# Simulating complex PV problems with Lusim – applications to shading, bifacial PV and agrivoltaics

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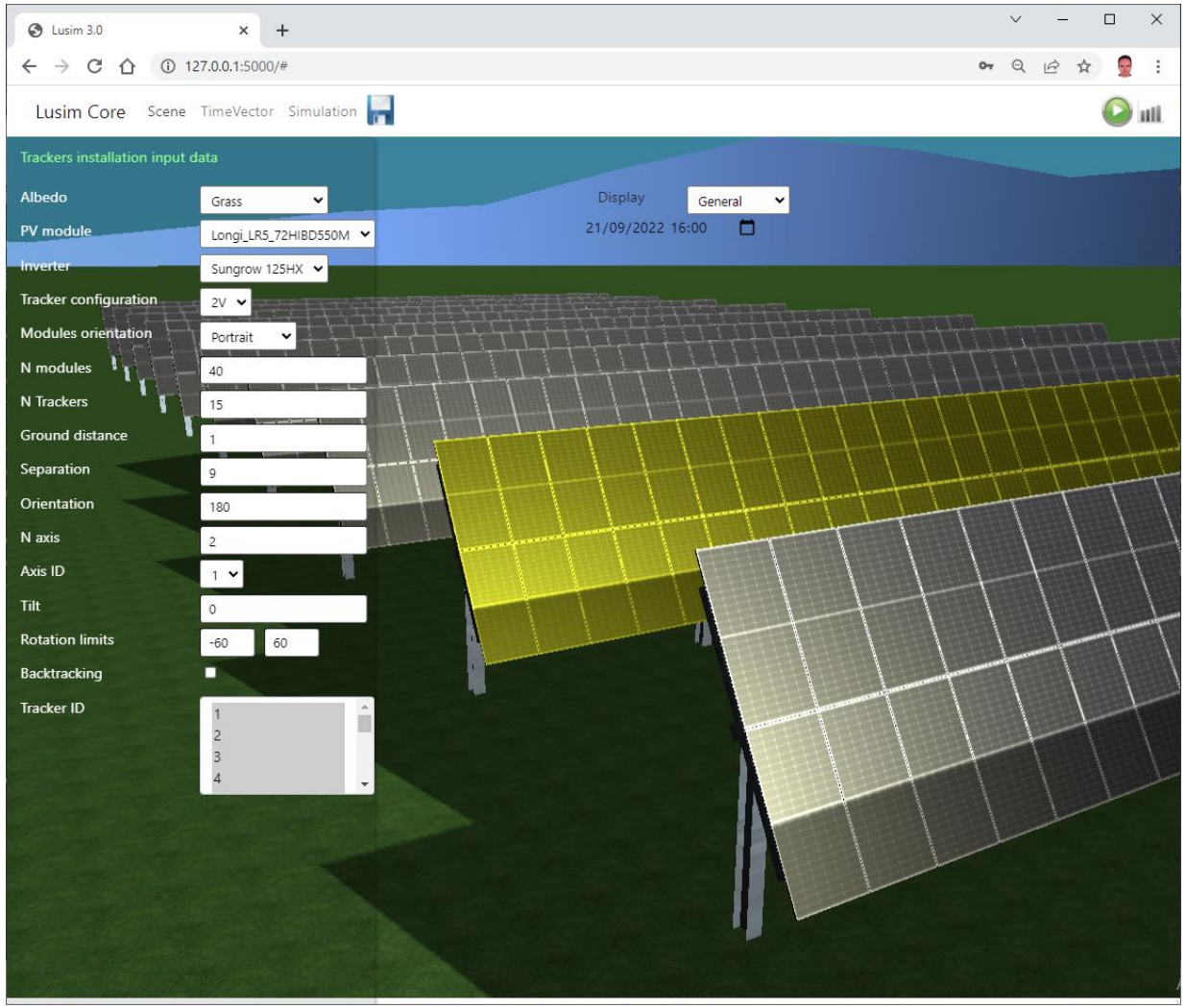
# Background

- Lucisun was founded in 2019
- Core business in complex PV simulations and consulting services
- Participant in Serendi PV (Horizon 2020 european Project)
- Currently 6 team members

