REGACE
Using Co2 for Green Energy

TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

Here comes the Sun on strawberry fields

the agrivoltaics project REGACE

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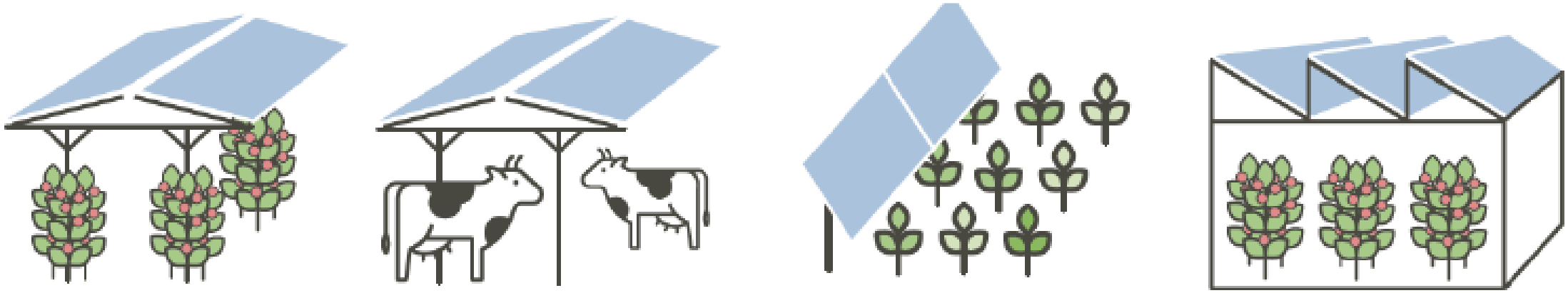
What is Agri-Photovoltaics?

Agri-Photovoltaics (Agri-PV, APV, Agrivoltaic) consists of the simultaneous use of areas of land for both solar photovoltaic power generation and agriculture. Its multi-use of land has the potential to make a major contribution to achieving the targets set in the **2022 Repower EU program** **(almost 600 GW PV @2030)**.



Source (Agrivoltaics 2022 Conference Catalog)

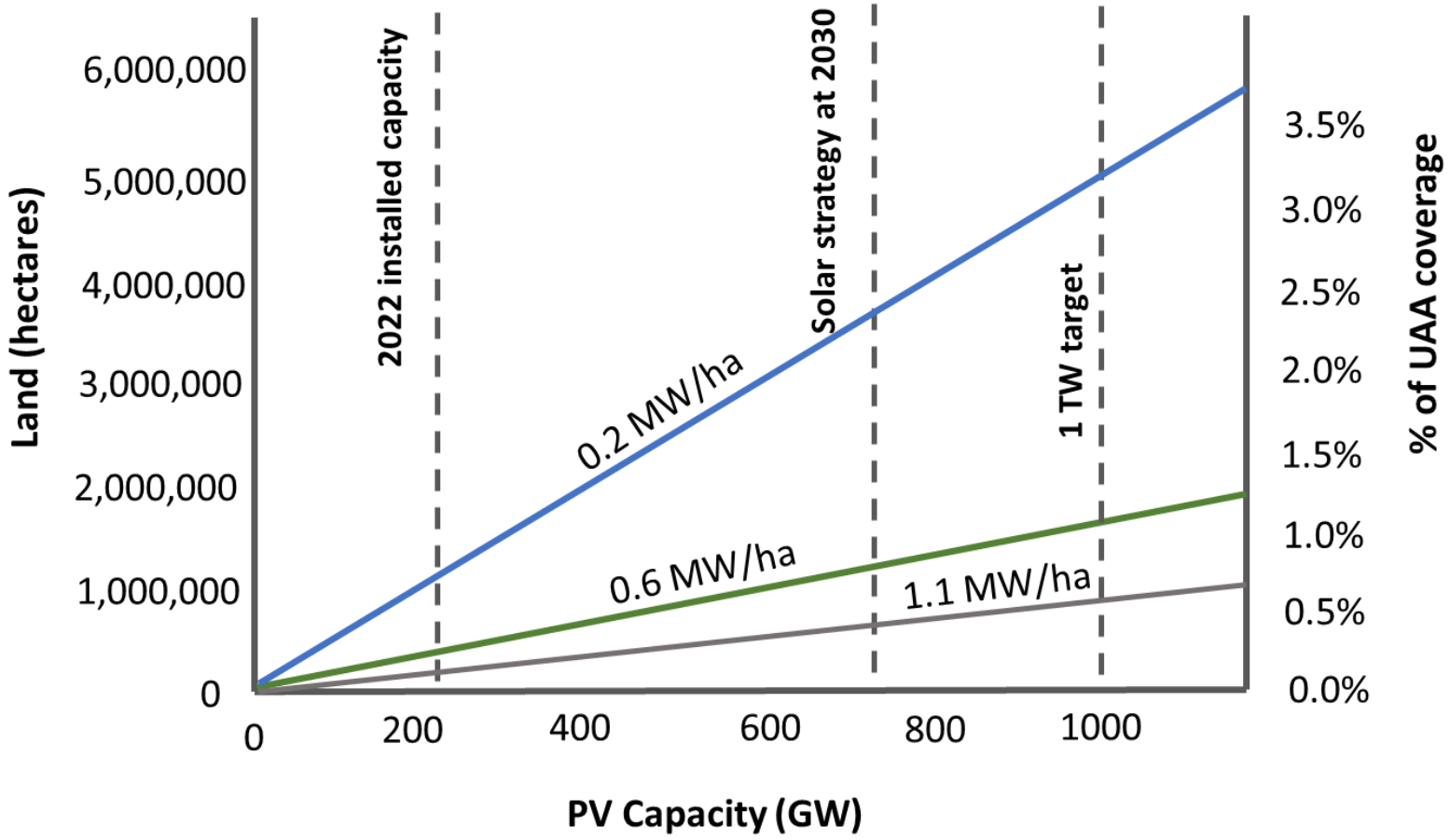
Some numbers on Agri-PV

1 % of Utilised Agricultural Area (UAA)

