9th AIEE Energy Symposium - PLENARY SESSION

Renewable energy, clean energy technologies and critical raw materials

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Executive summary

1. Introduction: about RSE
2. Global warming and the role of albedo
3. CO_2 compensation of albedo change
4. High-albedo solutions and applications

Executive summary

1. **Introduction: about RSE**
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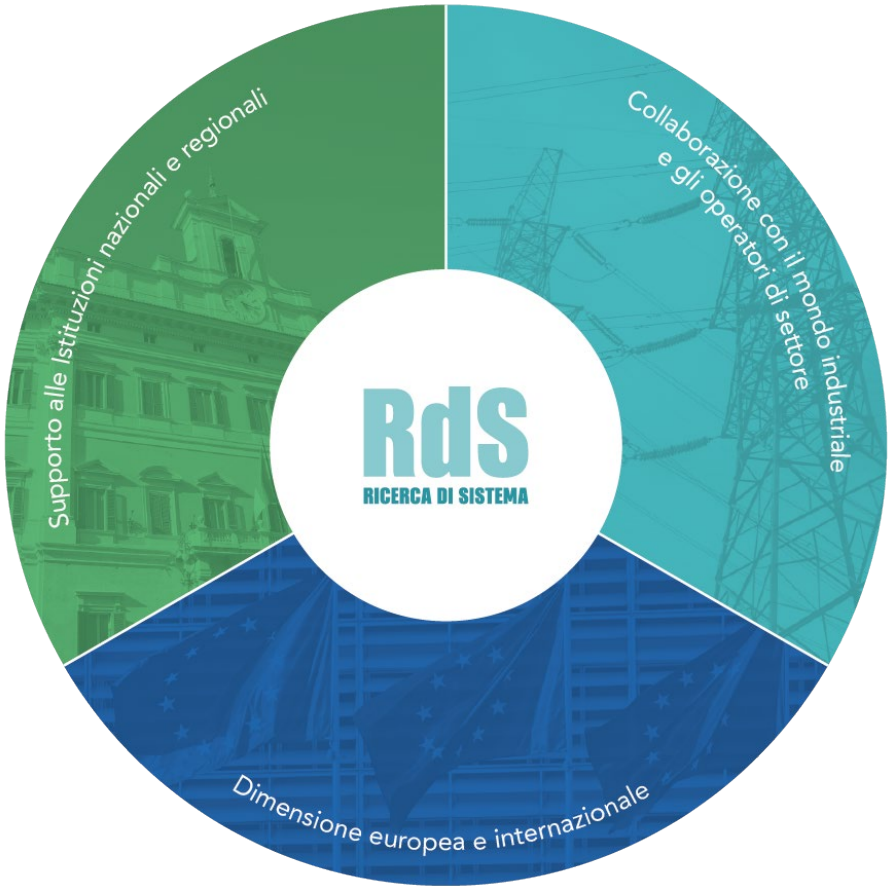
1. Introduction | About RSE

RSE S.p.A. – Research on the **Energy System** is fully owned by the Ministry of Economy and Finance through the corporate group **GSE S.p.A.**
It provides support to the **Ministry of Environment and Energy Security (MASE)** and to the **Regulatory Authority for Energy, Networks and Environment (ARERA)**.

Through the direct **funding** from the **Ministry of the Environment (Ricerca di Sistema - RdS)**, RSE conducts **experimental** and **applied research** across the entire **electric energy supply chain**, with a focus on **strategic national** and **European projects**, central and local public **administrations**, the broader production system, consumer associations, and SME clusters, often in synergy with other research centers.



RSE acts as a **bridge** between **policymakers, business**, and **citizens**.

1. Introduction | About RSE

STAFF

~400

women men

Average age
46 years

Average seniority
17 years

2019–2022 PERIOD

New hires
100+

women men

Average age
35 years

100
European Projects, 20 coordinated by RSE

1000
International partners & collaborations

1. Introduction | About RSE

Support for Energy System Planning

Decarbonisation Working Group - Presidency of the Council of Ministers

2016

SEN 2017

2017

National Energy Strategy

NECP 1.0

2019

National Energy and Climate Plan

EU STRATEGY for long-term EMISSIONS REDUCTION

2020

Long Term Strategy

- ✓ Hydrogen National Strategy
- ✓ Interminist. Committee Ecological Transition
- ✓ Regional Burden sharing Renewable energies

2021-2022

2023

NECP 2.0 (draft)

Minister of Environment and Energy Security

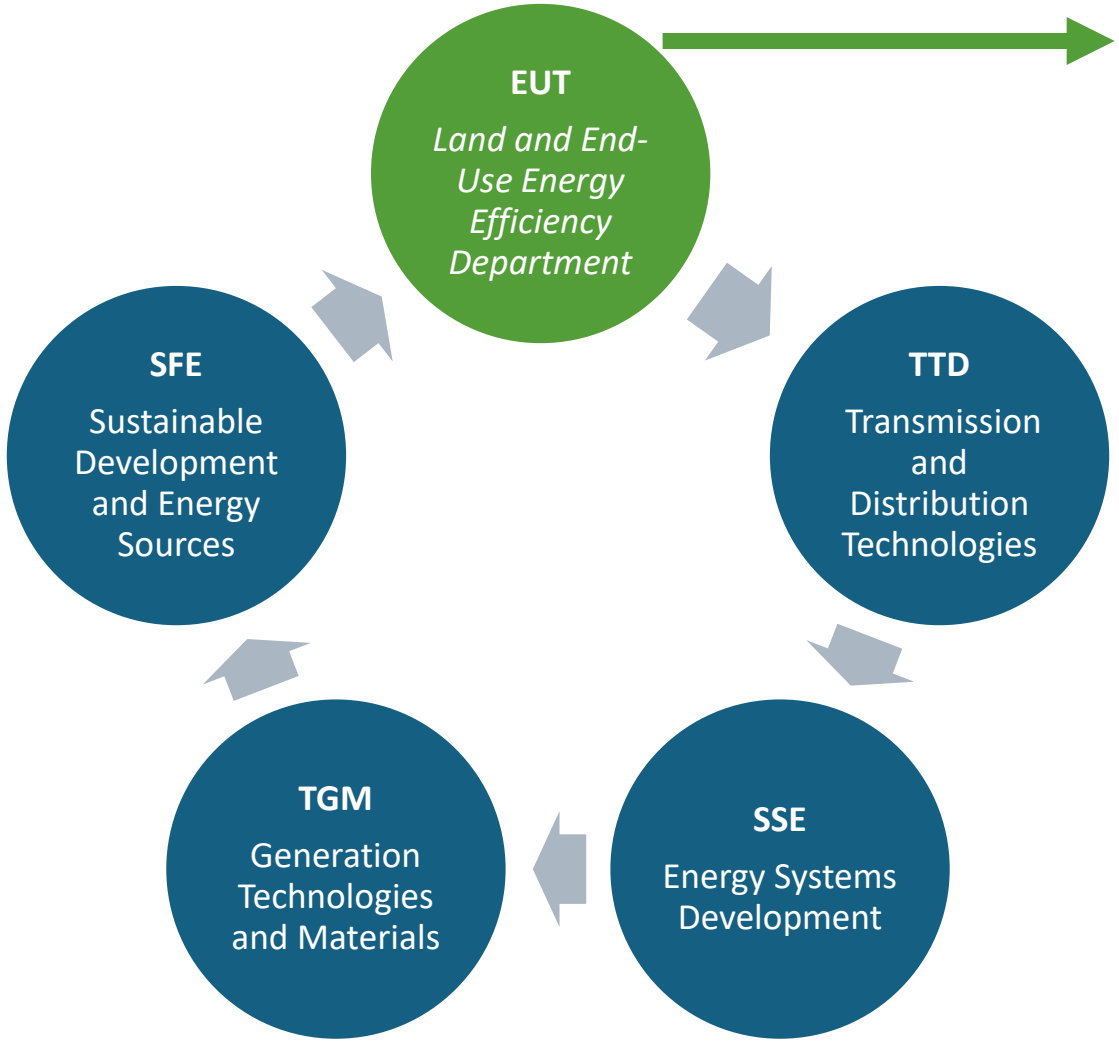
NECP 2.0

2024

Shaping Decarbonization Scenarios 2030 -2040 -2050 With or without NUCLEAR Energy (fissionSMR-fusion)

1. Introduction | About RSE

5 Departments



Develop research on the efficient use of energy and bio-energies, focusing on technologies, experimental analyses and governance within civil, industrial, transportation, agricultural, energy and end-user sector.

