Benefits of Intercropping in Solar Facilities

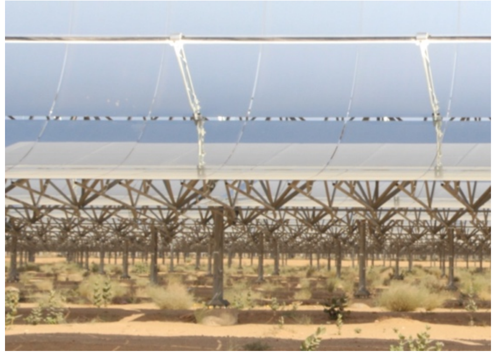
Sujith Ravi

Earth & Environmental Science

TEMPLE UNIVERSITY

Jordan Macknick (NREL), Chong Seok Choi (Temple University)




Solar Energy

Advantages

- Lower carbon emissions than fossil fuel generation
- LCOE decreasing

Disadvantages

- Larger land footprint
- Long-time commitment of land

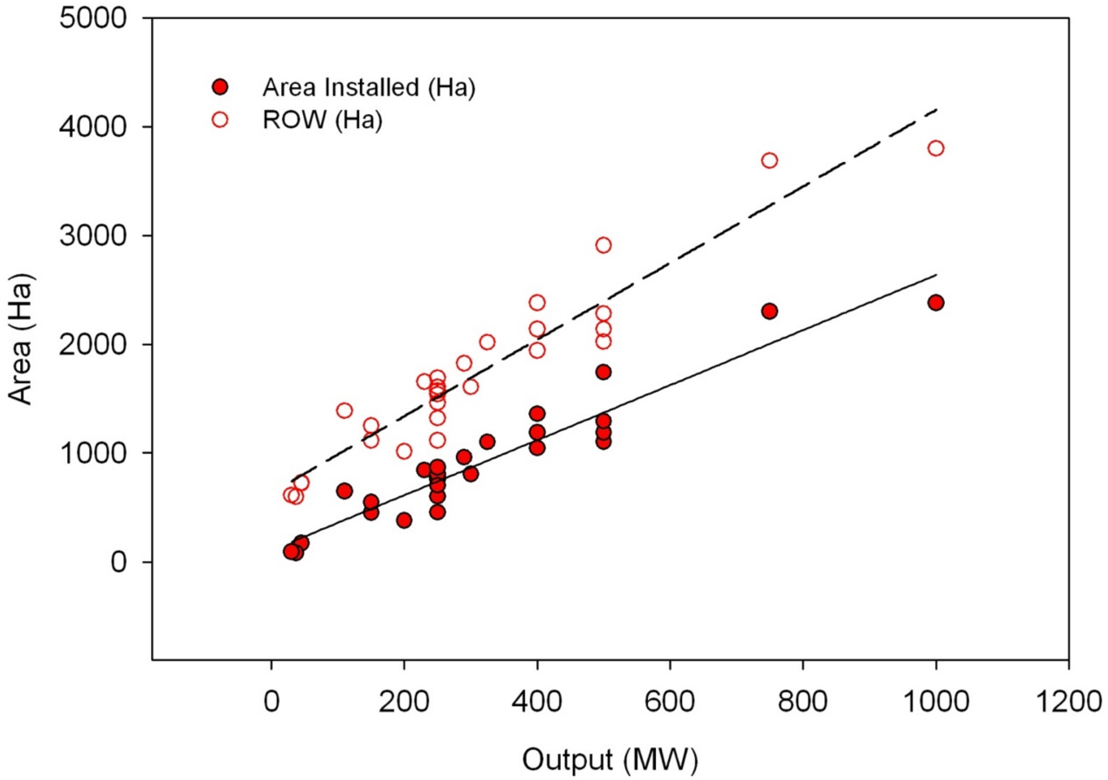
Mitigation

- Integration with other land uses

Large solar installations: Land Use

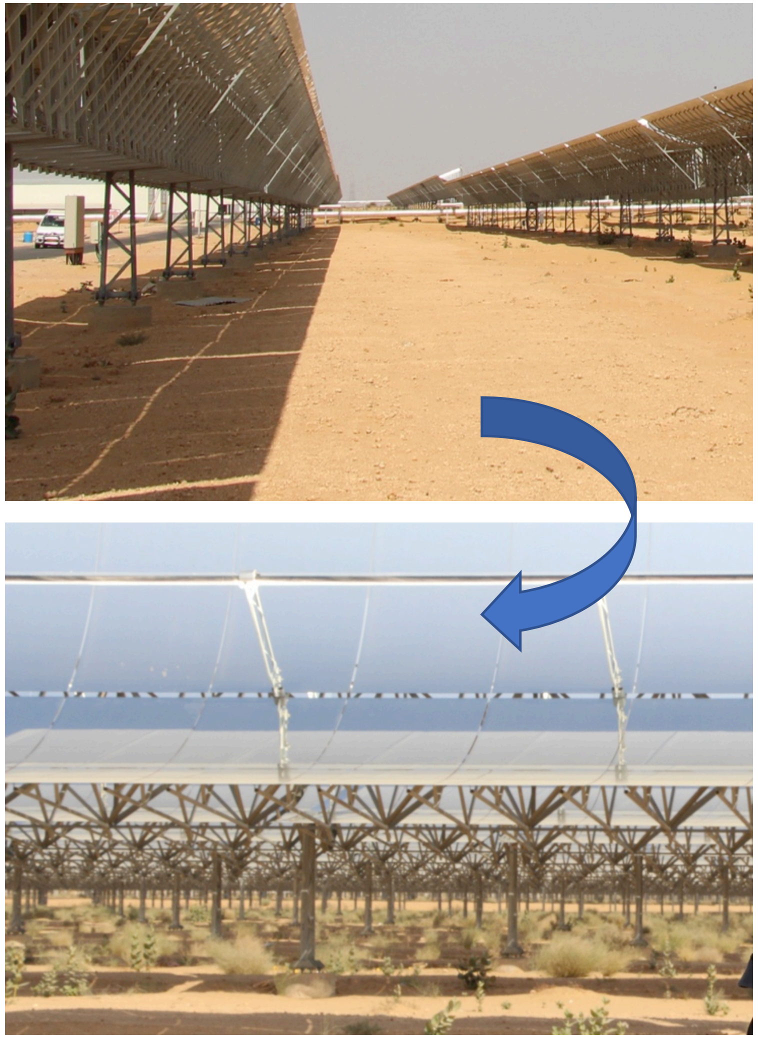
13 Km^2 site in Mojave desert

SOURCE: http://www.forbes.com/forbes/2011/0627/



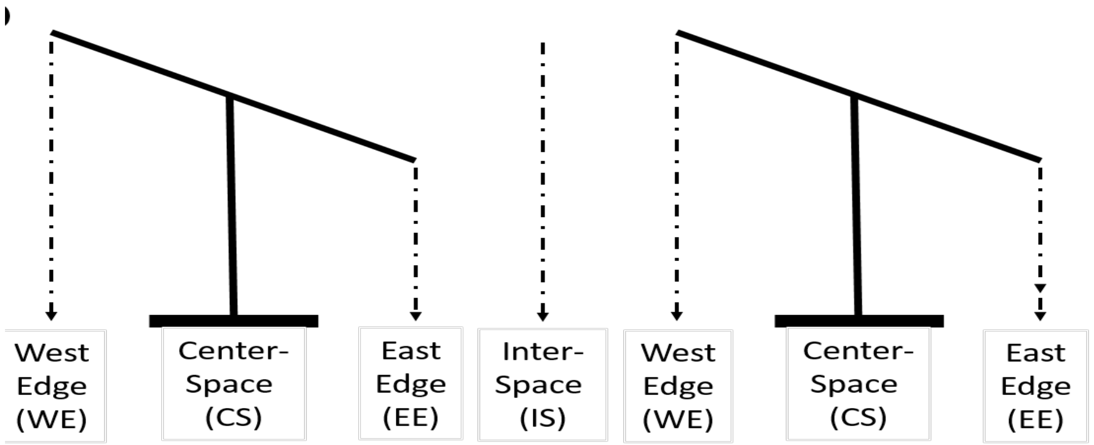
One million ha of direct land transformation in US by 2030 target of 350 GW
India - target of 200 GW by 2050 (PV & CSP)

