Arising landscapes 3/3

DESIGNING INNOVATIVE AGRIVOLTAIC SYSTEM. ENERGY PRODUCTION. The design of the agrivoltaic landscape is relatively complex, as it's necessary to combine solar infrastructure with food crops for optimising land use. Its design and evaluation must conform to the requirements set in the design phase, to meet the desired performance and quality objectives. Experimental results show that rice yield is positively related to solar radiation, especially during the reproductive and ripening stages; on the other hand, shading significantly affects the main components of the rice crop - panicle number, SPAD value and grain quality - reducing its yield.

TECHNICAL DATA APV SYSTEM

Three-dimensional pattern spatial attributes

PV pattern	density degree (PV area / pore area)	16,6%
modules height (m)		4,5+EST
number of crop zone types (depending on irradiance pore space volume (m^3)		
total area - area projected PV modules on the ground **x** H		188,208

Three-dimensional pattern depending solar potential and connectivity parameters

irradiance homogeneity degree on PV	Number ranging from 1 to 0 depending on whether the orientation of PV is homogeneous or not. No variation of tilt and azimuth is 1; no variation of azimuth, variation of tilt or variation of azimuth, no variation of tilt is 0.5; variation of azimuth and tilt is 0.	1
irradiance homogeneity degree on crops	Number ranging from 1 to 0 depending on whether the geometrical pattern of PV is homogeneous (1), dispersed (0.5) or random (0)	0
crop type zones	The crop selection depends on irradiance. If the irradiance is homogeneous, there is 1 zone type. If it is not there, are more. For standard patterns (parallel stripes with optimized distancing between the stripes), there are 2 (one underneath the PV modules, and the other in between the stripes of modules), but a more porous pattern may allow for a third zone with no shading.	3
PV type zones	Depending on how many different orientations of the PV modules are, the number of PV type zones can be determined.	1

Nominal power parameters

modules area (m^2)	8.062,08
PV nominal power (Wn)	1.560.000
crop area (m^2)	48.563

Solar conversion efficiency parameters

modules efficiency	up to 21,3%
energy density parameters	
PV density of power (W/m^2)	35,3
land use energy intensity ($kWh/m^2/y$)	47,55

Producibility parameters (calculated based on yearly equivalent sun hours)

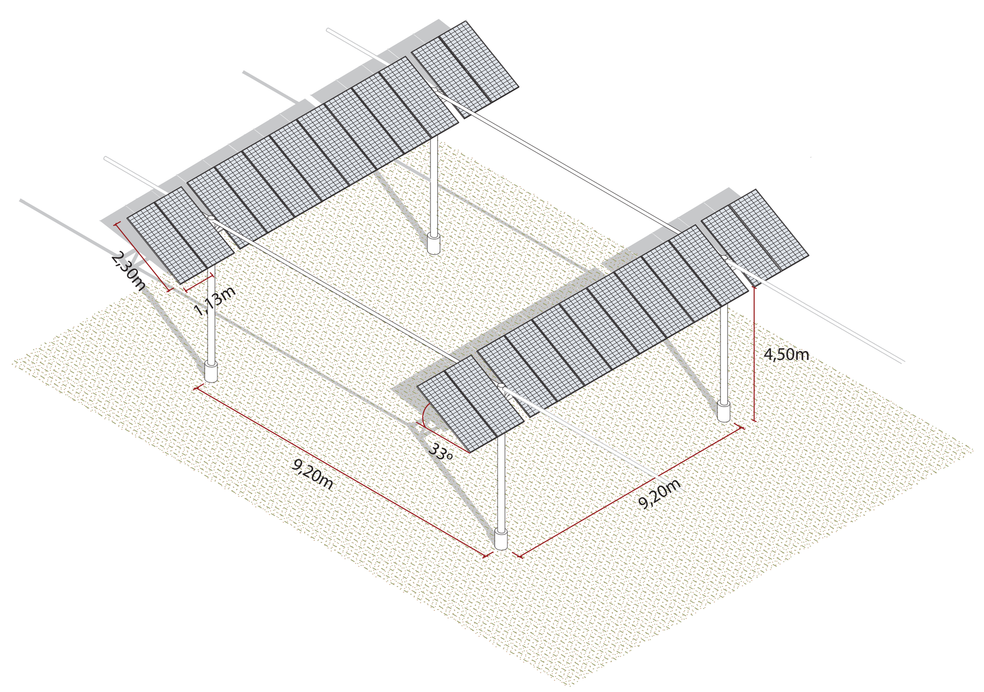
normalized PV producibility (kWh/kWp/y)	1.345,74
PV yearly yield (MWh/y)	2.309,28
crops yearly yield (q/y)	48

TECHNICAL INFORMATION

The technical solution proposes 550 W monocrystalline photovoltaic modules high energy efficiency up to 21.3%. PERC 10BB half-cell technology, maximum annual degradation of 0.55% after 25 years.