5 RESEARCH GROUPS:

- **Efficient Energy Use**

- **User-Centered Approach**

- **Bioenergy and Territory**
- **Monitoring of chemical and physical agents**
- **Digital Complex Models**

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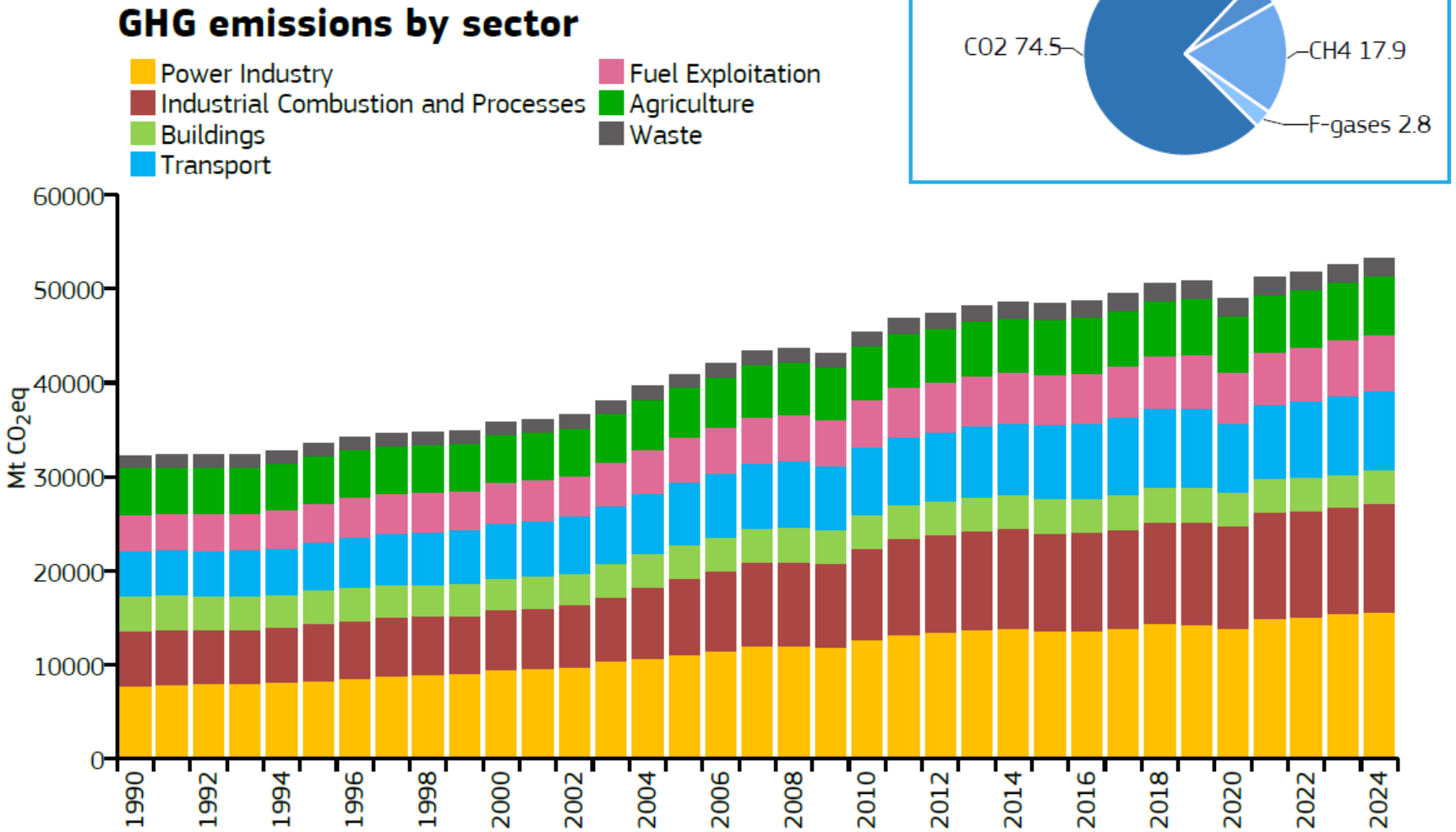
2. Global Warming and the role of albedo

WORLD



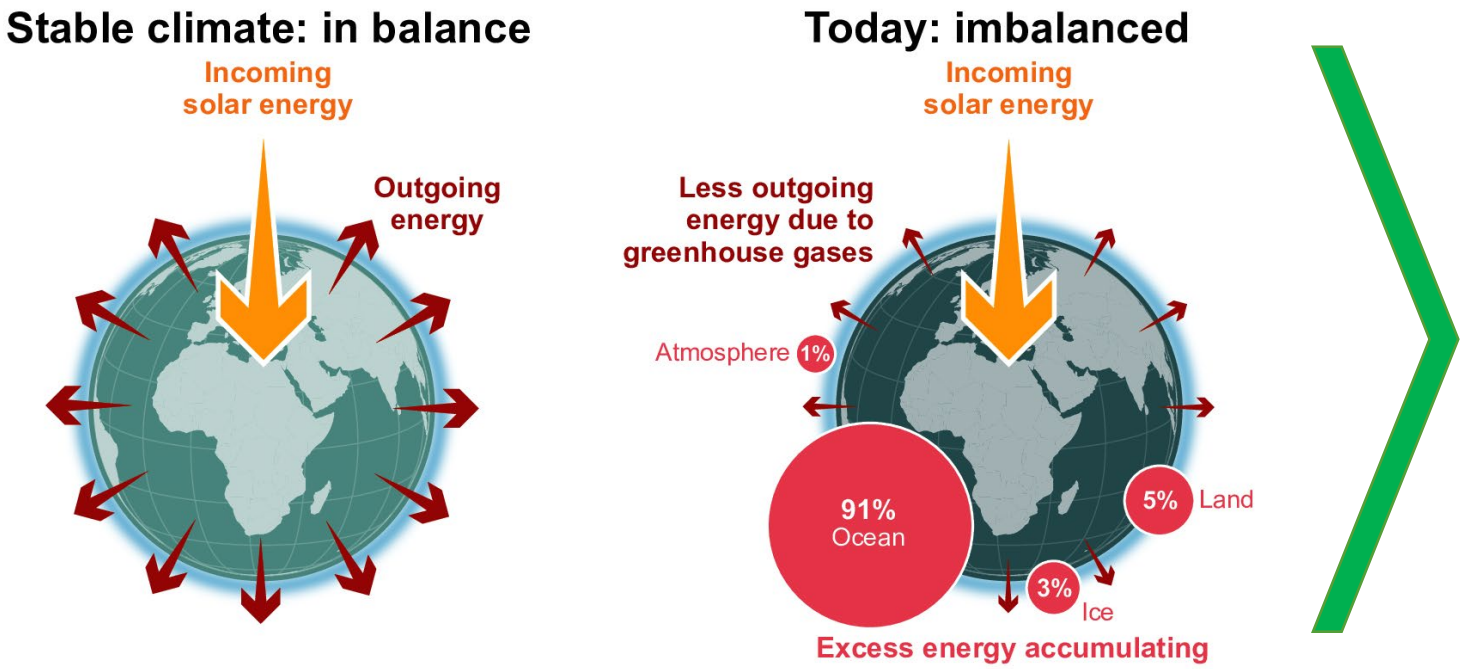
- In 2024, **global GHG emissions** reached **53.2 Gt CO_{2eq}** (+1.3%>2023)
- Compared to 2023, emissions **increased** across **all sectors**
- The **power industry** recorded the **largest rise** (+1.5%), always keeping the role of dominant sector with a share of nearly **30%** in global GHG emissions.