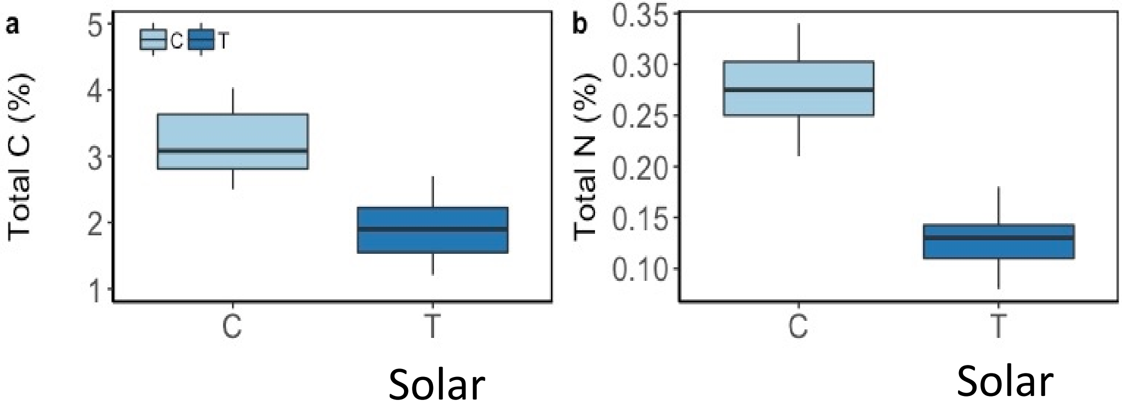
Large solar installations: Water Use

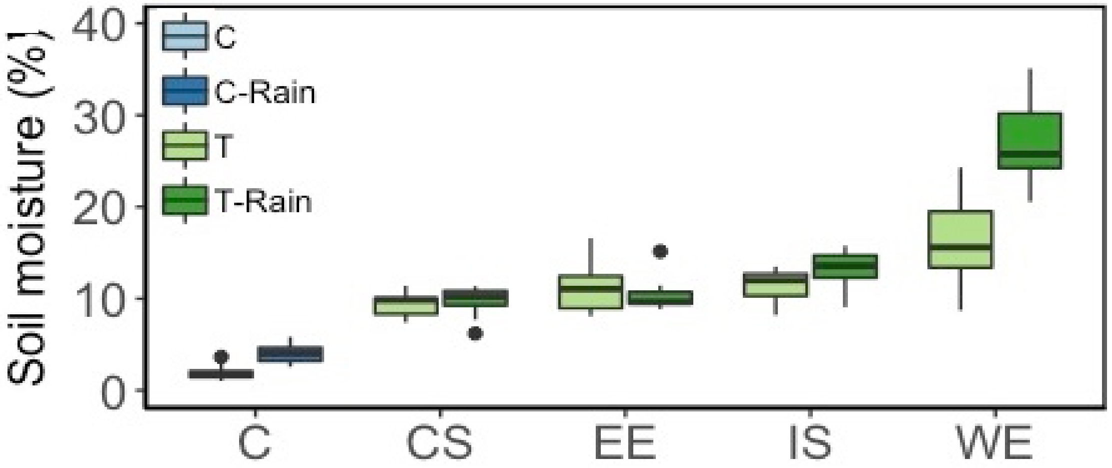


Water additions equivalent to 100 mm of rainfall/year in some systems

Impacts on Soil & Hydrological processes







Colocation

Solar Centric or Crop Centric

Land and water use efficiency, socio-economic & environmental co-benefits

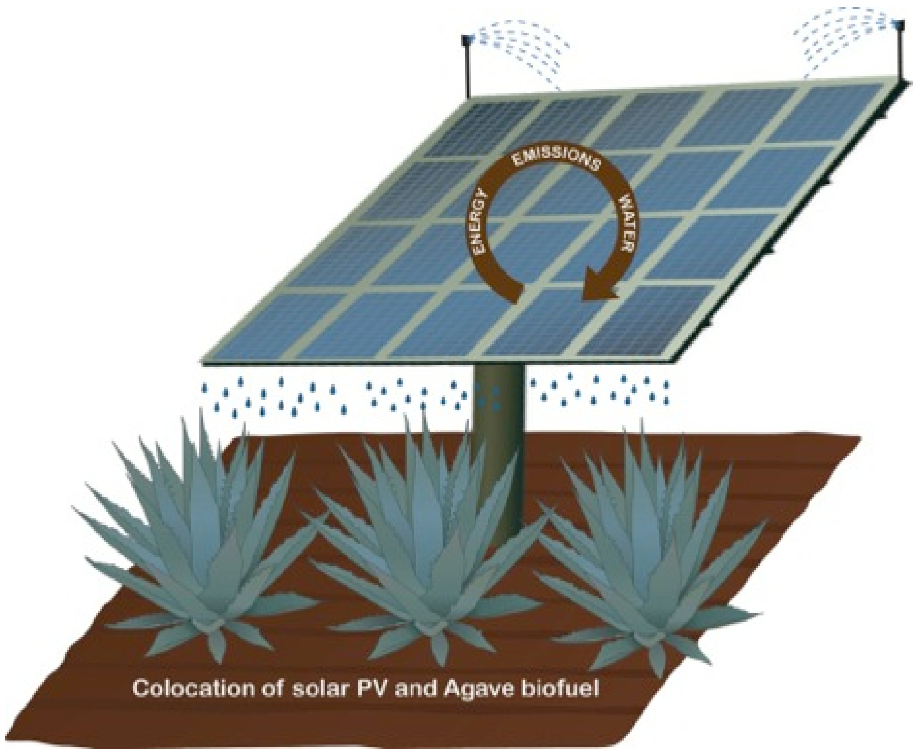
Ravi, S, Nature, (2015), Macknick et al., 2013; Ravi et al; Applied Energy (2015), Ravi et al; Environmental Science & Technology (2014), Hernandez, Ravi et al., Renewable & Sustainable Energy Reviews, (2014)