944 GW

5XEU installed capacity @2022

UAA = 158 million hectares at EU level

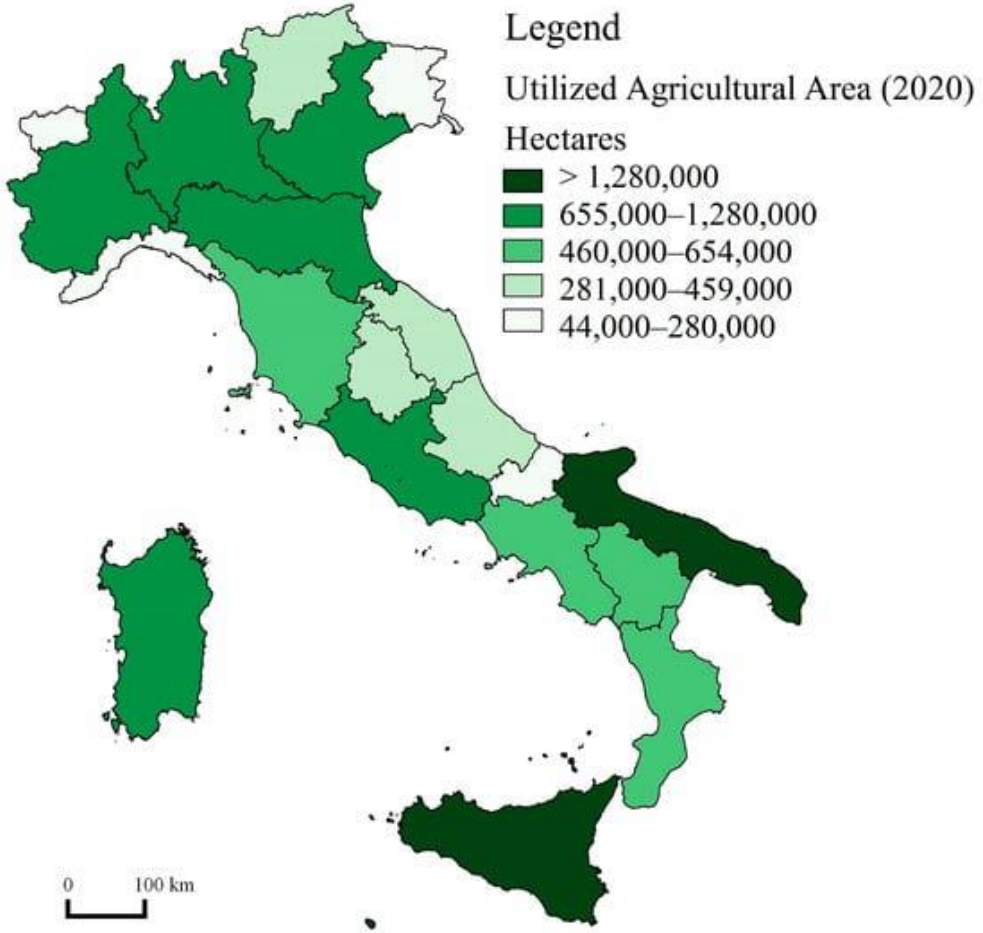


Source (JRC, Overview of the Potential and Challenges for Agri-Photovoltaics in the European Union 2023)

Some numbers on Agri-PV

1 % of Utilised Agricultural Area (UAA)

UAA = 12,5 million hectares at ITALY level



70 GW

3XIT installed capacity @2022

Labianca, 2023. Proposal of a Method for Identifying Socio-Economic Spatial Concentrations for the Development of Rural Areas: An Application to the Apulia Region (Southern Italy), Sustainability, 15 (4).

Some numbers on Agri-PV

APV in Italy (2022)

- **42,000** APV sites
- **2,600** MW Installed APV capacity
- **3,000** GWh Gross Production

Source (GSE Report Solare fotovoltaico, 2022)

Some numbers on AgriPV

Greenhouse potential in Italy (2022)

- **40,000** hectares of greenhouses
- **24 GW** of potential PV capacity
- **28.8 TWh** Gross Production

Source (ISTAT database, 2023)

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Core Technology

Responsive tracking system in the greenhouse driven by a **PLC controller** that changes the tracking angle according to the plants' needs. A system using **CO_2 enrichment** increases crop production in low light conditions optimizing electricity production of the **bifacial panels** in the tracking system.