Source:
GHG emissions of all world countries – Joint Research Centre (JRC) Report 2025

2. Global Warming and the role of albedo

The Earth's energy budget and climate change

Since at least the 1970s, there has been a **persistent imbalance** in the **energy flows** due to GHG, which leads to **excess energy being absorbed by the ocean, land, ice and atmosphere, with the ocean absorbing 91%.**



Main drivers:

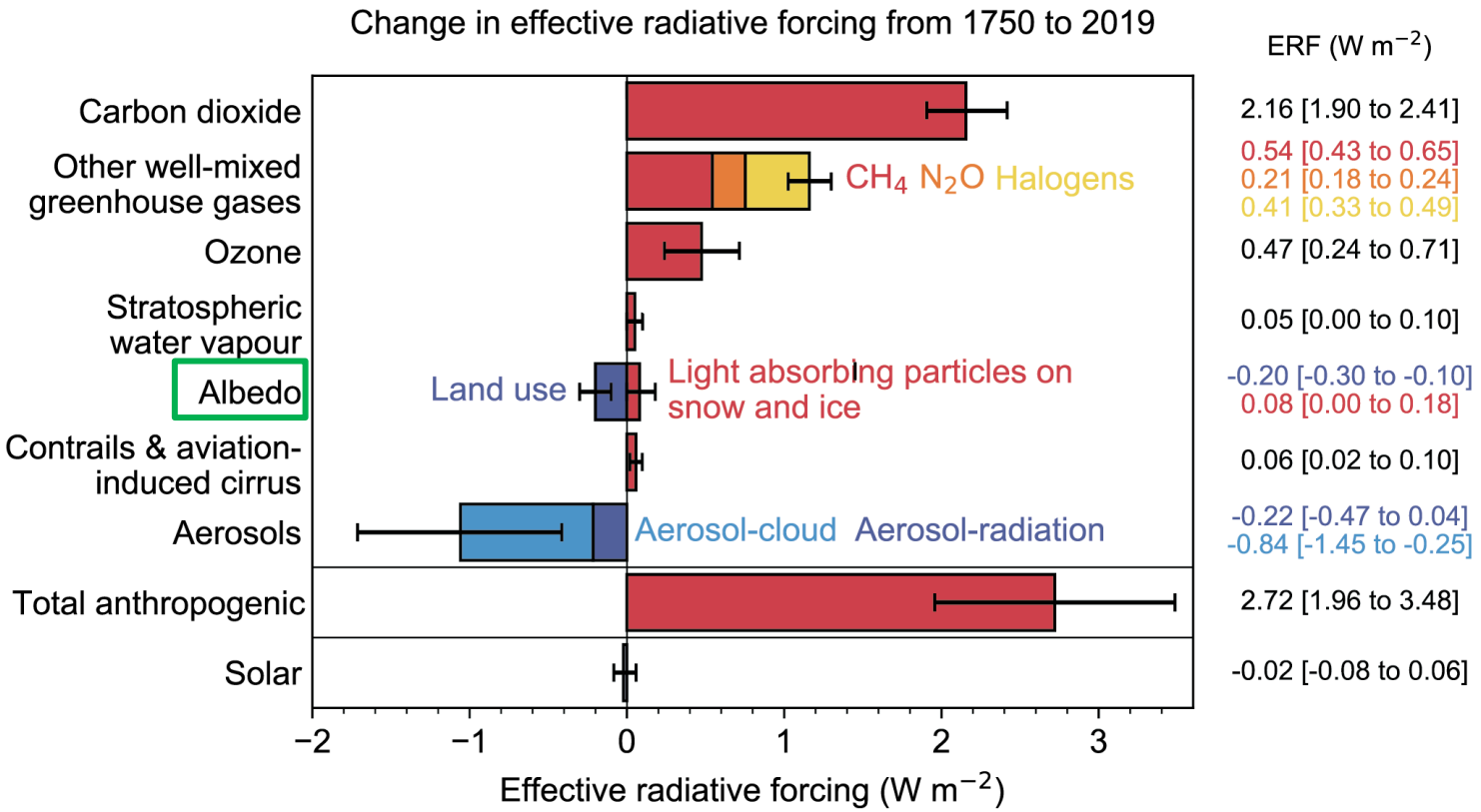
- GHGs (CO_2, N_2O, CH_4, O_3, SF_6, HFCs, PFCs, CFCs and others)
- Aerosols
- Land Use
- Solar radiation
- **Albedo**
  - Mitigation strategy (CO_2 offset)
  - Adaptation strategy (UHI mitigation and indoor comfort improvement)

Source: Intergovernmental Panel on Climate Change, Sixth Assessment Report, Working Group I

2. Global Warming and the role of albedo

The concept of Radiative Forcing (RF)

"RF is the net change in the energy balance of the Earth system due to some imposed perturbation. It is usually expressed in watts per square meter averaged over a particular period of time and quantifies the energy imbalance that occurs when the imposed change takes place."



- Albedo can change the Sun–Atmosphere–Earth energy balance producing a negative radiative forcing
- Albedo change can be related to the effect on global warming due to CO_2;
- CO_2 compensation due to albedo change can be quantified by defining an accurate relation between Δα and ΔRF.

Source: Intergovernmental Panel on Climate Change, Sixth Assessment Report, Working Group I

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3. CO_2 compensation of albedo change

From the concept of Radiative Forcing to the calculation of CO_2 compensation

Main methods for **CO_2 offset** calculation of albedo change (Δα):

- **Emissions Equivalent of Shortwave Forcing (EESF)** [Betts et al., 2000]: simplified method, using instantaneous values of CO_2 emissions, not considering temporal dynamics
- **Time-Dependent Emissions Equivalence (TDEE)** [Bright et al., 2021]: time-dependent metric to take into account the time dependency of CO_2 removal processes
- **Global Warming Potential (GWP)** [Sieber et al., 2019]: adapts the GWP framework used for GHGs to non-CO_2 forcings, such as albedo change. Uses a standard horizon (typically 100 years).

Main penalties:

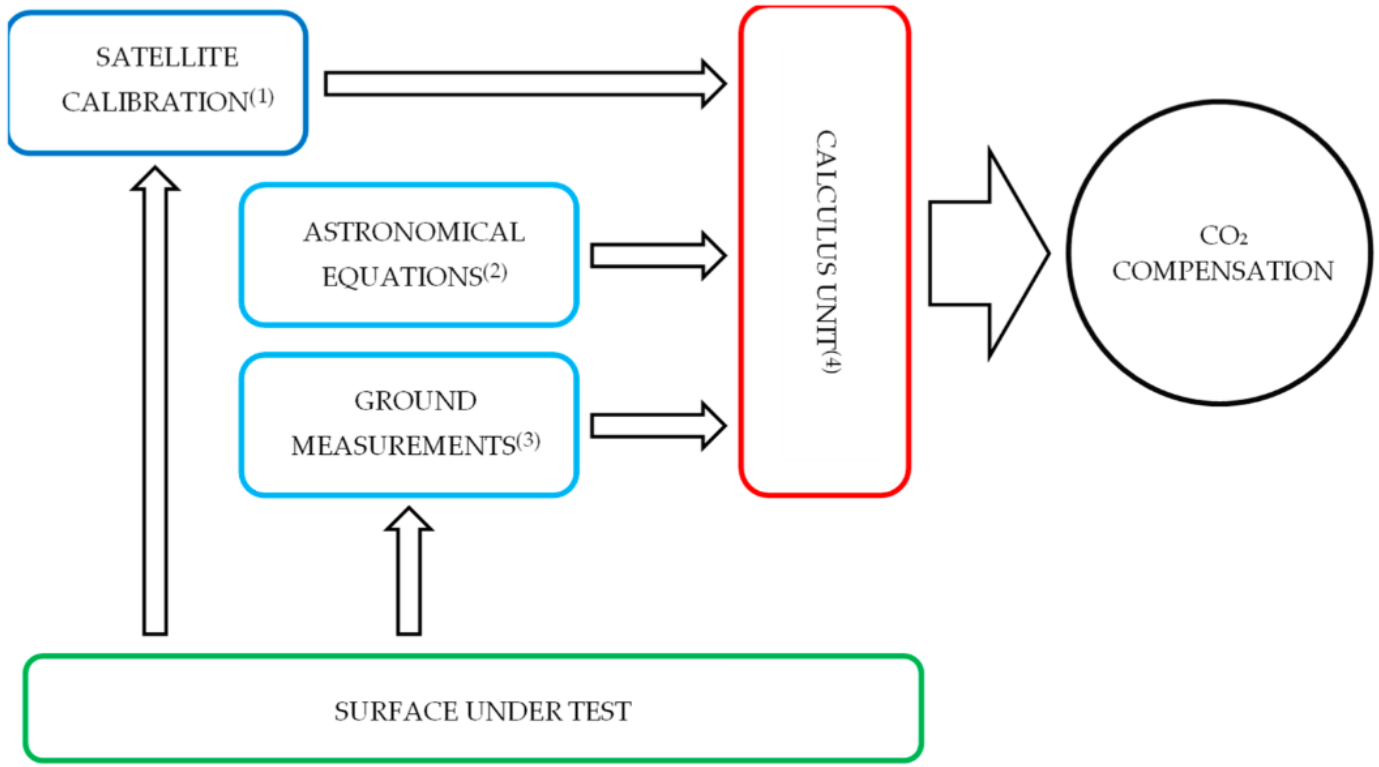
- Δα location (Lat, Long) is not considered;
- Δα time variation is not considered;
- Climatic conditions are not taken into account;
- Time variation of previous parameters is neither considered.