Key question: Identifying suitable crops

- Ecological and physiological adaptations (e.g. CAM photosynthesis) to achieve economical yields on marginal lands
- High demand & existing markets
- Low growth stature
- Low maintenance and long crop cycle
- Tolerate shade, drought, high temperature
- Respond well to light irrigation events

Panicum virgatum (switchgrass), *Aloe vera, Agave sp*

Example 1: Solar – Agave Colocation

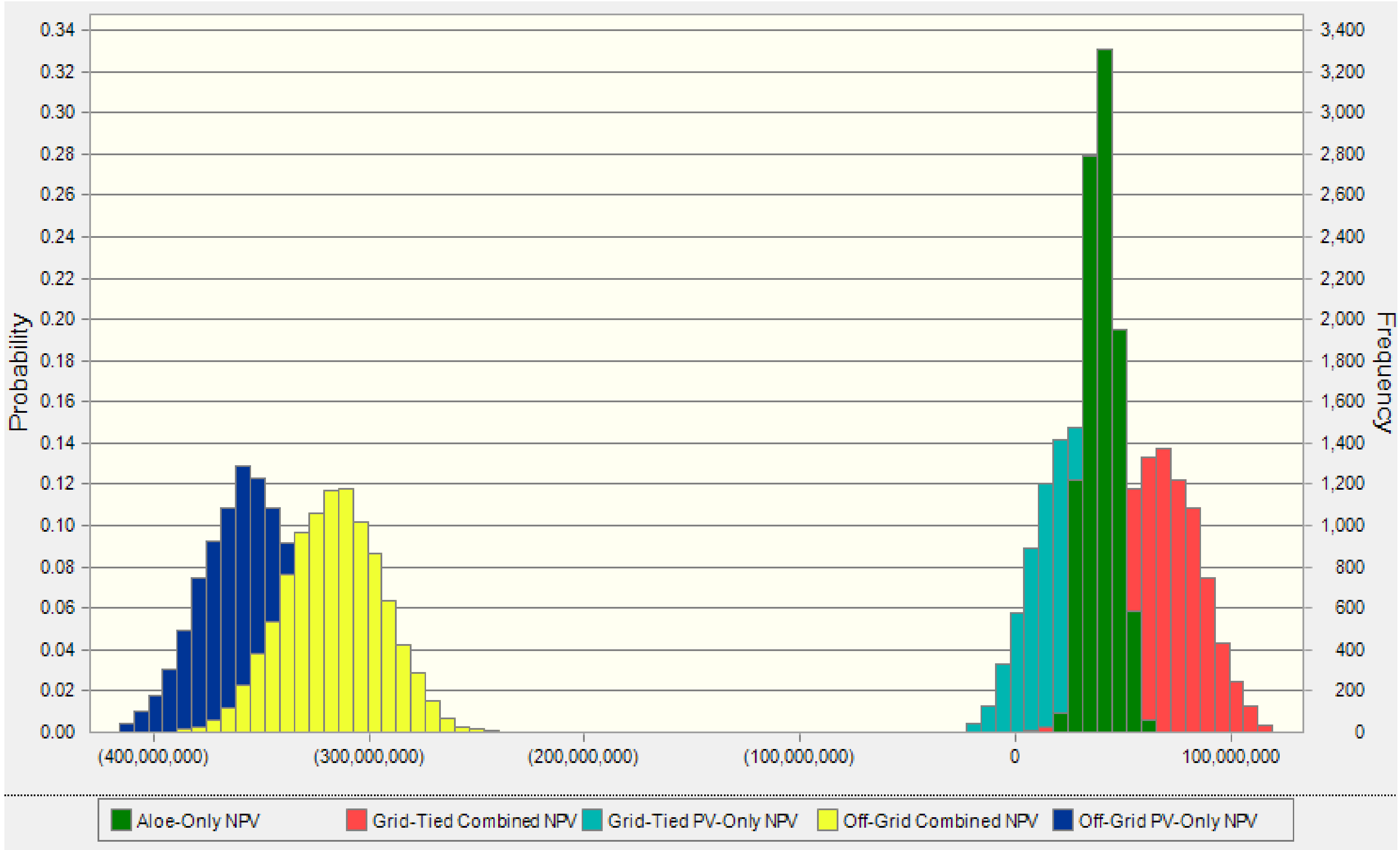


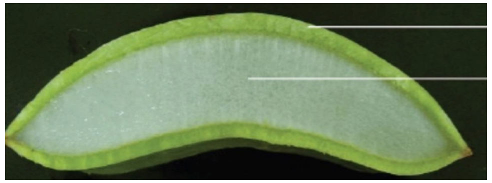
Agave americana
Agave tequilana

- Life cycle analysis of water, energy, emissions and economic feasibility