Key factors

- **Lightweight** and easy to mount system
- **Dual use** of land and dual use of infrastructure
- **Low visual** impact
- **€ 600/kW** compared to €880/kW for ground-based PV fields

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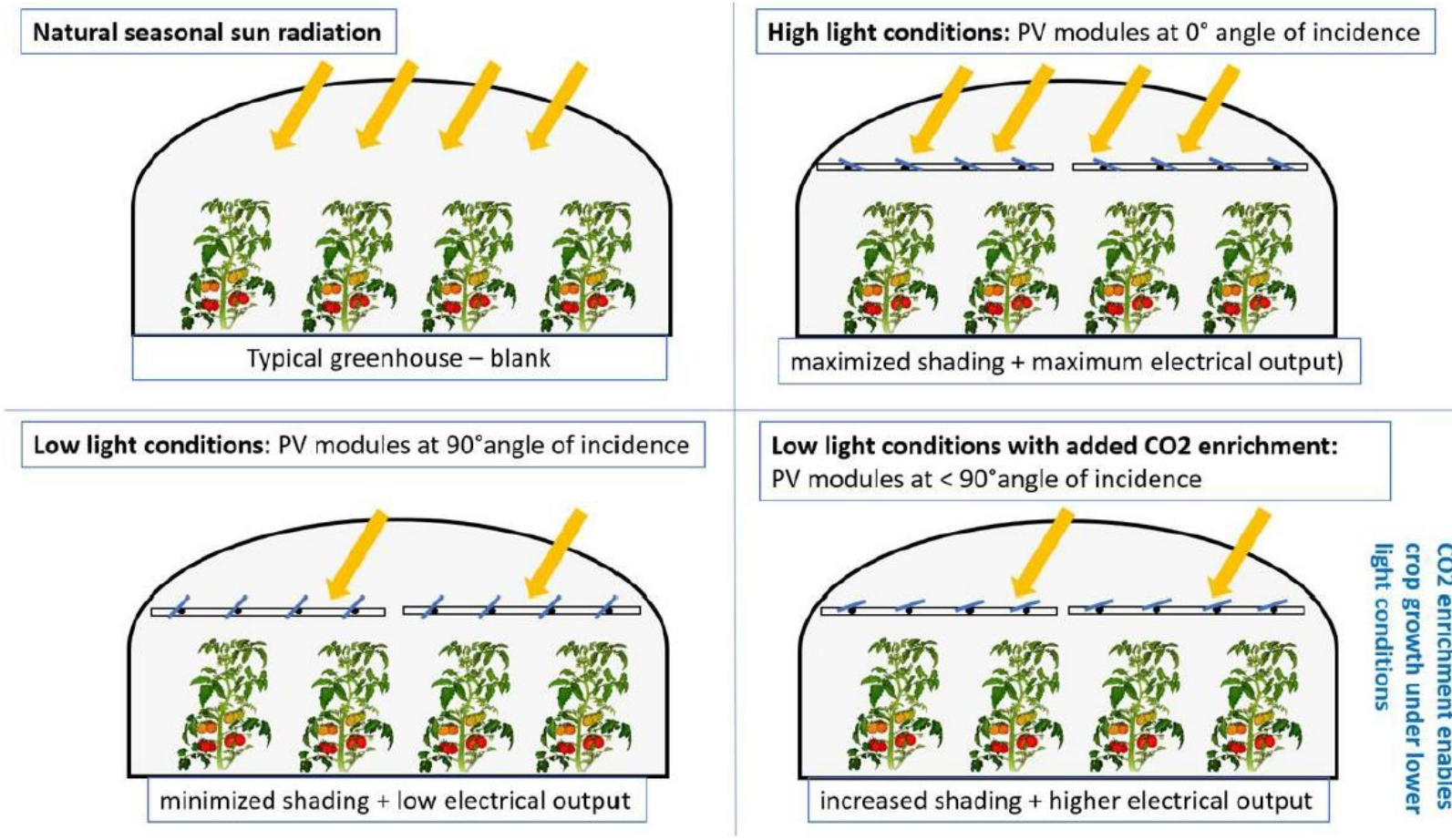
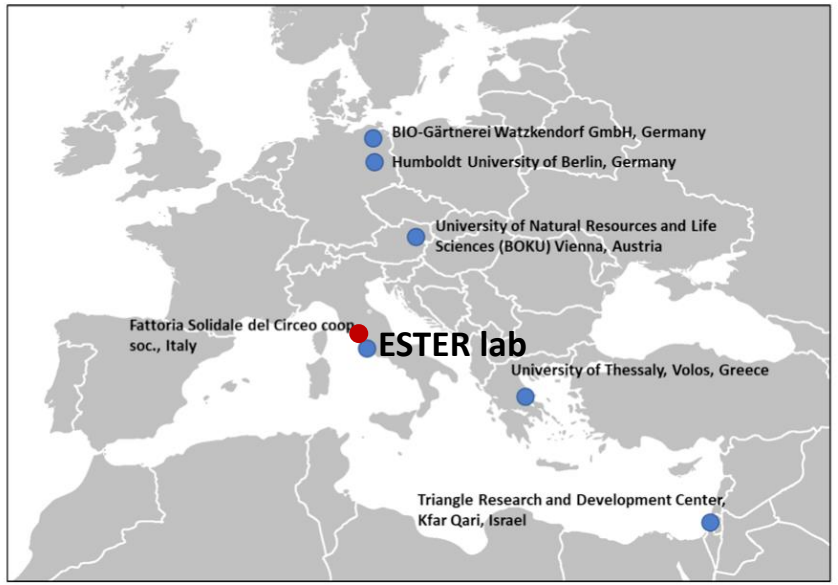
Using Co2 for Green Energy

