Cost effective Renewable Energy Sources innovations to Agriculture with emphasis on Solar Energy

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Introduction

- **Renewable Energy Sources (RES) technologies:** environmental friendly → should be promoted to combat the challenges posed by climate change

- **Solar Energy (SE):** presents a potential source of growth

- **Rural and remote areas:** usually not available grid connected electricity → RES (including SE) can provide environmental, social and economic benefits

- **Present work:** Cost effective, RES innovations to agriculture with emphasis on SE

  - Individual applications: Solar drying, desalination etc
  - Applications per sector: Greenhouses, farm buildings etc
  - Energy policy aspects regarding remote, rural areas

Solar Drying

- **Many countries: produce agricultural products**
  – Local consumption and export

- **Drying: important post-harvest operation**
  – Reduction of moisture content
  – Minimizes quality deterioration during storage

❑ **Drying by using SE:**

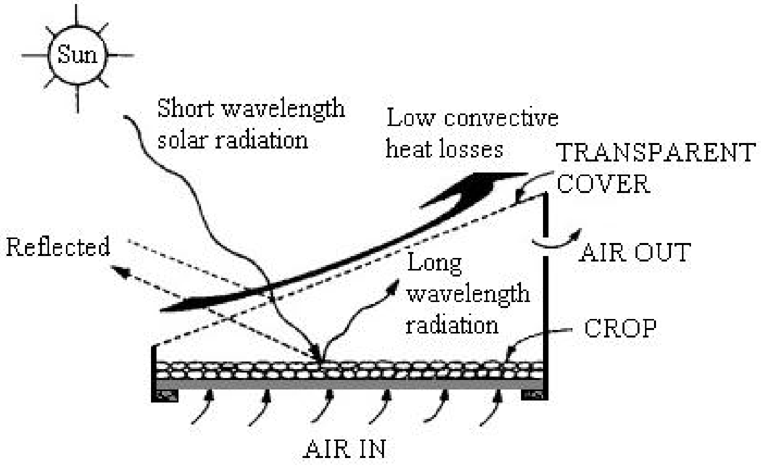
❑ Traditional open sun drying
  - spoilt due to rain, dust, insect / fungal attacks etc

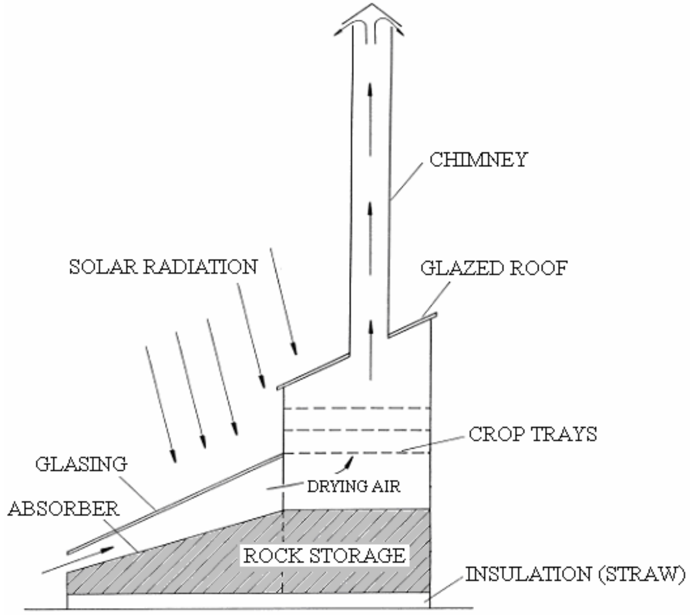
❑ Solar drying → Solar dryers
  - high quality products, attractive commercial

Peaches sun drying
(Source: Belessiotis and Delyannis, 2010)

❑ **Solar dryers:**
  – Passive and active
  – Low cost – simple devices and more advanced technologies

Simple, passive Solar Dryers





A direct, passive, solar cabinet dryer

(Source: Sharma et al., 2009)

- transparent box (glass or plastic)
- air-holes allow air to enter and exit the box
- product directly exposed to sun rays
- **suitable for drying small quantities of fruits and vegetables**

A mixed-mode (direct and indirect) passive, solar dryer with chimney and thermal energy storage

(Source: Ayensu and Asiedu-Bondzie, 1986)

- **simple flat plate air collector connected to the drying chamber**
- chimney helps natural air circulation

→ the efficiency of the system is improved

- includes thermal energy storage

Active Solar Dryers - Advanced technologies

Active solar dryers: use forced convection → include fans for moving the air, more efficient than passive → suitable for drying large quantities of products