3. CO_2 compensation of albedo change

From the concept of Radiative Forcing to the calculation of CO_2 compensation

The **Radiative Forcing (RF) meter** method [Rossi et al., 2022]

- The **new method** overtakes the literature penalties;
- Continuous **albedo measurements**, **satellite calibration** and **precise evaluation of RF**;
- **CO_2 compensation** assessment by considering the **IPCC definition and approach**.

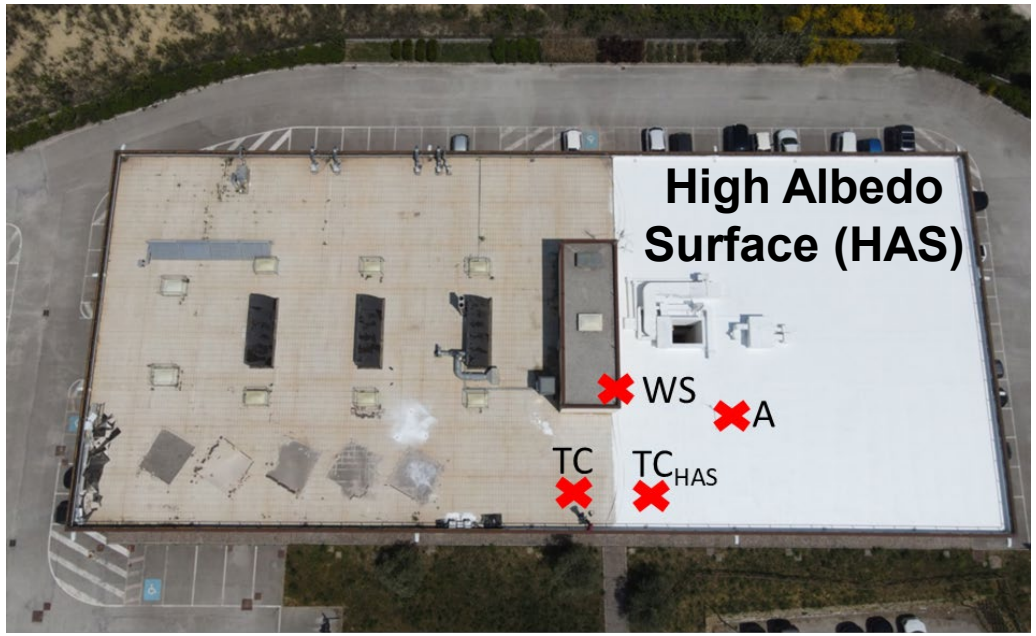


(1) Satellite periodically measures surface albedo and calibrates ground measurements
(2) Astronomical equations precisely define the incoming radiation at the top of atmosphere
(3) Ground measurements are performed by albedometer
(4) Calculus Unit calculates the RF time history and the compensated CO_2

Source: Rossi et al., 2022

3. CO_2 compensation of albedo change

A case study application: CIRIAF building, University of Perugia



BEFORE albedo change

AFTER albedo change

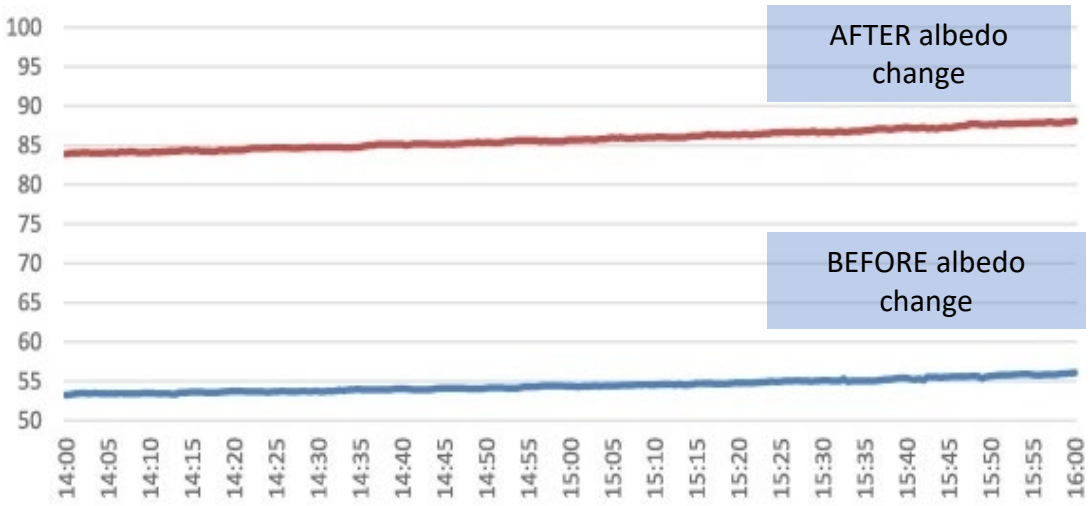
- A =Albedometer
- WS= Weather station
- TC= thermocouple in the roof without treatment
- TC_{HAS}= thermocouple in the High Albedo Surface (HAS)