The selected inverters are three-phase devices with a rated power of 20 kW, with a maximum DC voltage range of 200-1,000 V and without a transformer, with a standard interface for easy communication via WLAN or Ethernet. These units allow Plug-Play maintenance and their IP-66 degree of protection, ambient temperature range of -40°C to +65°C and admissible air humidity of 0-100% allow them to be installed outdoors.

The arrangement of the modules, south facing, with an inclination angle of 33° will ensure an energy efficiency of the system of 99.71%.

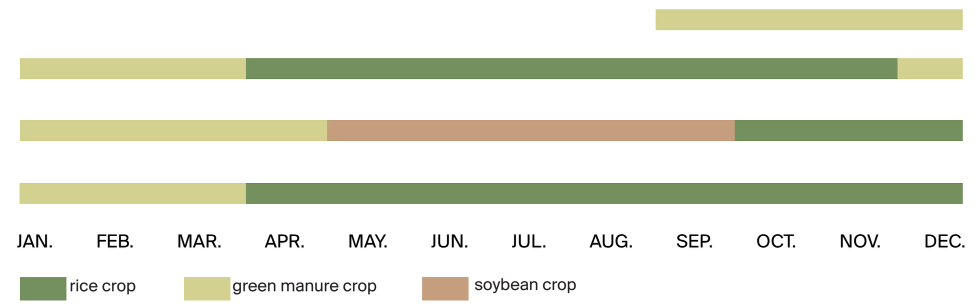


MEASURES APV SYSTEM

AGRIVOLTAIC PROPOSAL ANALYSIS

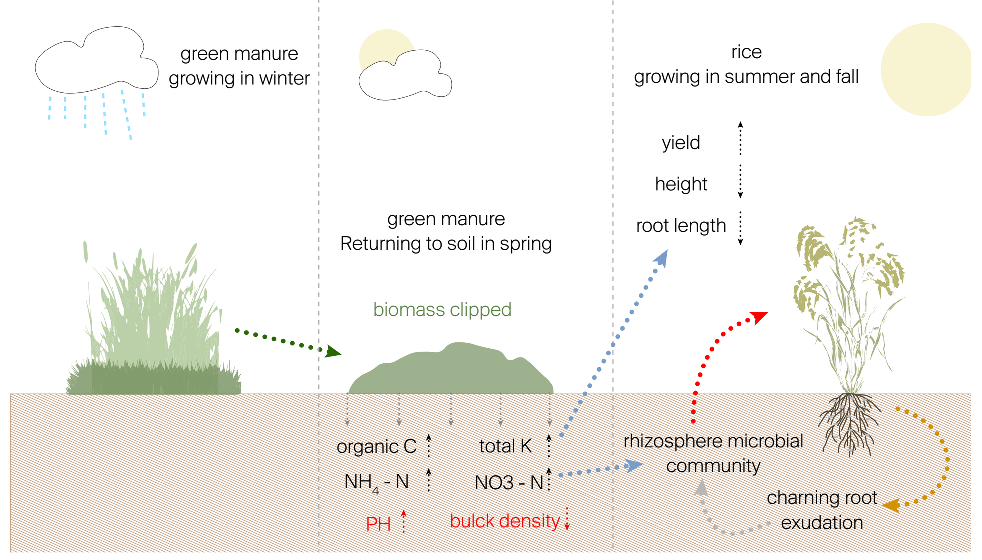
In addition to the design parameters (to ensure the maximum yield of agricultural and energy production), other factors need to be considered, such as: the good performance of agricultural tasks, ecological functionality, maintenance and management costs of the PV system, safety, visual integration. In relation to agricultural tasks, the proposal foresees that these can be carried out with the same machinery used in the adjacent fields.

AGRICULTURAL PRODUCTION. The plot is integrated into an organic farming system, so it is proposed to incorporate the practice of green manure cultivation into the crop rotation. Fig.1 shows the crop rotation sequence: green manure-rice-soybean-green manure-rice. This will reduce fertiliser input, increase organic matter content, and reduce pressure from adventitious flora (Filizadeh, Y. et al., 2007).



