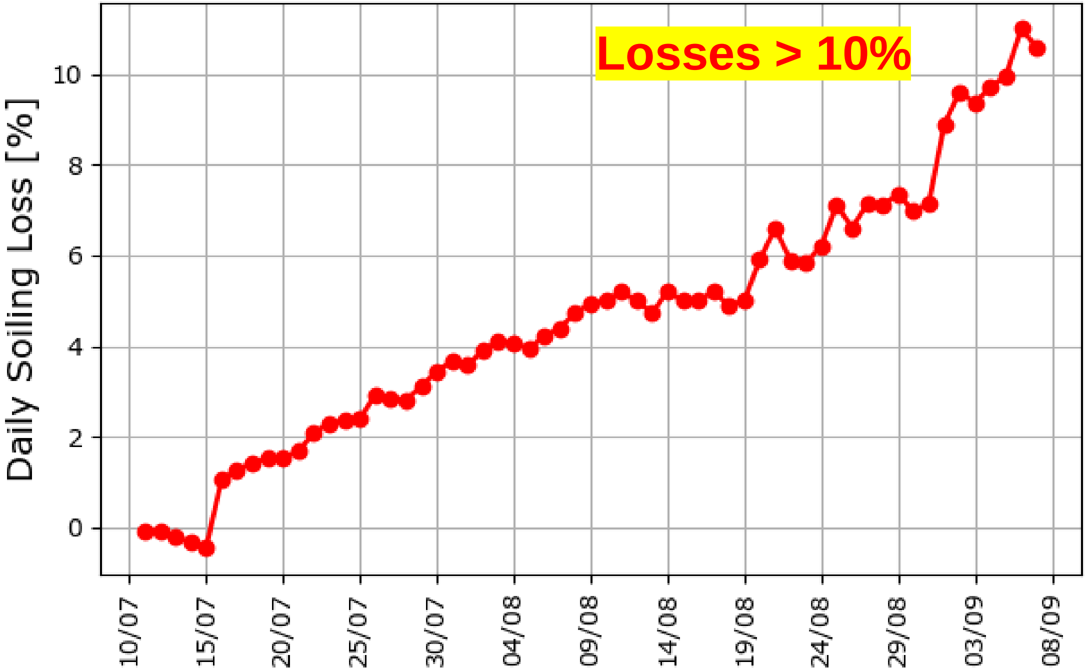
- The **motivation** behind the deployment of this **pilot APV system** was to **meet farmer's urgent needs** in **mitigating the negative effects of climate change** on grape yield.
- **Microclimate benefits**: Positive effects observed, helping to mitigate the impacts of extreme weather conditions.
- **Crop performance**: It performed as expected, with no negative impact on yield or quality detected during the first year of operation.
- **Farmer benefits**: Reduced electricity bills and crop protection against excessive radiation and hail.
  - This pilot site demonstrated the farmer that <u>simultaneous energy and grape production not only is possible, but can even enhance crop yield</u>.
- **Next steps**:
  - **As a result, the farmer is now convinced about the potential of agrivoltaics and ready to scale up the system with a tracked APV system and storage.**
  - Further validation of shading impacts on crop development and yield across multiple years with different rainfall patterns.
  - Integration of technical solutions to ensure uniform rainfall distribution below the panels.
  - Assessment of the O&M challenges (e.g. soiling) in elevated agrivoltaic systems.

EU PVSEC 2026

In EU PVSEC 2026:

Soiling in elevated agrivoltaics: a real challenge

↑ Soiling magnitude, Soiling seasonality



Let’s connect on LinkedIn

Thanks for your attention!

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Ready for a unique experience in Almería? Come and explore what Cortijo el Cura can offer (and take a look at the APV installation ☺!!!)

Cortijo el Cura Eco - Bodega

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