Source: Rossi et al., 2023

3. CO_2 compensation of albedo change

A case study application: CIRIAF building, University of Perugia

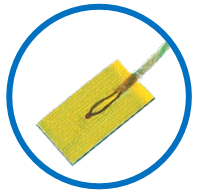
Albedo measurement

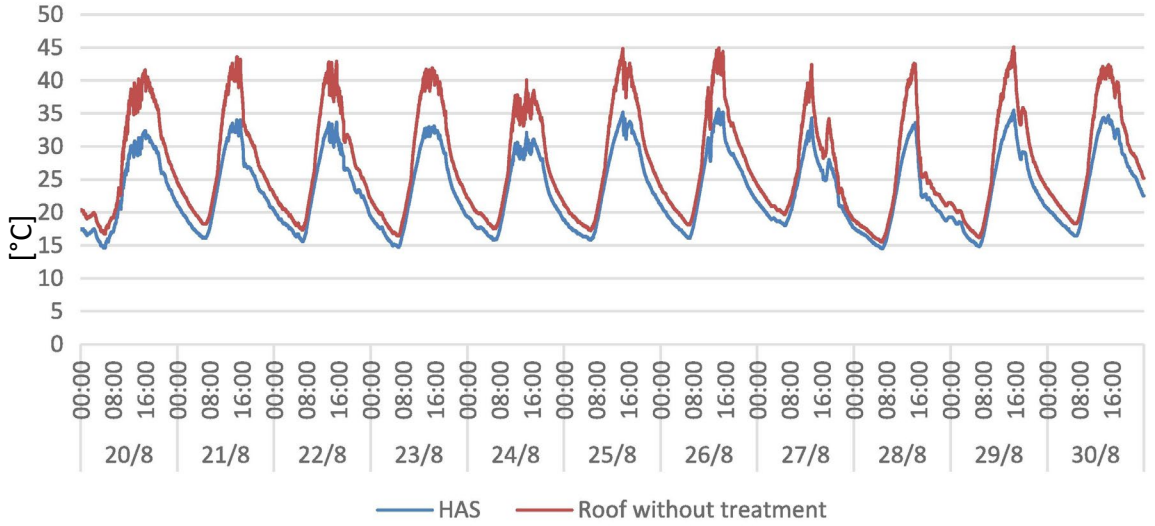


- **Δα** resulted an average equal to **0.3**

Source: Rossi et al., 2023

Superficial temperature analysis



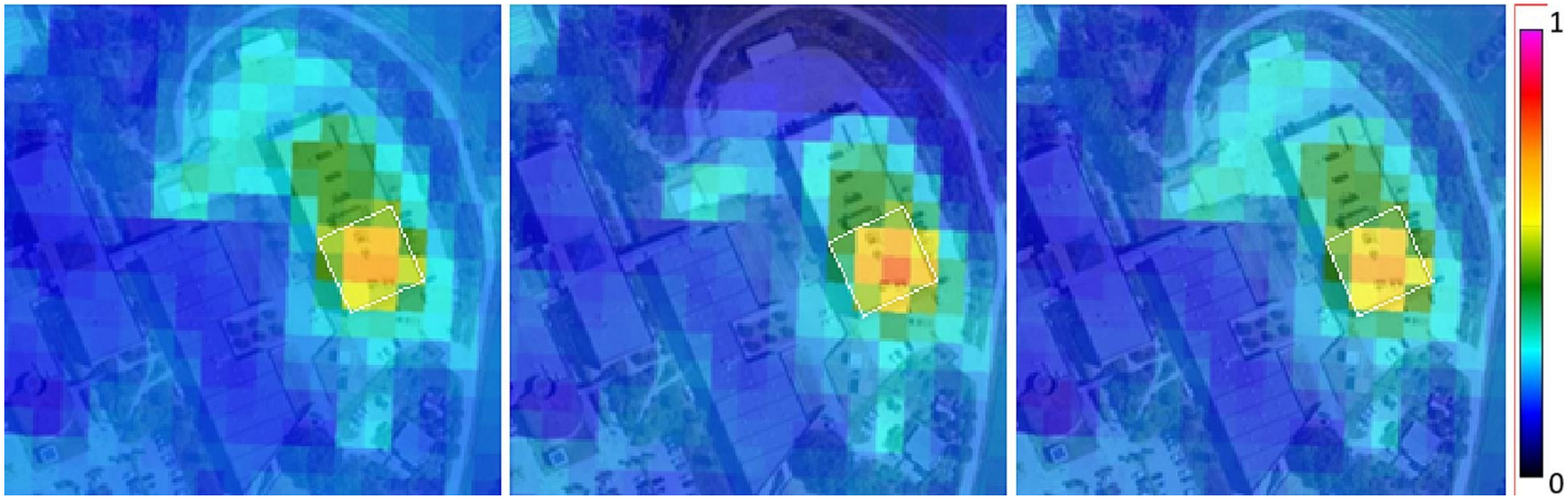


- **HAS** always show **lower superficial temperatures.** The highest ΔT values (up to 9.7°C) are shown during the daily warmest hours

3. CO_2 compensation of albedo change

A case study application: CIRIAF building, University of Perugia

Satellite calibration



The deep blue color corresponds to 0 while the purple color is 1

- Sentinel-2 passed over the HAS at 12 a.m.;
- Pixels over the **High Albedo Surface** correspond to albedo values of **0.80**;
- The roof part **without treatment** shows an albedo equal to **0.50**.

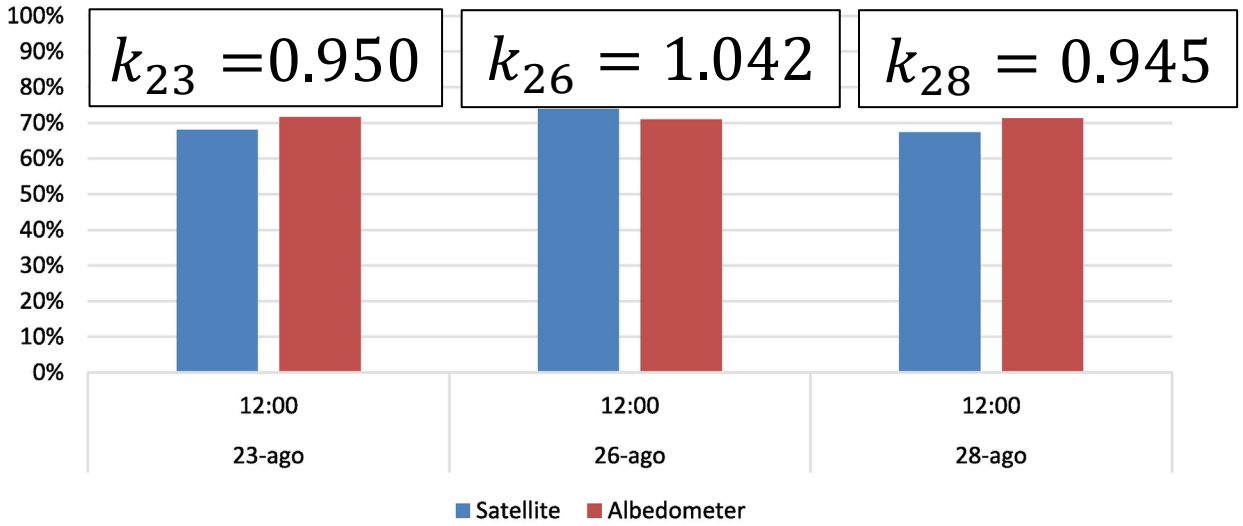
Source: Rossi et al., 2023

3. CO_2 compensation of albedo change

A case study application: CIRIAF building, University of Perugia

Calibration constant k_i is the **ratio between the albedo values from albedometer and satellite**:

$$k_i = \frac{\alpha_{sat,i}}{\alpha_{SUT}(t_i)}$$



Final CO_2 compensation equation:

$$CO_{2,\,comp} = \frac{\sum_{i=1}^{N} \int_{T_i}^{T_{i+1}} S \cdot RF_{\Delta\alpha,i}(t) \cdot dt}{\int_0^T A_E \cdot k_r \cdot y_r(t) \cdot dt}$$

T_i and T_{i+1}: time values at i-th and (i + 1)-th passages of satellite
N are the numbers of satellite passages during T
S is the area of the HAS
$RF_{\Delta\alpha}$ is the albedo-induced radiative forcing change
A_E is the Earth surface
k_r is the radiative efficiency of CO_2
$y_r(t)$ is the time-dependent decay in abundance of CO_2 following an instantaneous release of it at time t = 0.

Results showed **CO_2 compensated by HAS** equal to **73 $kgCO_{2eq}/m^2$** for **$\Delta\alpha$ = 0.3**

Source: Rossi et al., 2023

3. CO_2 compensation of albedo change

Agreement between the Italian Space Agency (ASI) and RSE – July 2024

Earth observation from space will be extremely useful for RSE research not only for **energy planning**, but also for **environmental aspects**, for measuring and monitoring the **Earth's albedo** and controlling solar and infrared radiation, towards **climate change mitigation** through joint initiatives, activities, and programs.

https://www.rse-web.it/news/spazio-mimit-accordo-tra-asi-e-rse-per-applicazioni-ai-fini-energetici/

Executive summary

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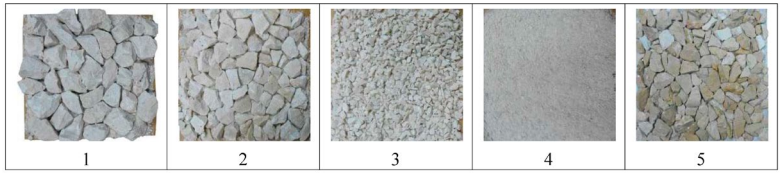
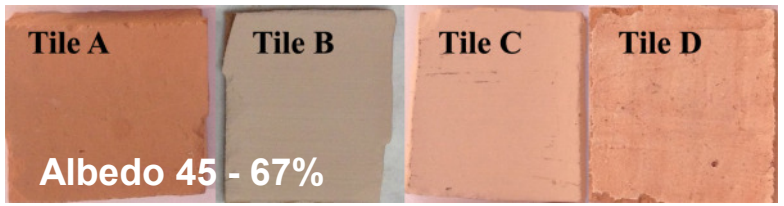
4. **High-albedo solutions and applications**

4. High-albedo solutions and applications

1. Urban environment: High Reflective materials

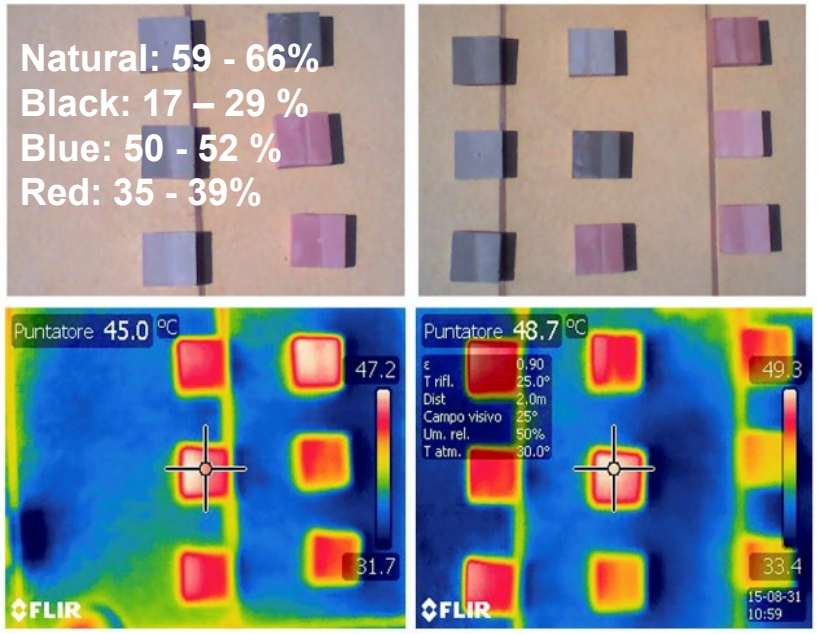


Pisello et al., 2014 – **cool gravel samples**



Pisello et al., 2015 – **cool tile samples**

Pisello et al., 2016 – **cool poliurethane-based membrane**



Rosso et al., 2017 – **cool-colored concrete with infrared reflective pigments**

Cool roof albedo 0.55
Dark roof albedo 0.15

Fabiani et al., 2019 – **thermocromic roof coating**

4. High-albedo solutions and applications

Application:

ABCD project: Albedo, Building green, Control of global warming, Desertification

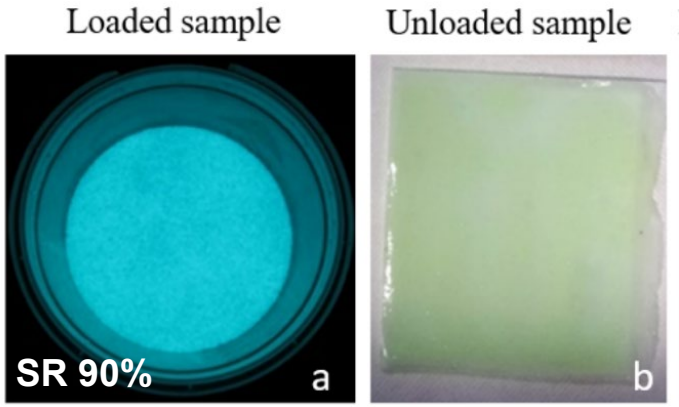
Tunisian factory site –
tCO_{2eq} compensated with **115,000 m^2** of **high-reflective surface** (pavement, roof, facade):

Albedo 70% → 10,455 tCO_{2eq}
Albedo 80% → 12,420 tCO_{2eq}
Albedo 90% → 14,385 tCO_{2eq}
Albedo 100% → 16,345 tCO_{2eq}

4. High-albedo solutions and applications

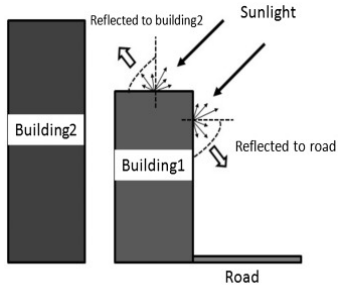
1. Urban environment: Photoluminescent and Retro Reflective materials

- Photoluminescence-induced cooling comes from the capability of **photoluminescent materials** to reject the incident solar radiation by means of a combined **reflection** and **luminescent emission phenomena.**

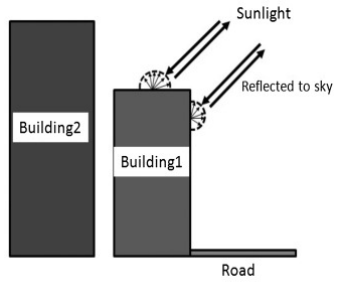


Rosso et al., 2019 – **cool photoluminescent paint**

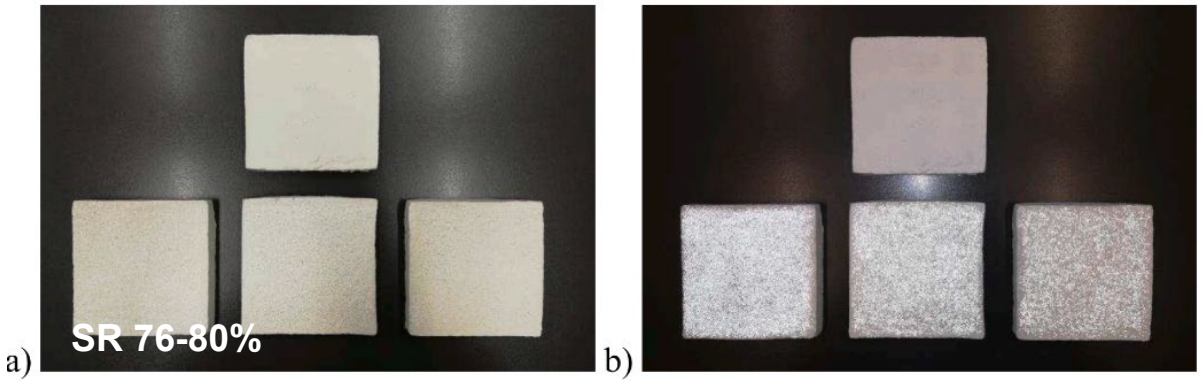
- **Retro Reflective materials** are cool materials that can **reflect light back along** the **incident direction**, to solve the problem of reflected sunlight reaching neighboring buildings and roads of high reflective materials .



a: Building with diffuse reflection



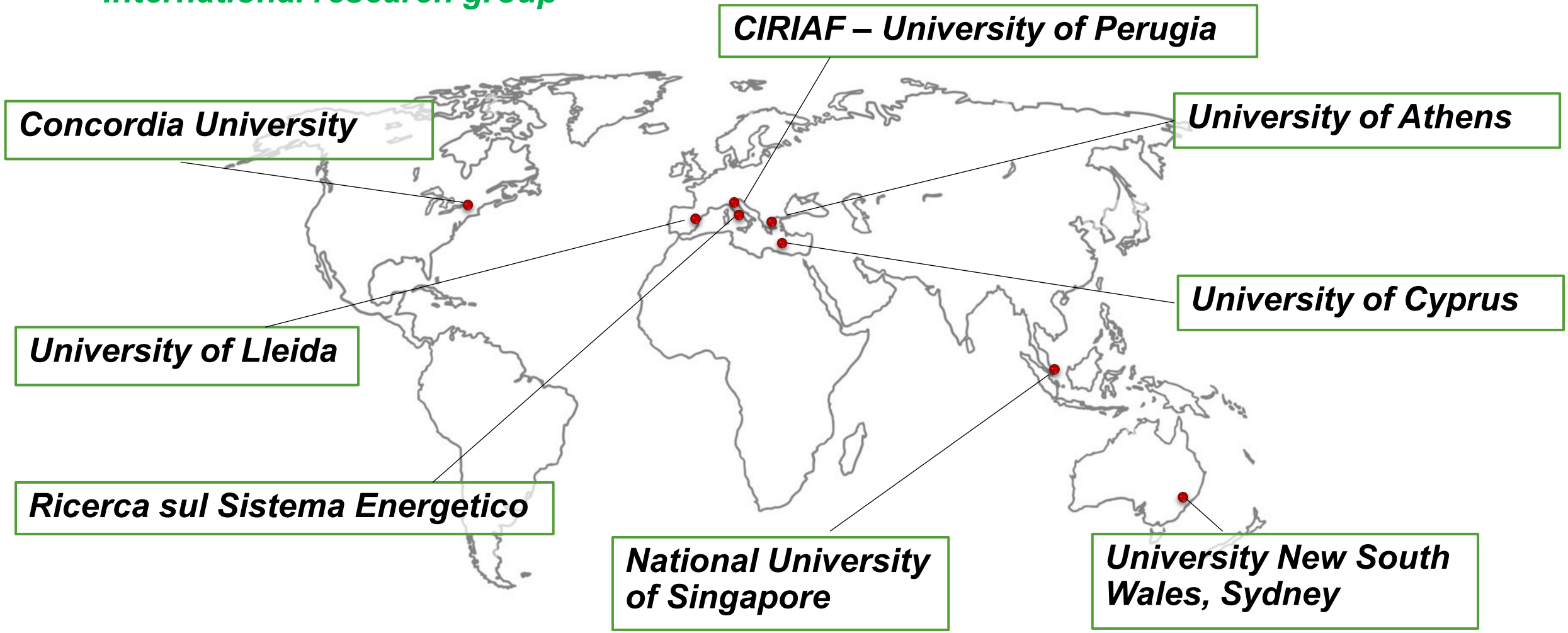
b: Building with retro-reflection



Cardinali et al., 2022 – **retro reflective samples** of exterior building plaster with glass beads (considering different diameters)