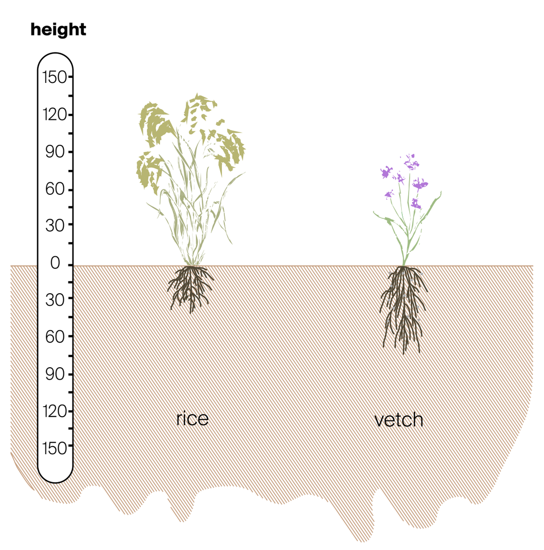
1. SEQUENCE OF CROPS ROTATION

A mixture of five annual clovers or similar will be chosen because of its high speed of implementation, which will limit the development of weeds. This mixture will provide nitrogen for the following crop and will incorporate organic matter into the soil, increasing its fertility. The clover is mowed, the clippings are evenly distributed on the field to prepare the land for the next rice crop (Figure 2).



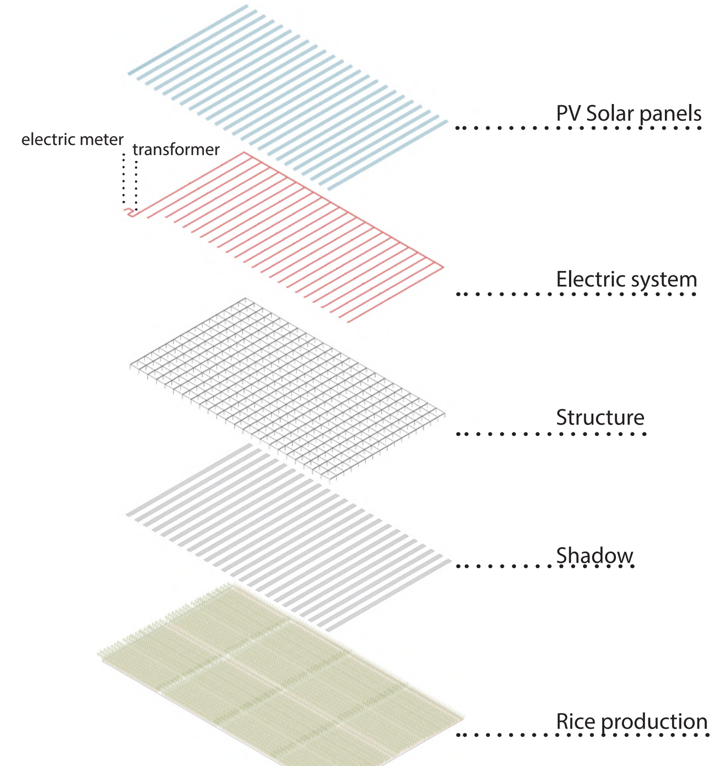
2. CROP ROTATION
(source: Xiaoxia Z. Et al., 2017.)

Then, after preparing the soil, the rice (*Oryza sativa* L.) is sown. For the management of the rice, direct dry sowing is proposed, as it saves seed. This will also save water: from sowing to the first flooding can take between 20-30 days depending on the sowing dates and the variety. Direct dry sowing can be a good tool for the control of the rice weevil (*Lissorhoptrus oryzophilus* Kuschel), as it delays the flooding of the paddy reducing the damage caused by the larvae of this pest (Villegas, J. M. et al., 2021). Post-emergence mechanical weed control will also be carried out using a precision harrow with flexible tines or a rotary hoe, and it is important to do this at the optimum time for effective weed suppression (Neeson, R., 2005). To complement the rice field fertilisation strategy, the foundation plant management biofertiliser will be applied before planting. During the winter break and weather permitting, a green manure crop, a mixture of rye (*Secale cereale* L.) and vetch (*Vicia sativa* L.), will be sown. This mixture is characterised by fixing nitrogen and improving the soil structure due to its deep roots (Figure 3); this will provide better soil drainage. The management will be the same as for the previous green manure: at the optimum stage it will be mowed and incorporated into the soil again.