Working principle



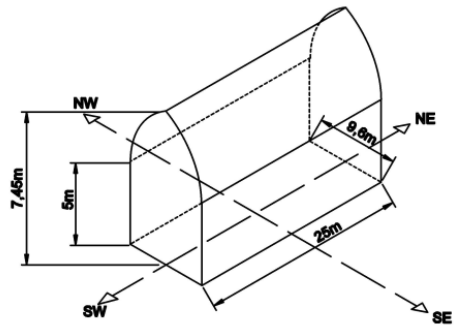
Installations



Regace Project

Partners Greenhouses summary

Volos (Greece)
39°23'40"N; 22°45' 30"E



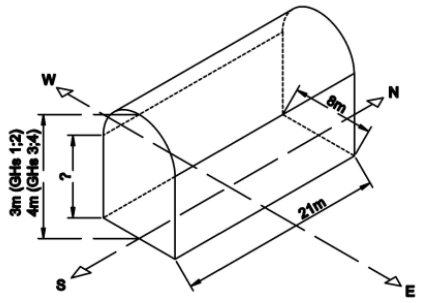
General informations

Number of greenhouses: 6 (Only 3 are part of Regace project)
Type of coltivation: hydroponics (3/3 GHs)
Watering type: ?
Cover material: PC for walls and HDPE for roofs (3/3 GHs)
Crop: Cucumber (3/3 GHs)
Heating system: boiler (3/3 GHs)
Cooling system: evaporative cooling (3/3 GHs)
CO2 enrichment: CO2 tank (3/3 GHs)

Monitoring systems

Microclimate: Yes (3/3GHs)
Solar radiation: Yes (3/3 GHs)
Crop: No
Soil: No
Heating: No
Cooling: No

Kfar Qara (Israel)
32°30'21"N; 35°3'14"E



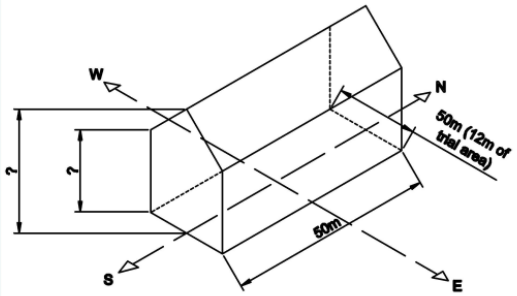
General informations

Number of Greenhouses: 4
Type of coltivation: traditional (4/4 GHs)
Watering type: drip irrigation (4/4 GHs)
Cover material: polyethylene (PE) (4/4 GHs)
Crop: cucumber/bell pepper (4/4 GHs)
Heating system: No
Cooling system: No
CO2 enrichment: biomass (GHs 3;4)

Monitoring systems

Microclimate: Yes (GHs 1;2)
Solar radiation: Yes (GHs 1;3;4)
Crop: No
Soil: No
Heating: No
Cooling: No

Mecklenburg-Vorpommern (Germany)
53°23'33"N; 13°19'11"E



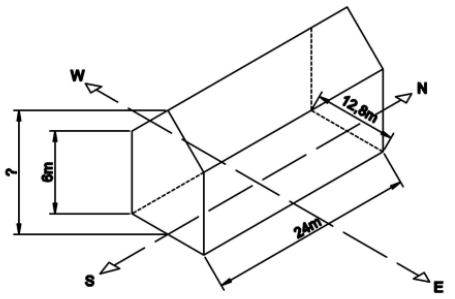
General informations

Number of Greenhouses: 1
Type of coltivation: traditional
Watering type: pipe with micro sprinkler
Cover material: glass
Crop: tomatoes, cucumber, lambs lettuce, radish
Heating system: boiler (biogas)
Cooling system: evaporative cooling
CO2 enrichment: biomass

Monitoring Systems

Microclimate: Yes
Solar radiation: Yes
Crop: No
Soil: No
Heating: No
Cooling: No

Berlin (Germany)
52°31'12"N;13°23'17"E



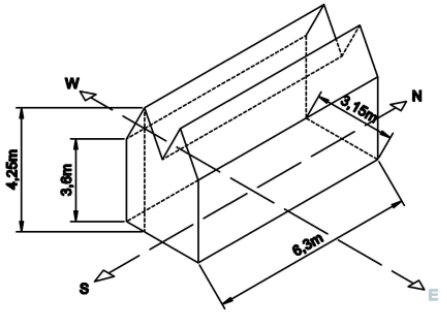
General informations

Number of greenhouses: 1?
Type of coltivation: hydroponics
Watering type: drip irrigation
Cover material: glass
Crop: tomatoes
Heating system: district heating/ heat pump
Cooling system: heat pump
CO2 enrichment: CO2 tank

Monitoring systems

Microclimate: Yes
Solar radiation: Yes
Crop: Yes
Soil: Yes
Heating: No
Cooling: No

Vienna (Austria)
48°12'30"N;16°22'21"E



General informations

Number of greenhouses: 6 (Only 3 are part of Regace project)
Type of coltivation: on tables
Watering type: ?
Cover material: polycarbonate (3/3 GHs)
Crop: to be determined (3/3 GHs)
Heating system: district heating (3/3 GHs)
Cooling system: gable and side ventilation (3/3 GHs)
CO2 enrichment: CO2 tank (GH 3)