4. High-albedo solutions and applications

International research group

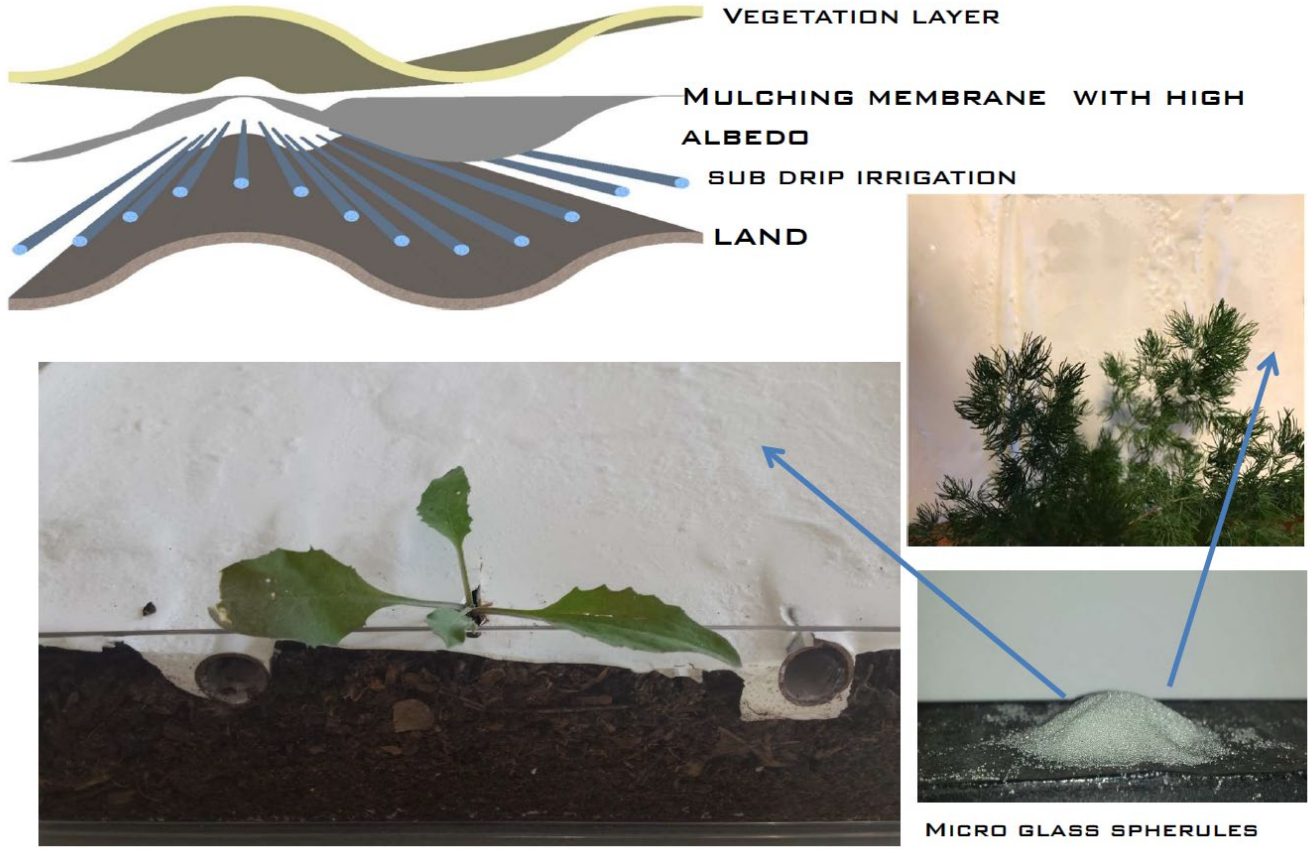


4. High-albedo solutions and applications

2. Agriculture: Albedo mulching

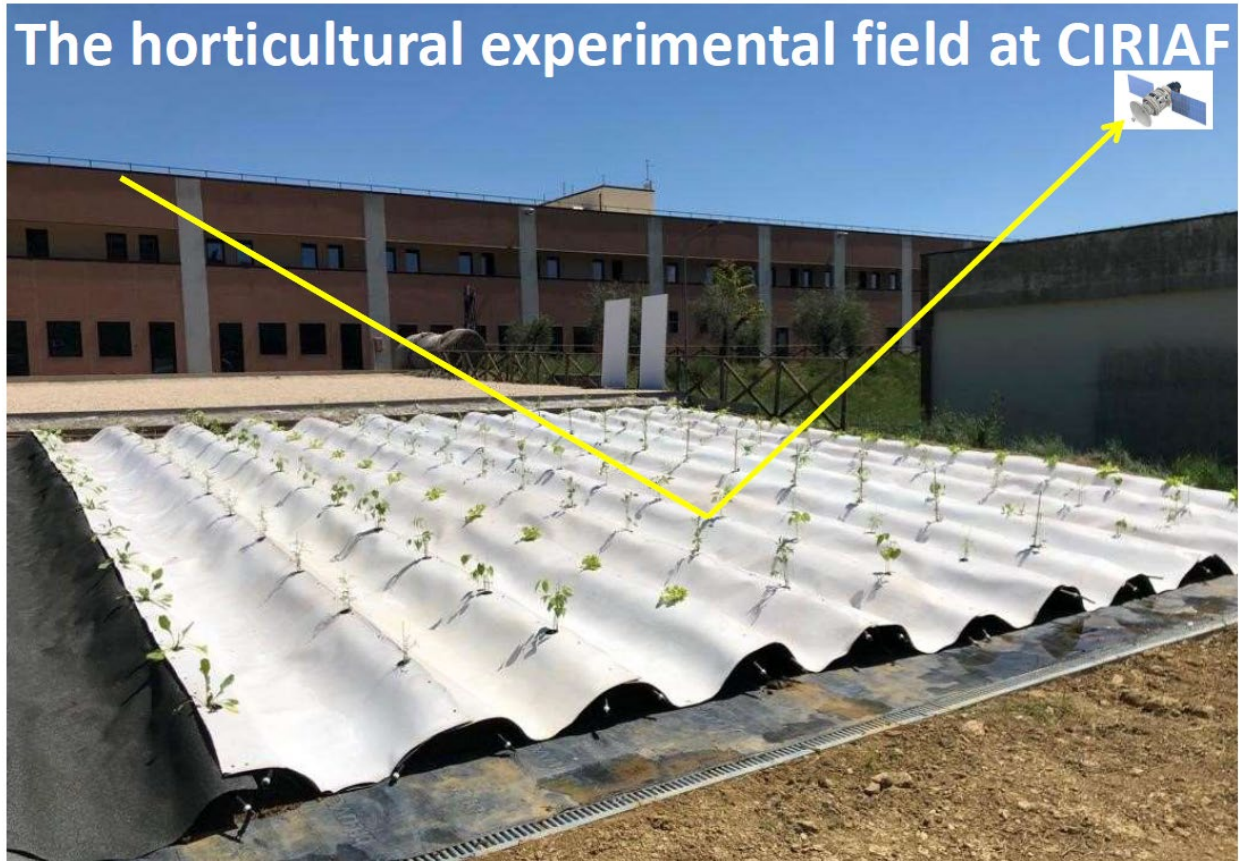
- **Agriculture** is **responsible** for large volumes of **GHG**;
- Agricultural activities are **negatively affected** by **climate change** effects;

- **High-reflective mulching** membrane with a **sub drip irrigation** system can **reduce** the **surface** and **soil temperature** by around 1 and 3 °C, respectively tha can lead to **water storage, reduction of evaporation rates** and **increment of productivity**.