3. ROOTING DEPTH OF RYE AND VETCH
source: : Cotwoldseed

In the second year, the rotation will alternate with soybean (Glycine max), which is an annual legume and has a high commercial value (as it is used in food and feed). Field preparation will start in April for sowing in early May. The sowing rate is between 140-160 kg/ha. Mechanical post-emergence weed control will be carried out with the finger weeder with blind cultivator, which will be used before soybean emergence and approximately every five days thereafter. Two to five blind cultivations are made before inter-row cultivation commences. To obtain satisfactory yields, irrigation should be carried out only when necessary. Once the soya beans have been harvested, the green manure crop is cultivated, and it is advisable on this occasion to mix two short-cycle species: chervil (Vicia ervilia) and mustard (Alba Synapse). Vervil is a legume that will help fix nitrogen and provide fertility. Mustard is a fast-growing crucifer, very good at suppressing weeds (Rosenfeld, A. and Rayns, F., 2018) and high in glucosinolates; under the right conditions it can deter and even kill pests and diseases. Management will be the same as for previous green manure crops.



AGRICULTURAL PRODUCTIVITY EFFICIENCY . The main benefit of the combined production of agricultural products and clean electricity comes from a higher overall productivity of the combined system compared to the sole use or mono-production of agriculture or solar PV in the same area. To validate this assumption and actually measure the effect, the concept of Equivalent Land Ratio is used.

$$\textit{Land Equivalent Ratio (LER)} = \left(\frac{\text{Yieldcrop in dual use}}{\text{Yieldmonocrop}}\right) + \left(\frac{\text{Yieldelectricity in dual use}}{\text{YieldelectricityPV}}\right)$$

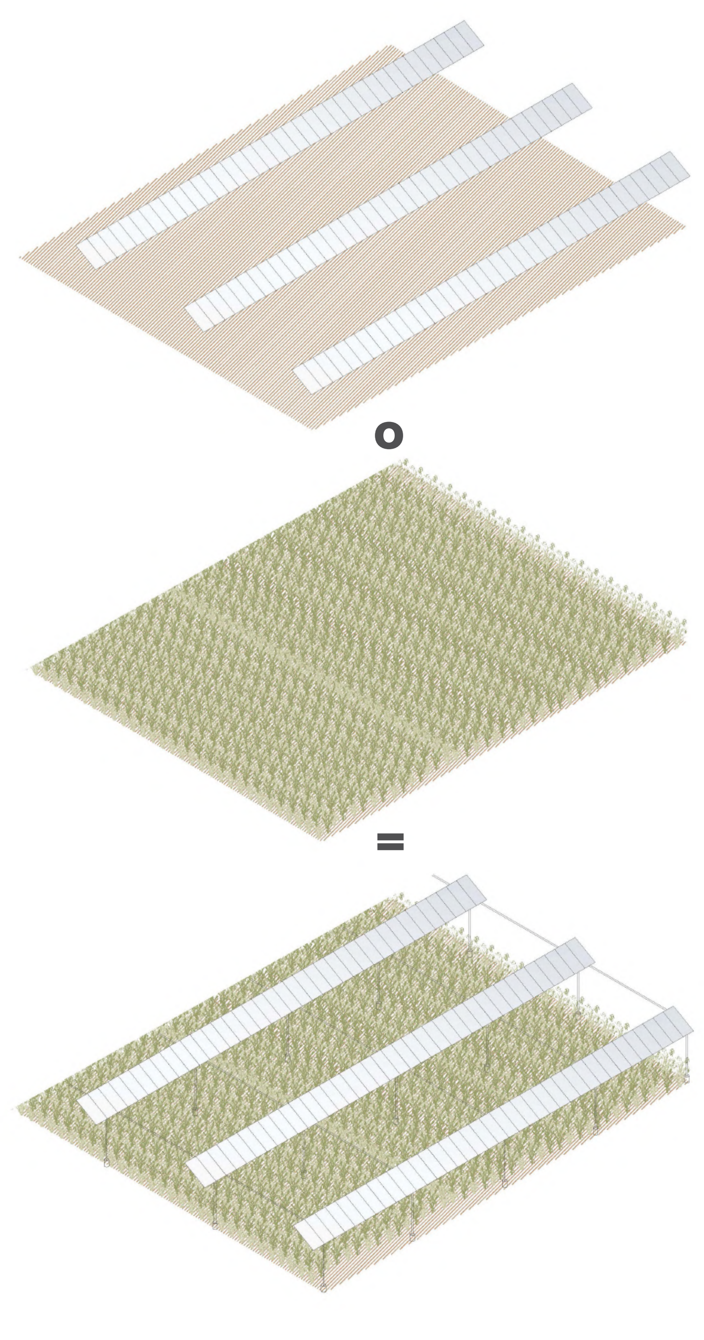
$$\textit{Land Equivalent Ratio (LER)} = \left(\frac{4{,}8}{6}\right) + \left(\frac{475.524{,}54}{1.143.879}\right) = 1{,}2157$$