Monitoring Systems

Microclimate: Yes (3/3 GHs)
Solar radiation: (3/3 GHs)
Crop: No
Soil: No
Heating: No
Cooling: No

Pontinia (Italy)
41°24'29"N; 13°02'39"E

This greenhouse is still to be installed

General informations

Number of greenhouses:
Type of coltivation:
Watering type:
Cover material:
Crop:
Heating System:
Cooling System:
CO2 enrichment:

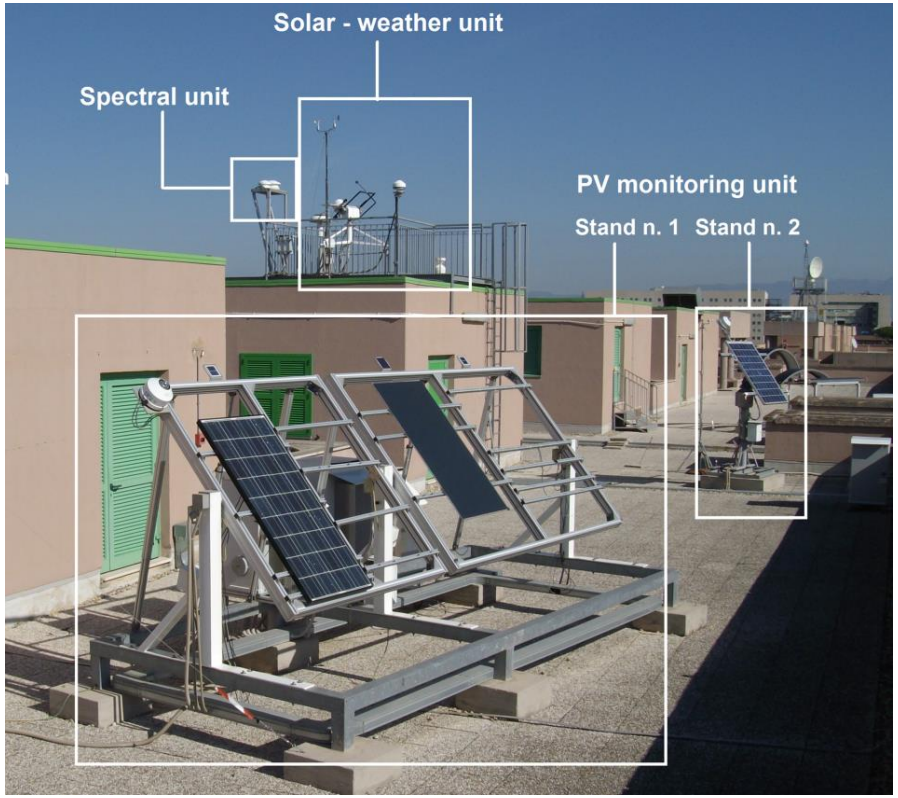
Monitoring Systems

Microclimate:
Solar radiation:
Crop:
Soil:
Heating:
Cooling:

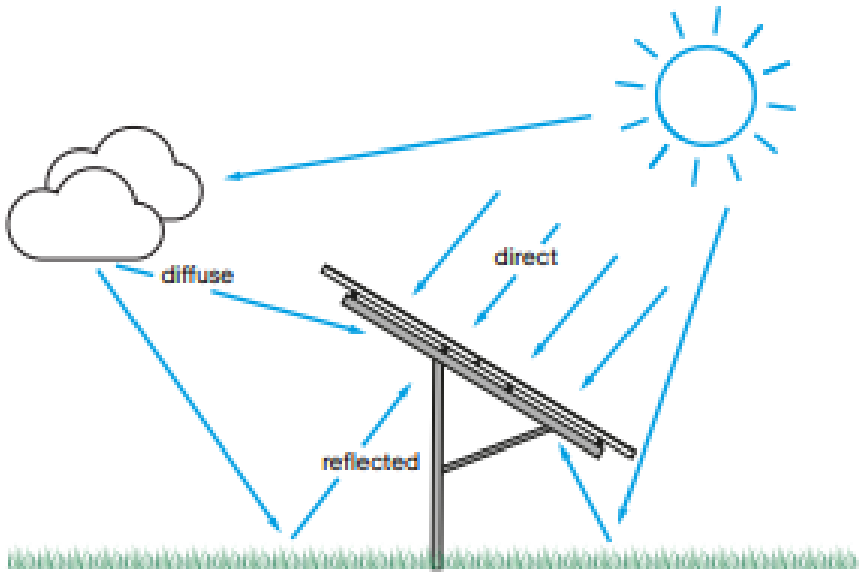
ESTER Lab

ESTER

Energia Solare TEst e Ricerca
Laboratori di fisica Tecnica Ambientale
Università degli Studi di Roma 'Tor Vergata'



Bifacial PV performance



85W-135W

Trisolar Bi-Facial Solar module

Electrical Characteristics(STC)

Module Type: LWMH32-85-G1

Maximum Power:Pmax: **85**

Open Circuit Voltage:Voc: 20V

Short Circuit Current:Isc: 4.25A

Voltage at Maximum Power:Vmp: 23.6V

Current at Maximum Power:Imp: 4.68A

Cell Size:105*105MM

Cell Efficiency: 22.5%

Module Efficiency: 21%

STC Test Conditions :