- Water inputs for solar are sufficient
- Electricity (solar) and liquid fuel (agave)
- More $ per unit of water use
- Biofuels in marginal lands

Ravi et al; Environmental Science & Technology (2014)

Example 2: Colocation of solar PV and Aloe Vera in India



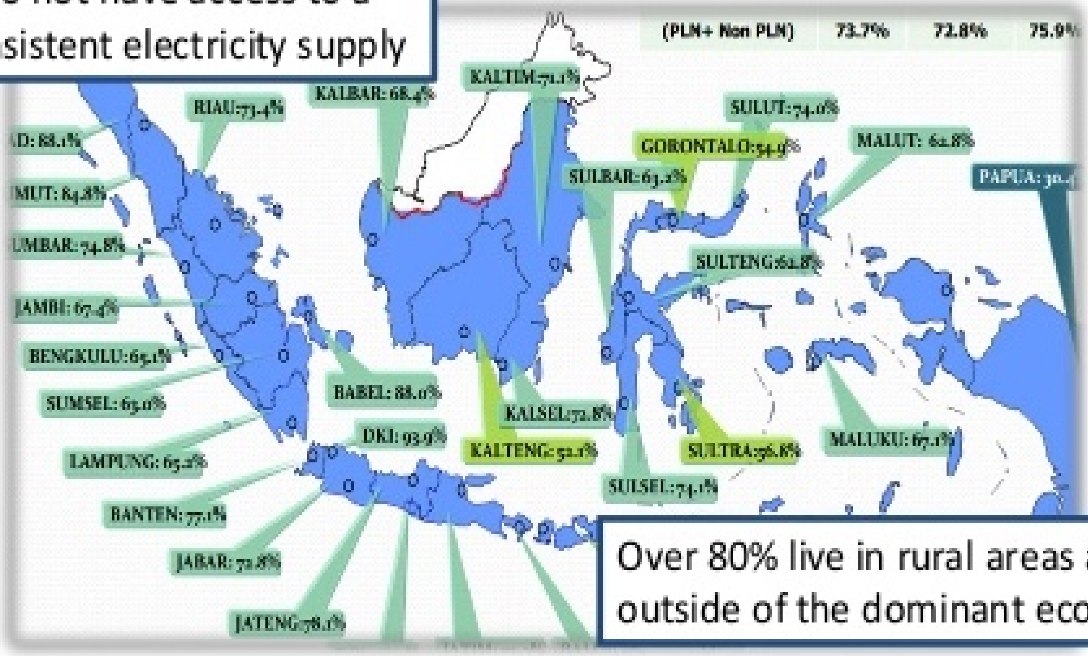


The uncertainty in Net Present Value (NPV) determined by Monte Carlo analysis that varied the most important parameters, as determined by sensitivity analysis. (Ravi et al. 2016 Applied Energy)

Example 3: In the tropics

Rural Electrification Challenges

Over 70 million Indonesians do not have access to a consistent electricity supply