# Needs identified

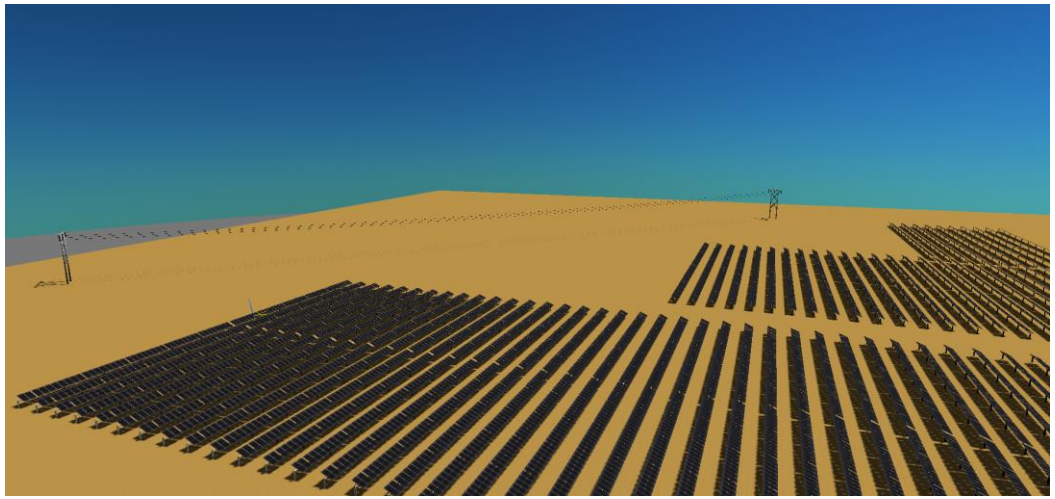
- Complex 3D scenarios with several cross related parameters
- Dynamic effects
- Customized layout generation for real and irregular terrains
- Detailed bifacial analysis considering the influence of certain obstacles
- Real reflection material properties (not only Lambertian surfaces)
- Structure influence on bifacial gains
- Trade off capabilities in “batch” mode
- “Non photovoltaic mind set” approach (combination of agriculture and PV)

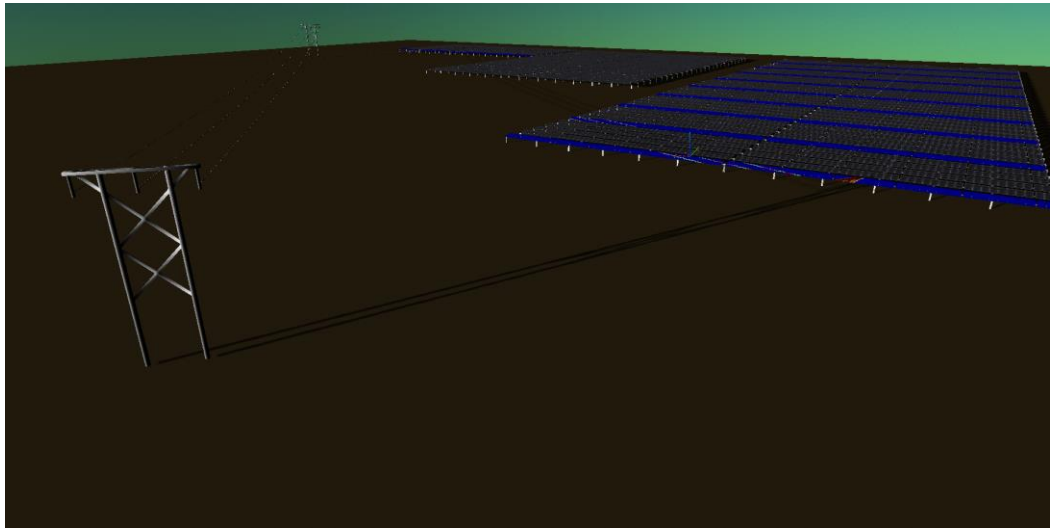
# Lusim methodology and architecture




- User customizable web based 3D interface
- Python core in a Flask framework with scalable add-ons for external collaborations
- Database for modules, inverters and material reflection properties
- GPU property computation engine for complex tasks as shading at cell level or bifacial irradiance evaluation
- Detailed yield analysis and uncertainties analysis through in house developed Python scripts