Irradiance 1000W/㎡,

Cell Temperature 25℃, AM=1.5,

Test Uncertainty: ±3%

12 year Warranty for Material and Processing

30 year Warranty for Linear Power output

85W-135W

Trisolar Bi-Facial Solar module

Electrical Characteristics(STC)

Module Type: LWMH32-105-G1

Maximum Power:Pmax: **105**

Open Circuit Voltage:Voc: 25V

Short Circuit Current:Isc: 4.2A

Voltage at Maximum Power:Vmp: 29.5V

Current at Maximum Power:Imp: 4.62A

Cell Size:105*105MM

Cell Efficiency: 22.5%

Module Efficiency: 21%

STC Test Conditions :

Irradiance 1000W/㎡,

Cell Temperature 25℃, AM=1.5,

Test Uncertainty: ±3%

12 year Warranty for Material and Processing

30 year Warranty for Linear Power output

85W-135W

Trisolar Bi-Facial Solar modul

Electrical Characteristics(STC)

Module Type: LWMH32-135-G1

Maximum Power:Pmax: **135**

Open Circuit Voltage:Voc: 37.17V

Short Circuit Current:Isc: 4.71A

Voltage at Maximum Power:Vmp: 31.5V

Current at Maximum Power:Imp: 4.29A

Cell Size:105*105MM

Cell Efficiency: 22.5%

Module Efficiency: 21%

STC Test Conditions :

Irradiance 1000W/㎡,

Cell Temperature 25℃, AM=1.5,

Test Uncertainty: ±3%

12 year Warranty for Material and Processing

30 year Warranty for Linear Power output

85W-135W

Trisolar Bi-Facial Solar module

Electrical Characteristics(STC)

Module Type: LWMH32-90-G1

Maximum Power:Pmax: **90**

Open Circuit Voltage:Voc: 24.78V

Short Circuit Current:Isc: 4.71A

Voltage at Maximum Power:Vmp: 21V

Current at Maximum Power:Imp: 4.29A

Cell Size:182*60.7MM

Cell Efficiency: 22.5%

Module Efficiency: 21%

STC Test Conditions :

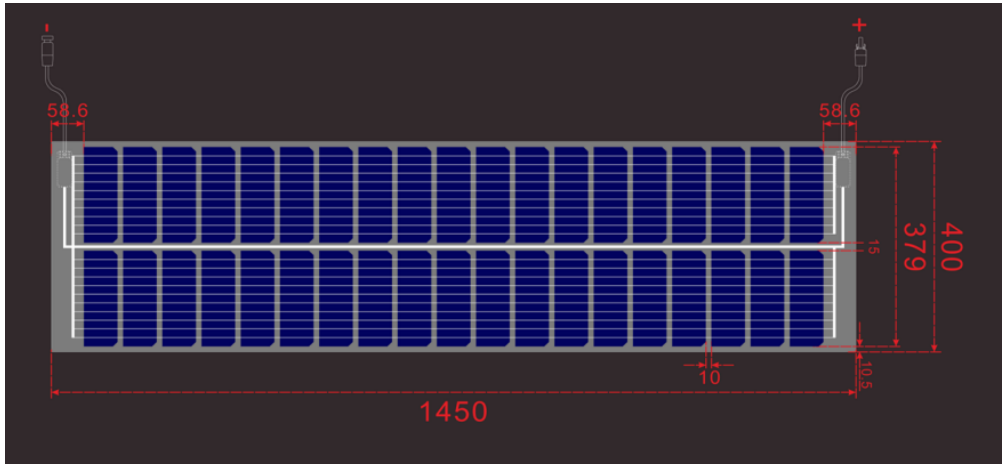
Irradiance 1000W/㎡,

Cell Temperature 25℃, AM=1.5,

Test Uncertainty: ±3%

12 year Warranty for Material and Processing

30 year Warranty for Linear Power output



Bifacial PV performance

BIFACIALITY COEFFICIENTS

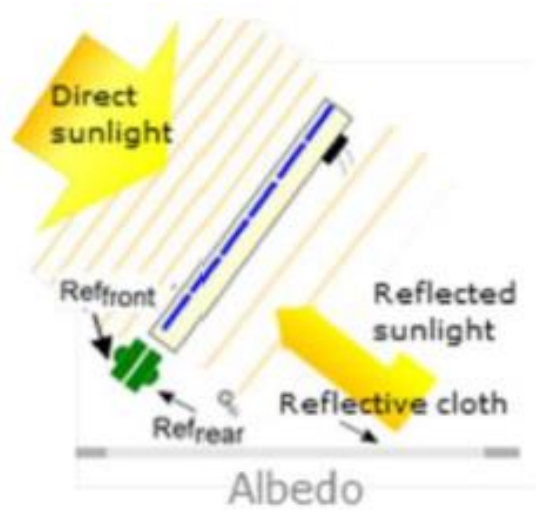
a) $\varphi I_{SC,} = \frac{I_{SC,r}}{I_{SC,f}}$

b) $\varphi V_{OC} = \frac{V_{OC,r}}{V_{OC,f}}$

c) $\varphi P_{max} = \frac{P_{max,r}}{P_{max,f}}$

Task 13 Performance, Operation and Reliability of Photovoltaic Systems – Bifacial PV Modules and Systems Report IEA-PVPS T13-14:2021

BIFI (Rear Irradiance Driven Power Gain Yield)



Bifacial Standard Test Condition (BSTC) [1]

$G_f = 1000\ W/m^2$

$G_r = 135\ W/m^2$

$G_E = 1000 + \varphi * 135\ W/m^2$

Field parameter	Bifacial reference conditions
Albedo	0.21 (light soil)
Height above ground	1 m
Inclination angle	37°
Front side irradiance	1000 W/m^2

Herrmann, Werner., Markus Schweiger, and Johanna Bonilla. "Performance characteristics of bifacial PV modules and power labeling." Presented at the 4th Bifi PV Workshop, Konstanz, Germany (2017).