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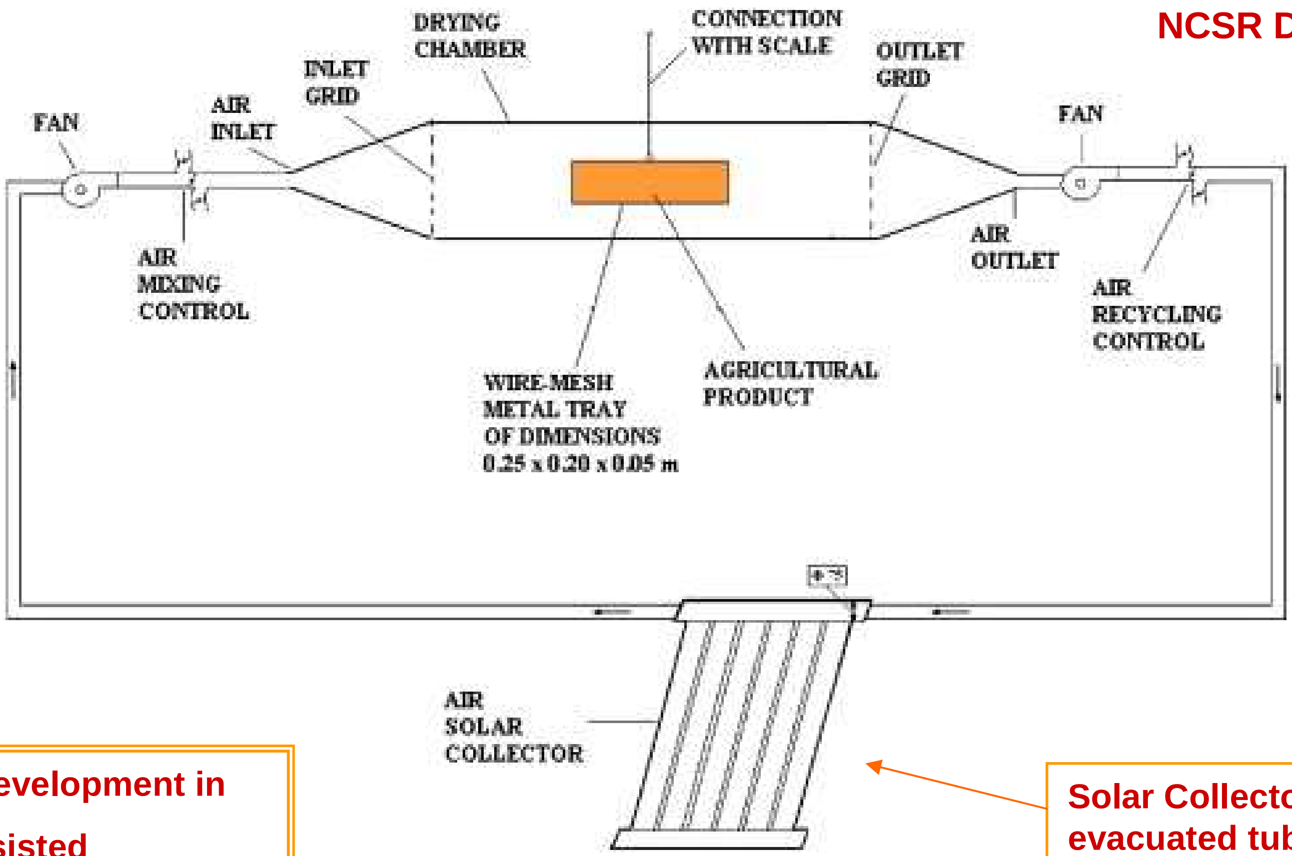


Recent development in Solar-Assisted Mechanical drying

(Source: Lamnatou et al., 2010)

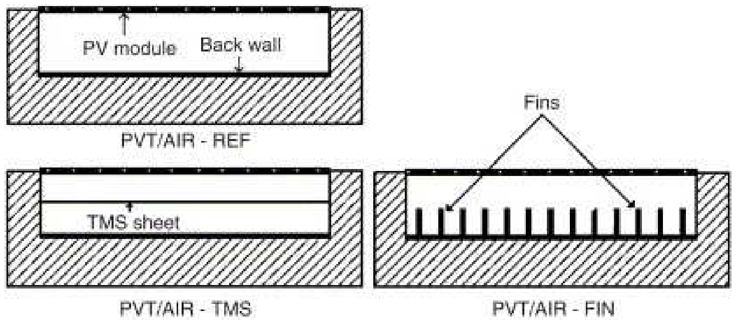
Solar Collector with evacuated tubes

Active Solar Dryers - Advanced technologies

Hybrid Photovoltaic/Thermal (PV/T) systems:

- **can also be applied in the frame of developing an innovative solar dryer**
- **PV/T: PV combined with a heat extraction thermal unit:**
  - PV cooling → increase of the electrical efficiency
  - provides electricity and heat (for low temperature applications)
- **University of Patras: simple, cheap heat extraction improvement modifications**
  - thin (flat) metallic sheet in the middle of the channel (TMS)
  - rectangular fins at the back wall of the channel (FIN)

Source: Tonui and Tripanagnostopoulos, 2007



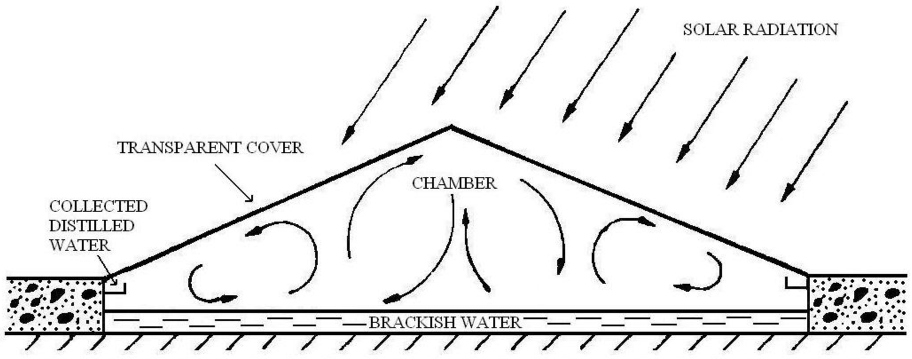
Solar Desalination

A simple, passive Solar Still

- ***Advantage:*** can easily be constructed from simple, local materials

- ***Disadvantage:*** low efficiency, summer ≈ 7 kg/m^2 day →

  leads to high fresh water cost (10.41 to 12.46 €/m^3) (Lamnatou et al., 2005)



More advanced technologies

-***Active Solar Still:*** PV/T → heat (preheating of basin water),

electricity (runs the pump); autumn efficiency ≈ 5.5 kg/m^2 day (Kumar and Tiwari, 2008)

-***Hybrid PV-Wind RO:*** 13.2 kW_p → production 12 m^3/day (summer), 6 m^3/day (winter), covers the needs of a 60 inhabitants village, promising cost: 5.21 €/m^3 (hybrid operation) (Mohamed and Papadakis, 2004)

Solar Cooking – Heating / Pasteurizing water

Hybrid food processor:

- Cooking, heating/pasteurizing water, distillation of small quantity of water, drying
- The device uses solar and electric energy if required and consists of:
    - Inclined stainless steel box, insulation, absorbing surface, reflector

- ***Solar cookers benefits:***
    - Environmental friendly, smoke free (don't irritate eyes and lugs)
    - Moderate cooking temperature → preserve nutrients
    - Reduce risks associated with the fact that millions of women routinely walk for miles to collect woods for cooking

Source: Nandwani, 2007

Cooking

Water Pasteurization

Drying

Other Solar Energy Applications

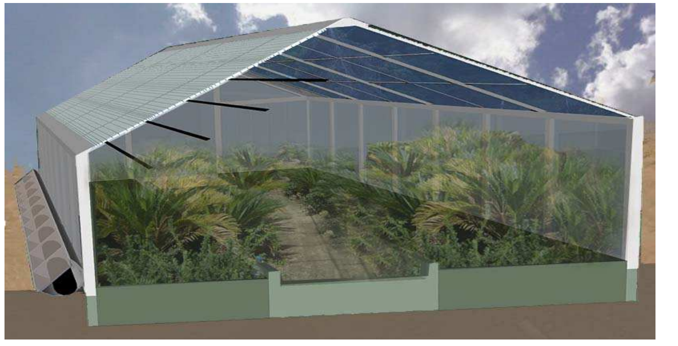
- **Solar Photocatalytic Detoxification (SPD):**
- **Sunlight** → deactivation of toxic liquid wastes
  - suitable for climatic conditions of Greece
- Best utilization of sunlight → ***Combination of transparent tubes with reflectors*** (Poulios and Tripanagnostopoulos, 2007)

- **Solar water pumping:**
- PV pumps → ***domestic and livestock drinking water, irrigation***
  - negligible operation-maintenance costs (Omer, 2001)