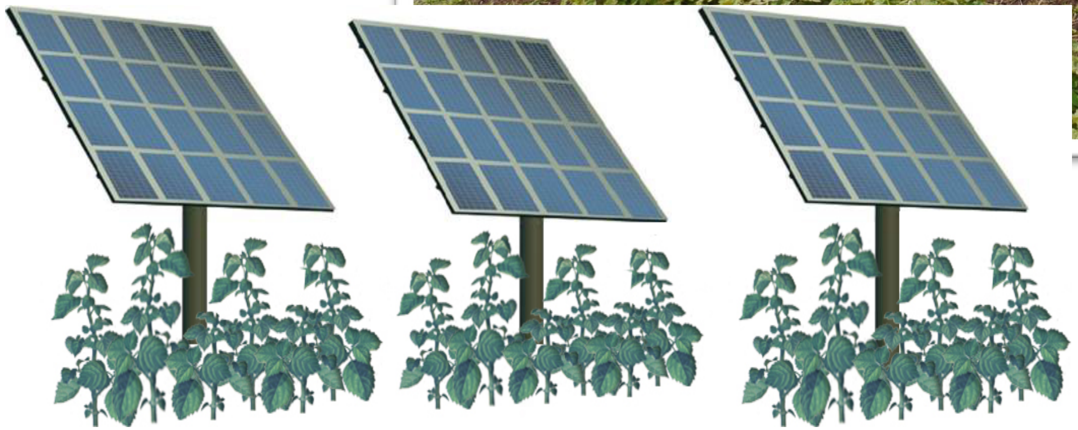
Electrification ratio (2012)

Category:
- >60%
- 41-50%
- 20-40%

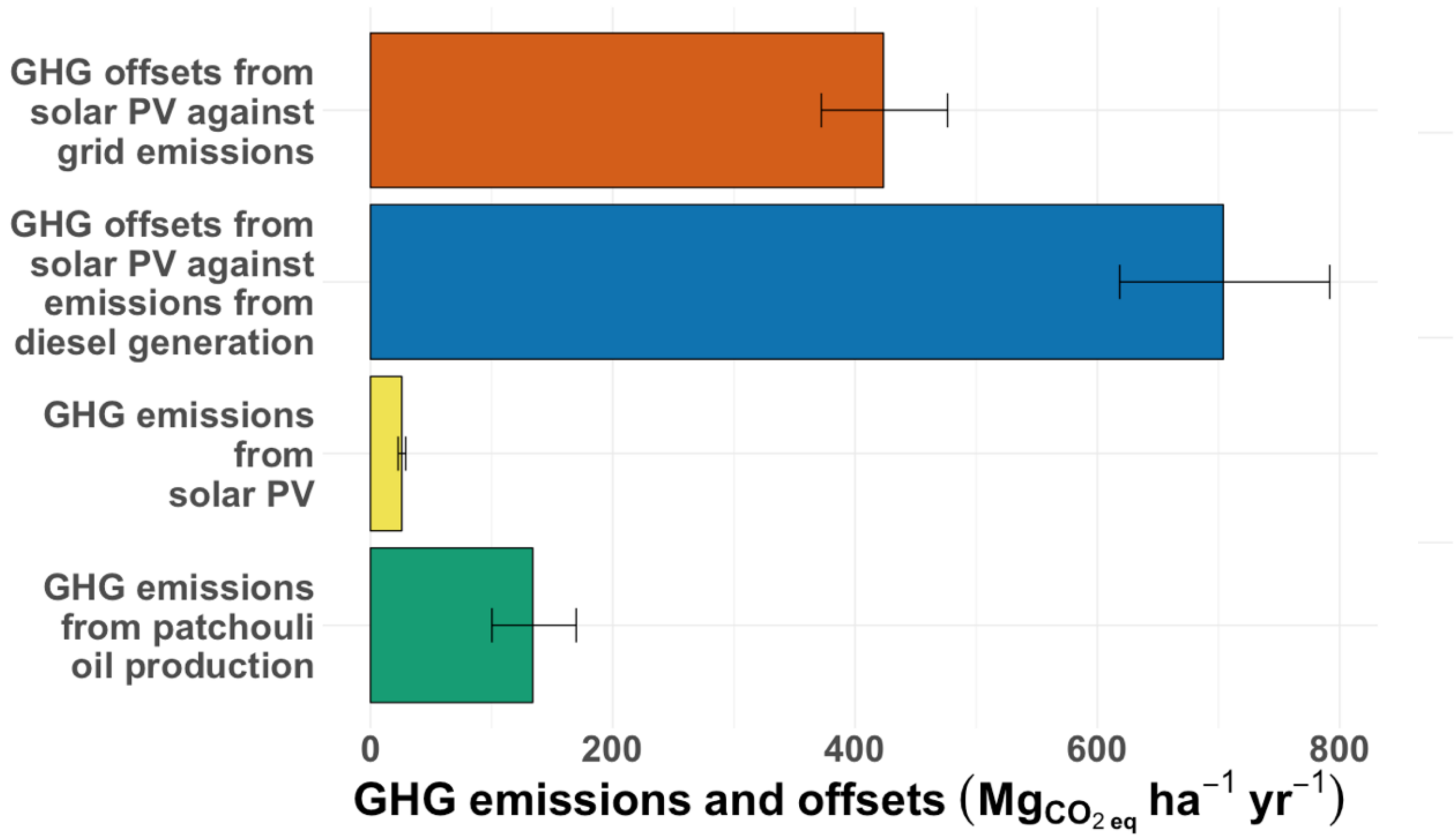
Over 80% live in rural areas and over half live outside of the dominant economic centers