$$1{,}2157 > 1$$

PROPOSED CONCEPT OF THE LAND EQUIVALENT RATIO (LER)

LER 21.57% increase in soil yield compared to single use.
A higher yield has not been obtained, due to the low density of installed modules, so that the occupation surface is less than 20% to limit the negative effect of shade on the crop.

Yieldcrop in dual use	4,8 tn/ha	Production reduced by 20% due to shadow effect
Yieldmonocrop	6 tn/ha	Average production area
Yieldelectricity in dual use	475.524,54 kWh/ha	P roposal 353,35 kWp/ha and 1345,74 kWh/kWp/y
YieldelectricityPV	1.143.879 kWh/ha	With 850 kWp/ha and 1345,74 kWh/kWp/y



COMBINED LAND USE PROPOSAL ON RICE CROPLAND
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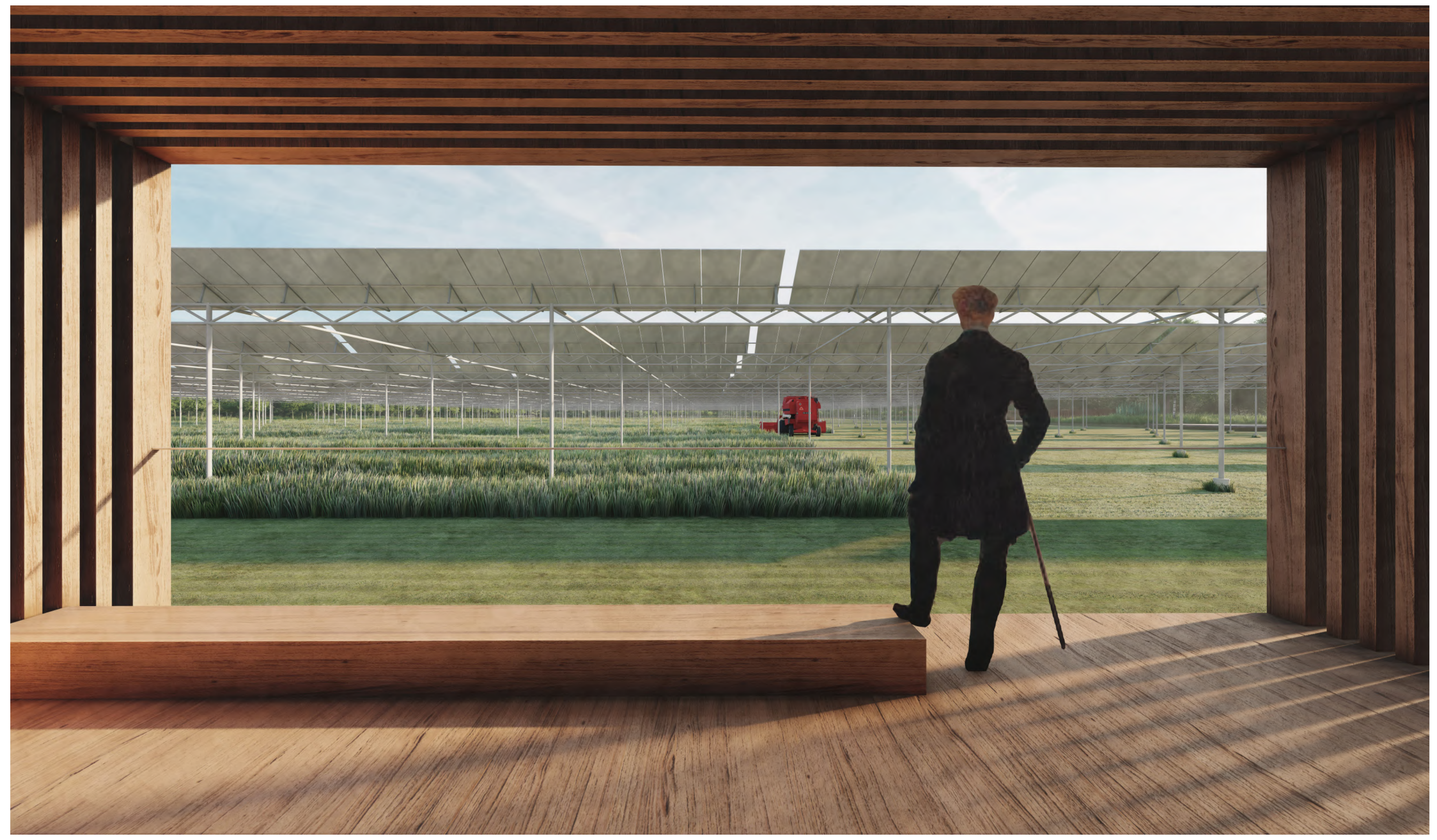
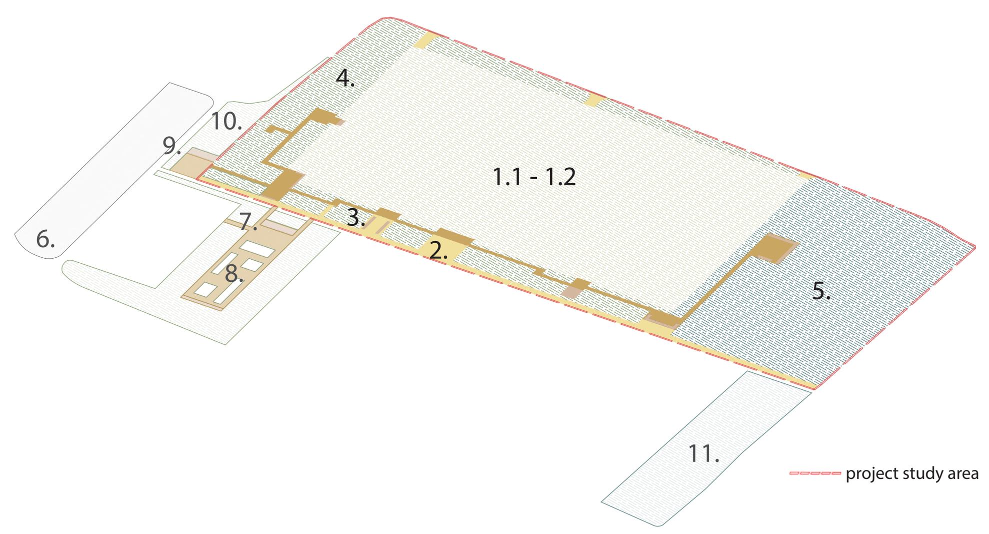
EFFICIENCY INCREASES OVER 21,57%





ECONOMIC ASSESSMENT

PROJECT AREA	SURFACE (m^2)	COST
1.1 Energy field	48.563	1.140.175 €
1.2 Agricultural field	48.563	8.280 €
2. Mobility and activity areas (cultural, scientific,etc.)	4.323	561.990 €
3. Pavillions and service facilities	401	401.000 €
4. Semi-humid areas	10.420	208.400 €
5. Wetland areas	23.094	230.940 €
GLOBAL AMOUNT (taxes and VAT included)	**86.801**	**2.550.785 €**

OUT OF THE PROJECT SCOPE		
6. Main entrance	7.487	299.480 €
7. Pavillion exibition area	256	256.000 €
8. Open space exibition area	2.609	104.360 €
9. Pavillion entrance	133	133.000 €
10. Semi-humid areas	12.155	243.100 €
11. Wetland areas	8.180	81.800 €
GLOBAL AMOUNT (taxes and VAT included)	**30.820**	**1.117.740 €**

Team members_ Architect: Agata Buscemi (B2B Arquitectes) - Architect / Landscape Architect: Jordi Bellmunt (B2B Arquitectes) - Landscape Architect: Giuseppe Allegra - Tecnical Agronomist: Francesca Ibañez Ros - Energy expert :Salvatore Inguanta (ELIOS) - Structural engineer: Tommaso Gibiralo - Ecologist: Xavier Mayor (IRBIS) - Agronomist: Laura Rovira Pigem