IEC TS 60904-1-2 Measurement of Current-Voltage characteristics of Bifacial Photovoltaic (PV) Devices

Digital Twins

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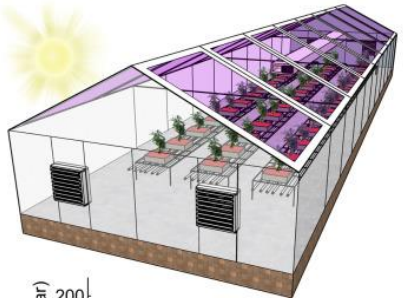
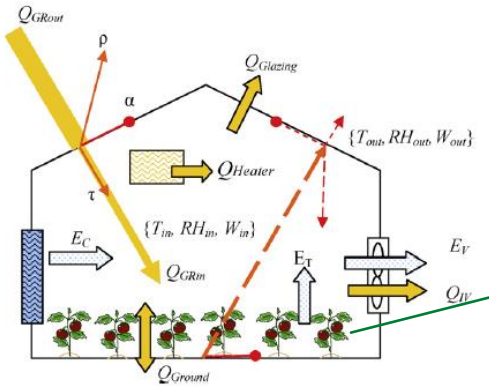
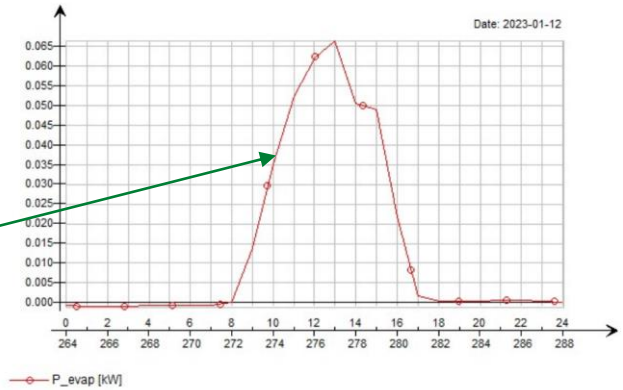
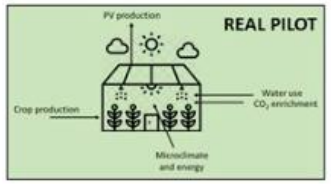
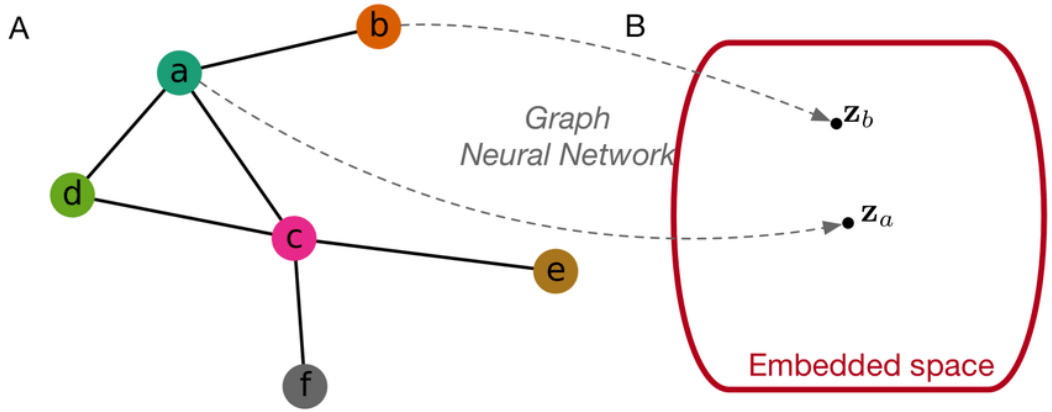