- **Solar distillation:**
- Essential oils (aromatic plants) → used in foods,cosmetics,medicines etc
- On-farm solar distillation unit afforded by:
  - ***Farmers***
  - ***Small scale companies*** (Munir and Hensel, 2010)

RES applications in Greenhouses

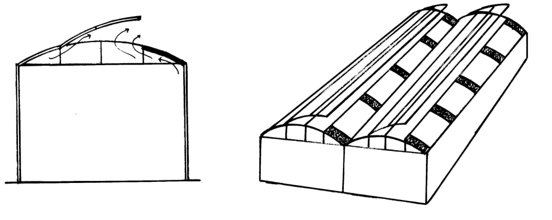
- **<u>Glass type Fresnel lenses</u>**



- Mounted on the roof combined with:
  - <u>Linear absorbers PVs</u> →
    control light and temperature
  - <u>Stirling engine</u> →
    power for water pumping, fans for ventilation etc

(Tripanagnostopoulos et al., 2004; Tripanagnostopoulos et al., 2006)

- **<u>PV/T</u>**
- PV/Ts installed → forming a kind of solar chimney
- *<u>Winter operation:</u>*
  closed panels → **water heating**
- *<u>Summer operation:</u>*
  openings at the roof → **power for fans etc**



- *<u>Case study (South Spain):</u>*
  satisfactory summer - not satisfactory winter operation

(Rocamora and Tripanagnostopoulos, 2006)

RES applications in Greenhouses

Other RES technologies:

-***Underground earth-air heat exchangers:***
regulation of greenhouse air temperature (Mavrogianopoulos and Kyritsis, 1986)

-***Geostill:*** salty geothermal water →
greenhouse heating and pure water for irrigation (Mavrogianopoulos, 1991)

-***Passive solar sleeves:*** plastic, transparent sleeves filled with water between plants rows → collect heat during day → provide this heat during night (Mavrogianopoulos and Kyritsis, 1993)

-***Trombe wall:*** south-facing, heat absorption and storage → radiation of this heat into the greenhouse (Bellows, 2010)

-***Solar cooling:*** desiccant system more efficient compared to simple fan ventilation (Davies, 2005)

RES applications in Agricultural Buildings

Desiccant - Solar cooling

-**Cooling stored grains**

-Reduction of ambient air humidity

-Suitable for climates with high ambient air humidity during night

(Thorpe and Ahmad, 1998)

PV

-Example: PVs in Tennessee **poultry industry**

-economically feasible given that all state and federal incentives are obtained

(Bazen and Brown, 2009)

Solar collectors

-**Air heater:** pig and poultry farms ventilation

-**Water heater:** houses; farms dairy operations

(US DOE, 2009)

Unglazed transpired collectors (UTC)

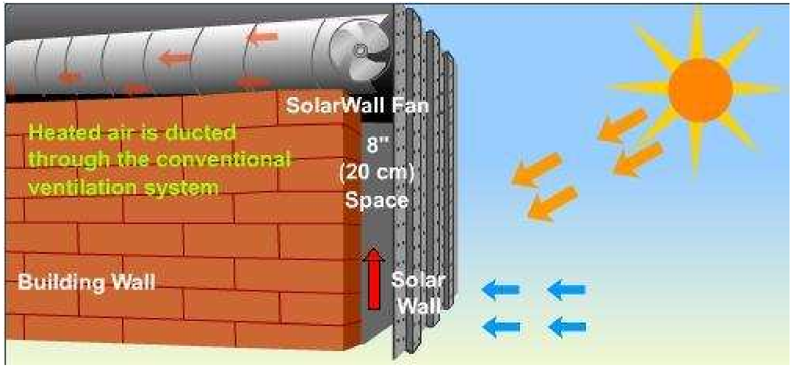
-Also known as solar walls

-Low cost and high efficiency

-**Hot air → Space heating; Drying**

(Augustus Leon and Kumar, 2007)

Air collector with evacuated tubes (Source: Papanicolaou et al., 2010)