4. High-albedo solutions and applications

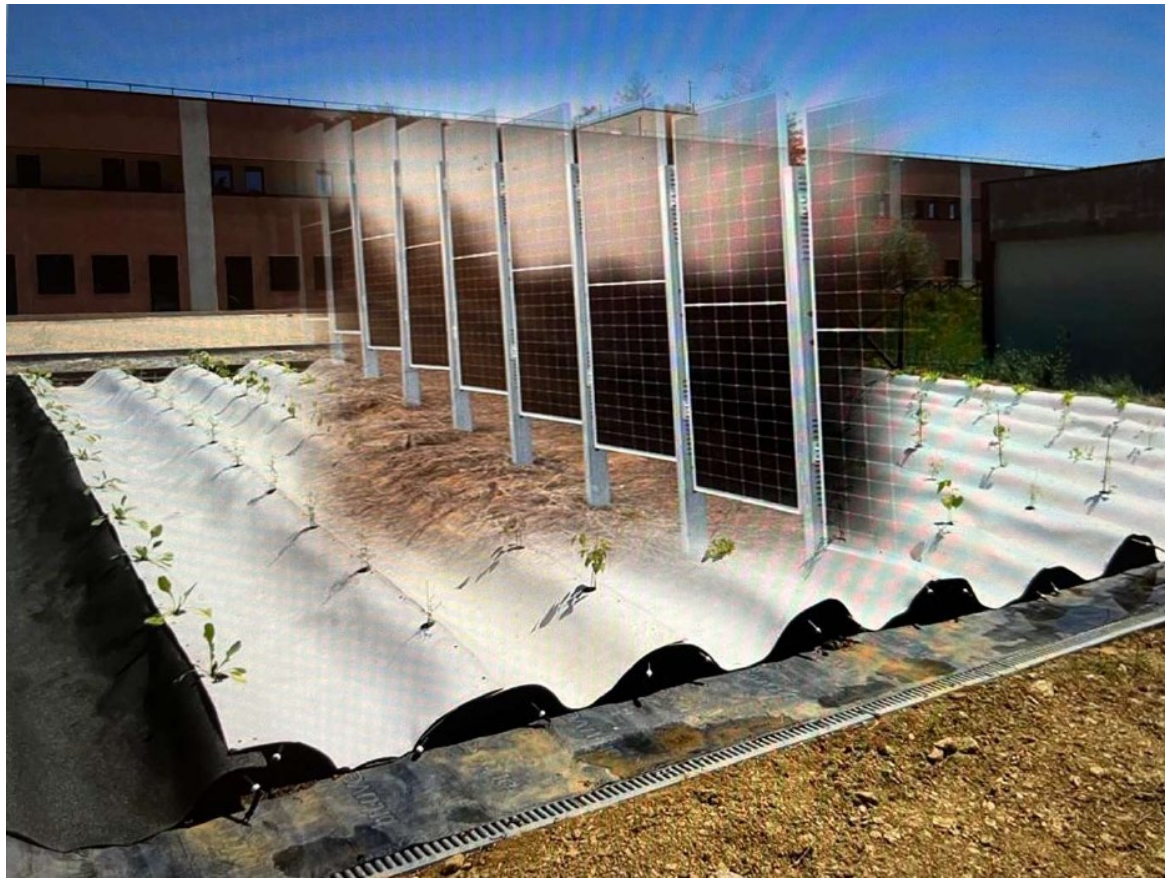
2. Agriculture: Albedo mulching - experimental field at CIRIAF



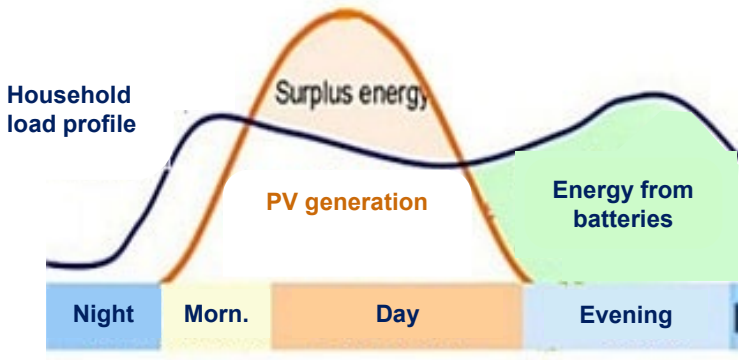
Manni et al., 2020

4. High-albedo solutions and applications

2. Agriculture: Albedo mulching with bifacial photovoltaic



- **Vertical bifacial photovoltaics** are PV panels installed vertically, capturing sunlight on the front and the back.
- They can generate **energy during** the **peaks** in the **morning** and **late afternoon**.
- The **reflective mulch** increases the ground albedo, **bouncing solar radiation** up to the bifacial panels, **boosting** their **energy output.**



4. High-albedo solutions and applications

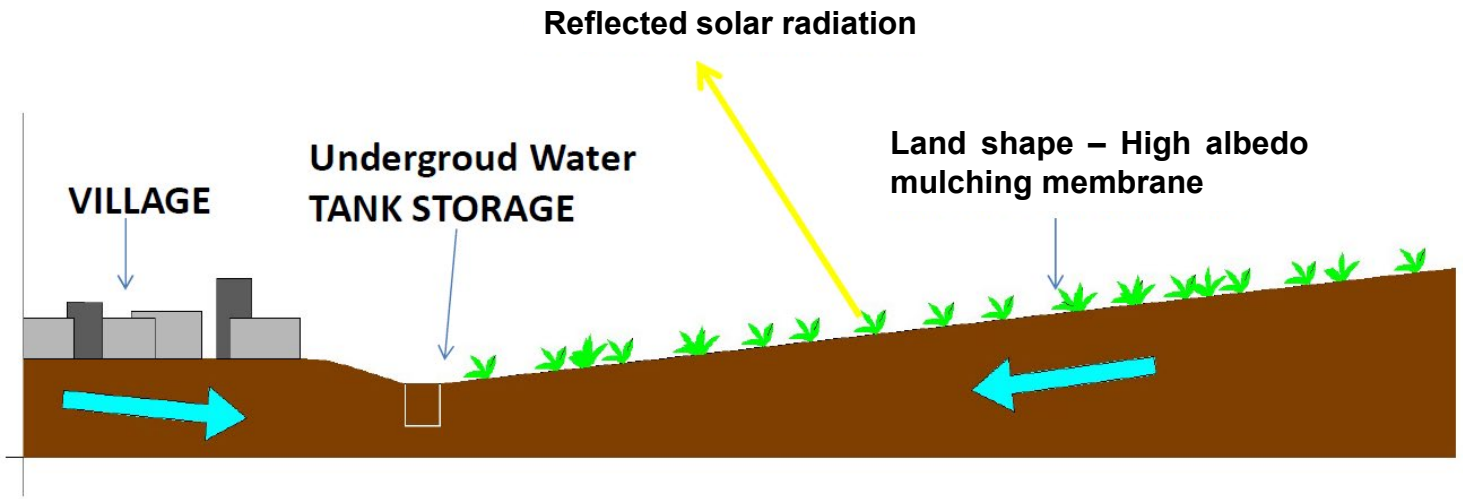
Application:
Albedo for Africa

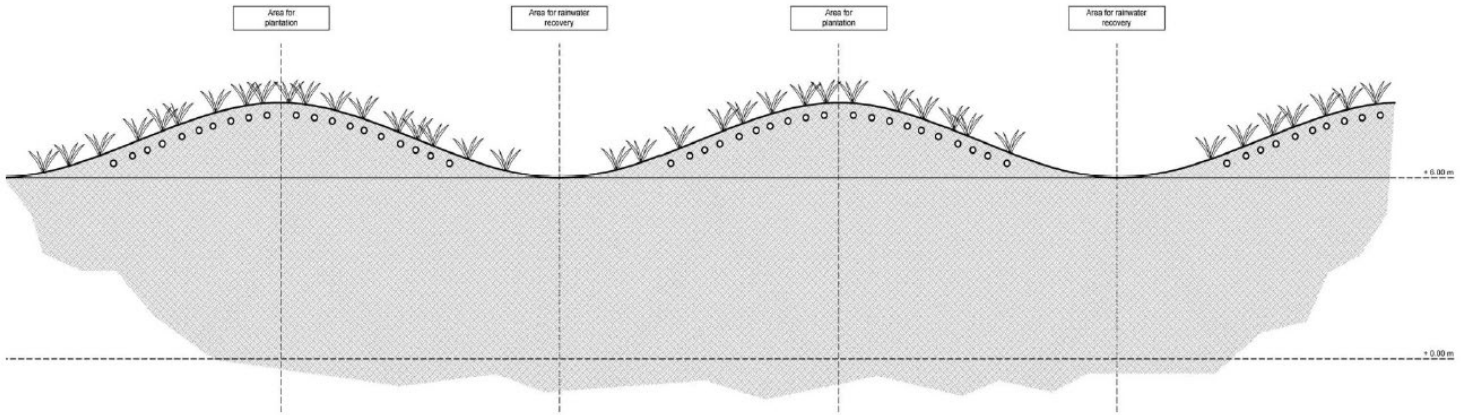
United Nations | Department of Economic and Social Affairs
Sustainable Development

- The **Albedo for Africa** project of CRB - CIRIAF Perugia University is a **Program of United Nations** https://sdgs.un.org/partnerships/albedo-africa-0
- Implementation of **high albedo solutions** and **water-saving techniques** in **agriculture** for **African farmers and communities**.
- By **reducing water loss** and **increasing crop yields**, high albedo solutions can help to **increase food security** and **reduce** the **impact of climate change on agriculture**.

4. High-albedo solutions and applications

Albedo for Africa





- For **Mediterranean latitudes:**

1 tCO_2 can be compensated by **15-20 m^2** of **high reflective surface**

- For **Sahel area latitudes:**

1 tCO_2 can be compensated by **5-6 m^2** of **high reflective surface**

Contatti

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