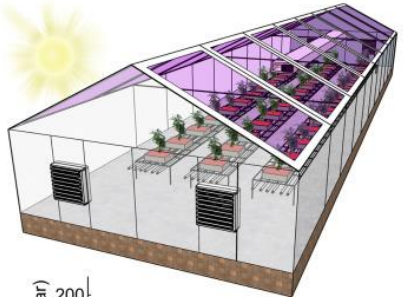


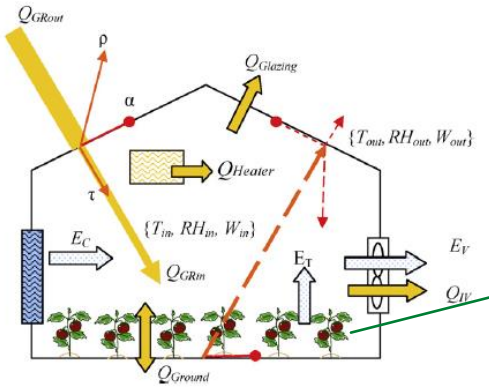


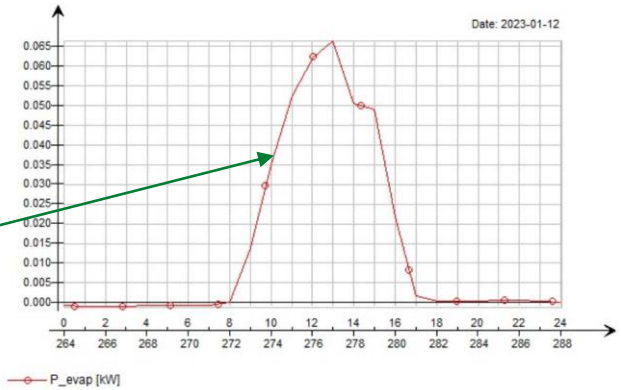


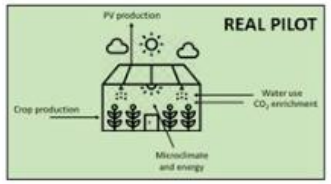


Digital Twins









Crop growth data

PV data

Calibration

Validation

Calibration

Validation

Crop production Model (Aquacrop)

PV production Model (SAPM)

Climate data

REGACE Digital Twin

Water use data

Calibration

Microclimate data

Energy audit

Validation

Microclimate and Energy Model (IDA ICE 4.8/Fluent)

CO_2 enrichment data

A

B

Graph Neural Network

$\mathbf{z}_b$

$\mathbf{z}_a$

Embedded space

Energy efficiency solutions, crop production optimization, PV production, performance at various locations, CO_2 enrichment efficiency

Social impact

Why using **participatory research** in sustaining AgriPV

User-Centered Design

Increased Adoption and Acceptance

Sustainable Solutions

Enhanced Relevance and Appropriateness

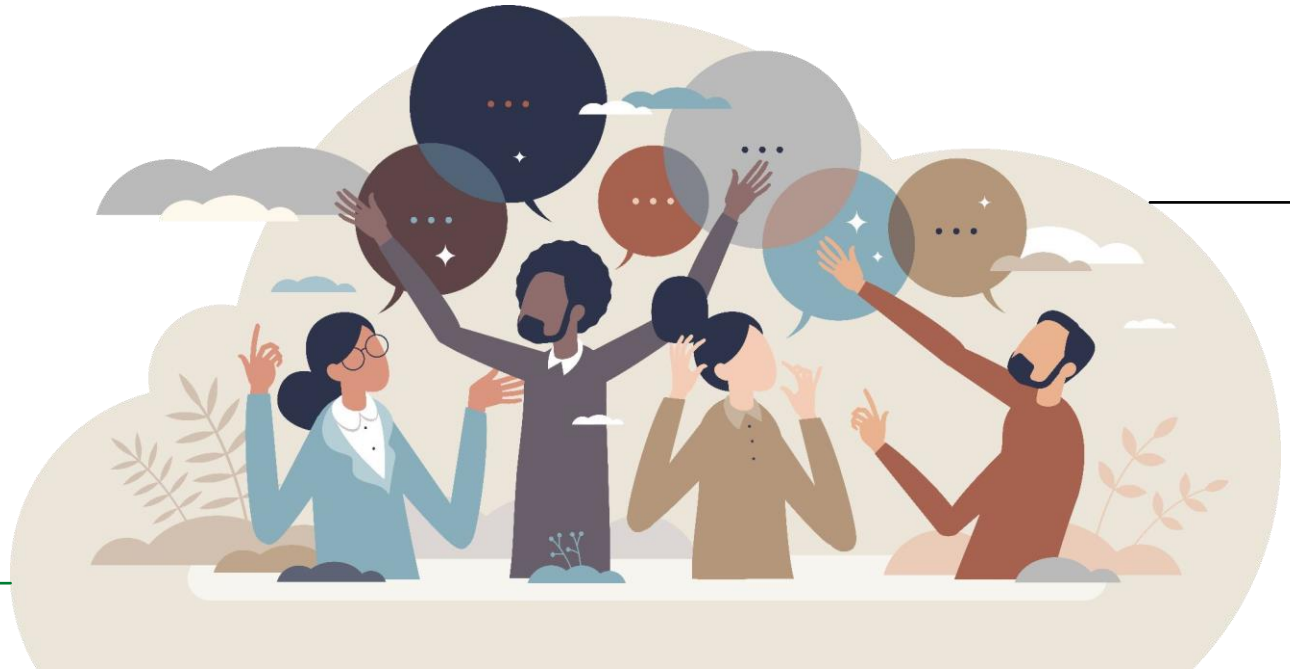
Co-Creation and Collaboration

Social impact

Participatory techniques

In-depth interviews

Sentiment Analysis



Focus groups

World Café

Social impact

The REGACE Spring School

WHERE Farm Research Project Partner, “Circeo Social Farm” (LT)

WHEN MAY 2-5, 2023

FACTS

The school welcomed 8 participants from 5 different countries involved in REGACE Projects. 6 participatory techniques were presented by 5 trainers specializing in social research unity including

- Icebreaking
- In-depth interviews
- Focus groups
- Sentiment Analysis
- World Café

REGACE
Using Co2 for Green Energy

Here comes the Sun on strawberry fields!

Source (Agrisolar, best practice and guidelines, SolarPowerEurope 2023)

Thank you

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ICEM, Padova 27 June 2023

This project has received funding from the European Commission's Horizon Europe Coordination and Support Actions programme under grant agreement No 101096056The European Commission is not responsible for any use that may be made of the information it contains.

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