Source: http://solarwall.com

RES applications in Agricultural Buildings

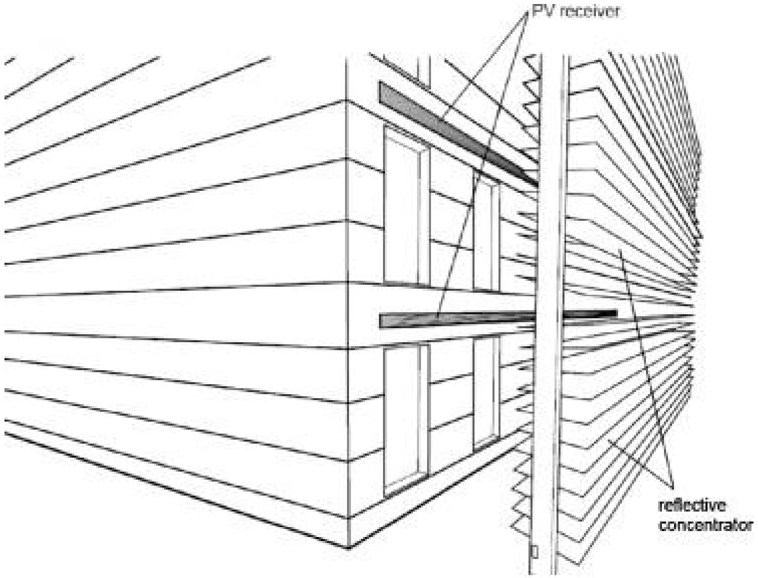
Building integrated concentrating PV (BICPV)

-CPV: **Higher electrical conversion** efficiency in the PV cells, better use of space

-University of Lleida (Spain) currently developing a system:

- linear fresnel reflectors (tracking) - static PV receiver
- overall movement is minimized → facilitating incorporation into buildings

(Chemisana, 2010)



Source: Chemisana, 2010

Other RES technologies

-Biomass, Trombe wall, micro hydro power, geothermal energy, PV/Ts, Fresnel lenses, wind power, ICSs etc

RES technologies for electricity supply

PV rural electrification projects:

- ***La Garroxta (Catalonia, Spain), 50 kW_p***

  (Vallve and Serrasolses, 1997)

- ***Jordan, nine solar home systems (each 400 kW_p)***

  (Al-Soud and Hrayshat, 2004)

Concentrating Solar Power (CSP) project:

Julich (Germany), Solar Tower, 1.5 MW_e

(Alexopoulos and Hoffschmidt, 2010)

Julich Solar Tower

Source: Stadtwerke Jülich

RES for electricity production: **Synergy between RES and rational use of energy**: selection of appliances with lowest consumption → decrease in total cost of production/consumption (Chabot, 1992)

Energy policy aspects regarding remote, rural areas

- For regional areas **local factors and local criteria** should be taken into consideration when a transition towards a new energy situation is taking place (Michalena, 2009)

- **Recommendations** → expand remote regions capacity for *adoption of new technologies such as the ones presented above*:

  - ***Factors: spatial, environmental, cultural*** (Butler, 1986)

  - ***Strategic approach of the State should be funded on the following principles:***

    - protection of vulnerable zones
    - potential economic and social results
    - promotion of the welfare of remote local communities
    - degree of local acceptance for innovation
    - existence of technical and financial infrastructure
    - dynamics of economic activities (i.e. tourism)
    - degree of natural processes understanding
    - absorption capacity of ecosystems on the basis of shared responsibilities

Energy policy aspects regarding remote, rural areas

- ***Participative governance***
- ***End users should:***
  - follow the operation of the RES projects (Dalianis et al., 1997)
  - participate through their engagement in energy projects
  - Depends on: politic, economic, local circumstances (Nilsson and Martensoon, 2003)
- ***Reduction of social risks***
  - equally important as reduction of technical risks (Ragueneau and Teule, 2006)
- ***Innovative technologies need some time to be adopted depending on:***
  - complexity and future advantages of the innovation etc (Rogers, 1995)
- ***Creation of platforms "learning by doing"*** *(Smits and Kuhlmann, 2004)*
  - creation of local laboratories, academics relate sustainability with intercommunal structure (Clarimont and Vles, 2006)
- ***Evaluation of actions on site*** *(Michalena, 2009)*
- ***Young people:***
  - should be trained on how to build and operate RES projects
  - maintain young populations on remote areas (Michalena, 2005)
- ***Regulatory framework should emphasize on:***
  - the use of innovative technologies and energy storage systems

Conclusions

- ***Under specific conditions***, RES technologies positive contribution → sustainable development of remote / rural areas

- Among RES, ***SE has many agricultural applications***
  - solar drying, desalination, space/water heating, cooking, distillation, water pumping and pasteurization, electricity production etc

- Some ***recent developments in SE technologies***
  - such as solar collectors with evacuated tubes, PV/T, Fresnel lenses, BICPV, UTC etc
  - can contribute positive towards the sustainable development of remote/rural areas provided they are used in a <u>cost-effective way</u>

- Synergy between RES and ***rational use of energy*** should be taken into consideration

- Design of ***local and national regulatory and political framework*** to attract investments on SE applications

Thank you for your attention!

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