Indonesia: PV - Patchouli Colocation

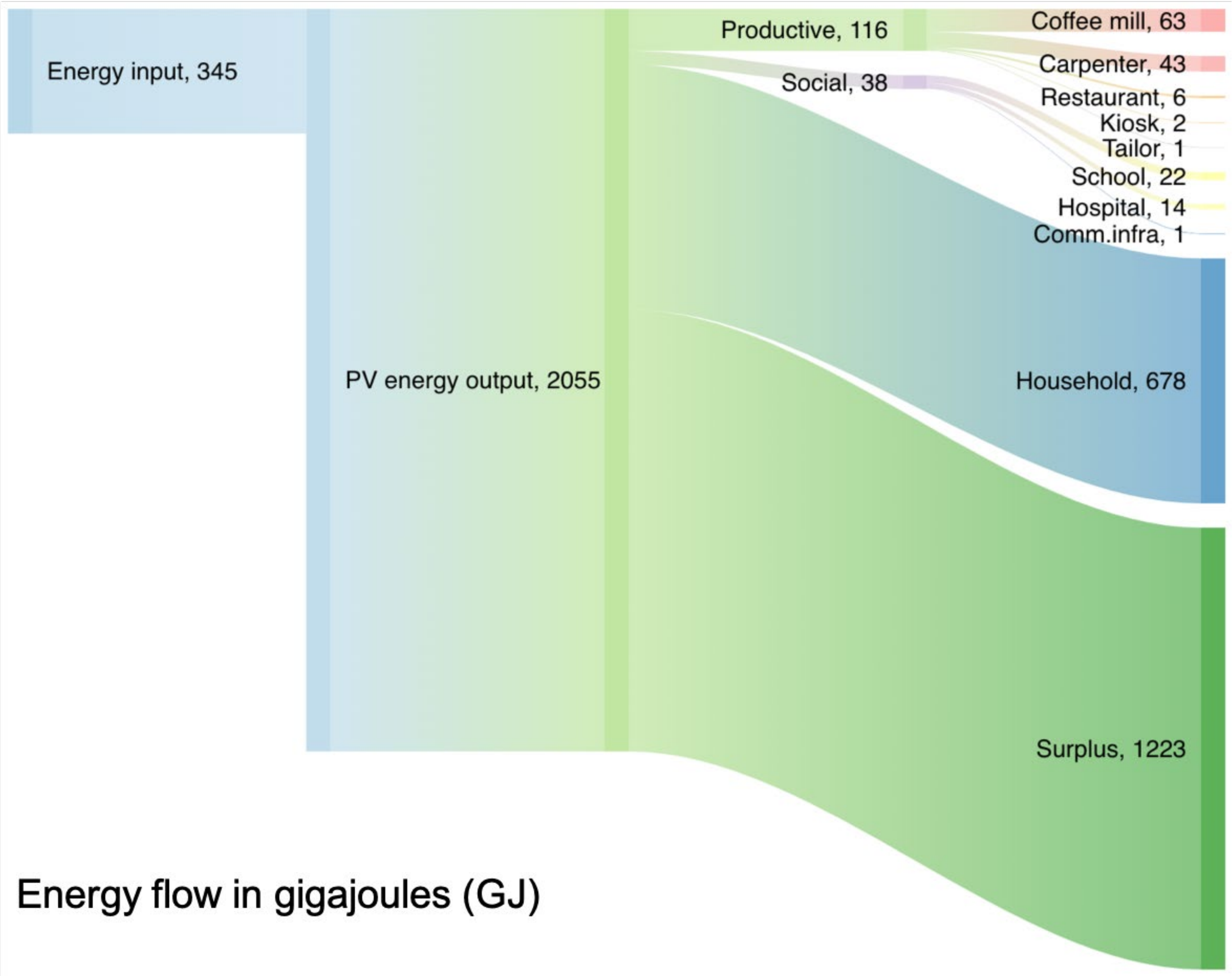
- Patchouli (*Pogostemon cablin*)
  - Extensively cultivated
  - Expensive essential oil
  - Physiologically viable
  - Tolerate shade
  - Crop centric approaches



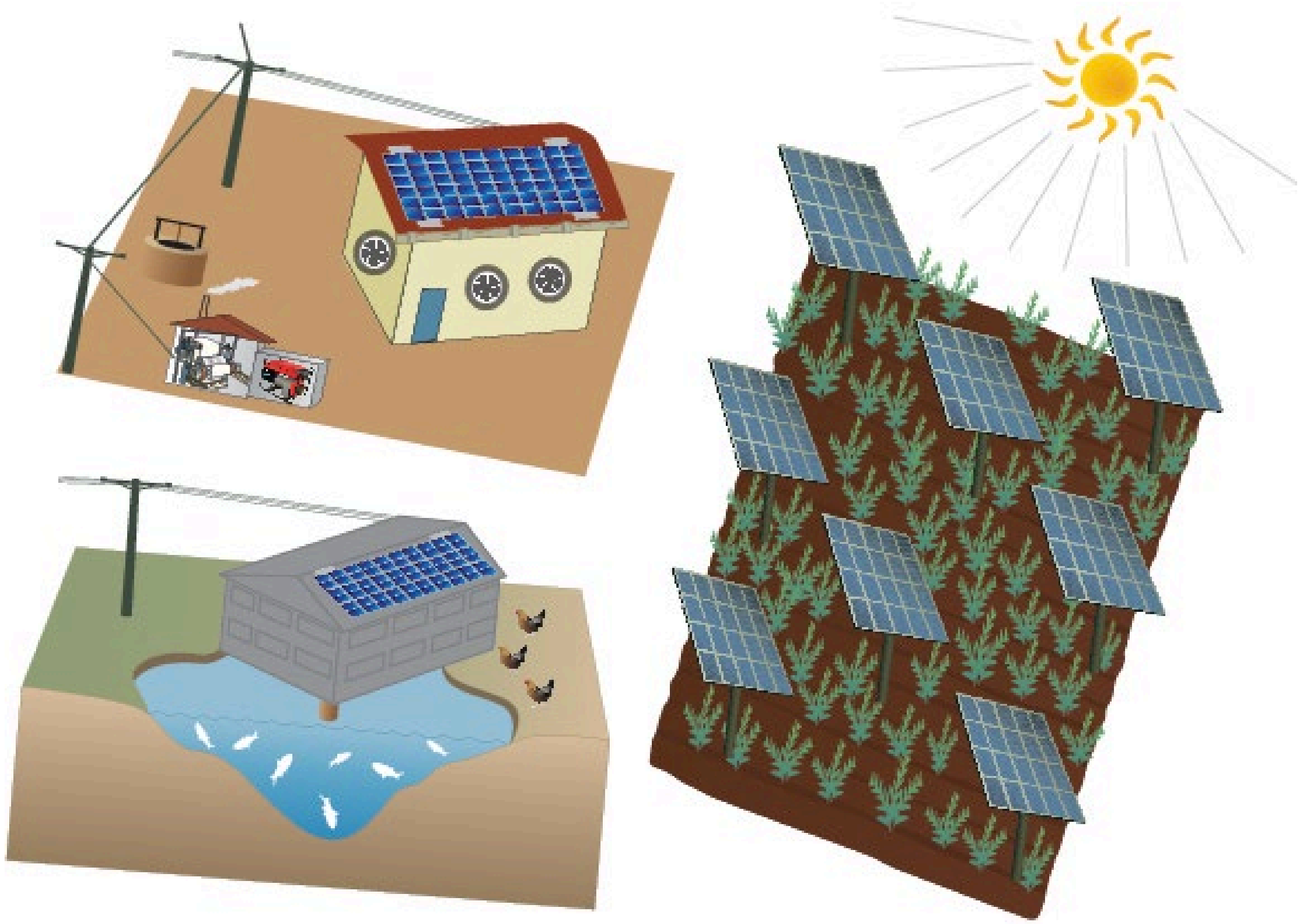
Environmental benefits



Potential socioeconomic benefits



Towards "**life style centric**" approaches to integrate renewable energy services in rural communities



Synergies of colocation

- Maximize efficiency of land and water use
- Deploying non-food crops in marginal lands
- Rural electrification & Employment generation
- Lower panel temperatures from crop cooling
- Other potential synergistic factors: rainfall concentration, reduced soil erosion, shading in extreme arid environments.

Funding sources :
Department of Energy, TomKat Center for Sustainable Energy, Stanford University
Joint Institute for Strategic Energy Analysis, NREL