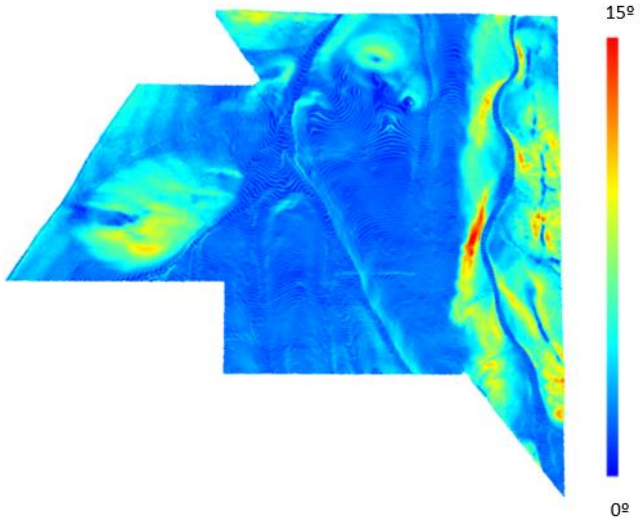
# Shading of power lines

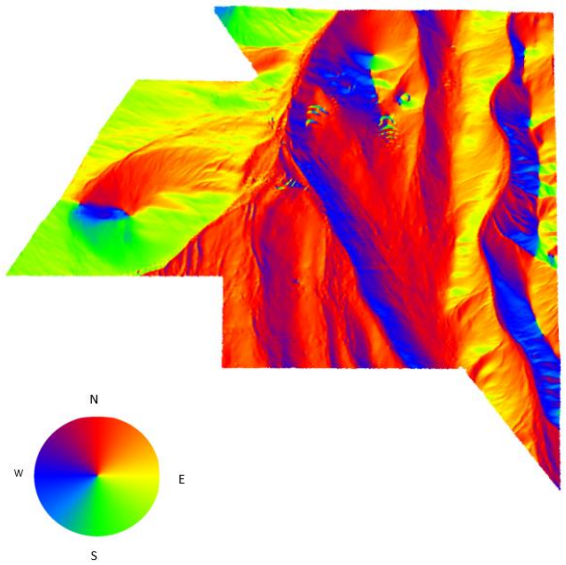


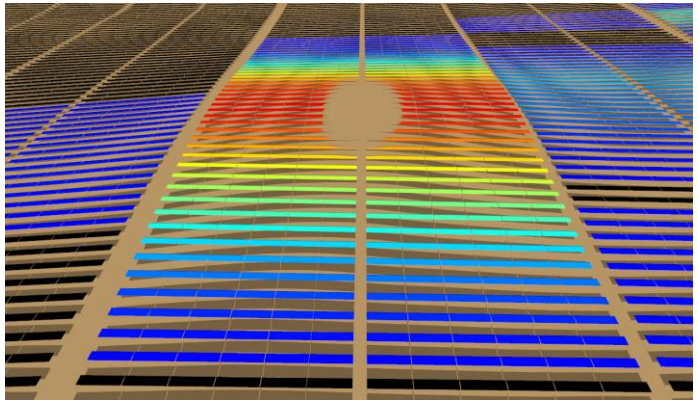


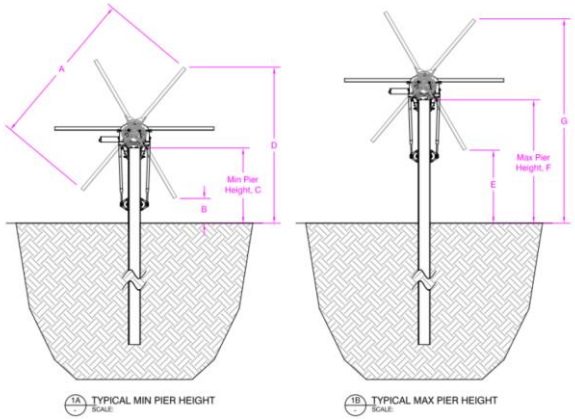
- Shadows from tiny elements (tower and wires) located in the perimeter of the installation area
- 1 axis trackers with backtracking implemented
- Electrical line along the west section of the perimeter
- Year electrical losses simulation
- Output – Cost function of electrical losses as a function of distance of the tracker to the line

# Irregular terrain implementation



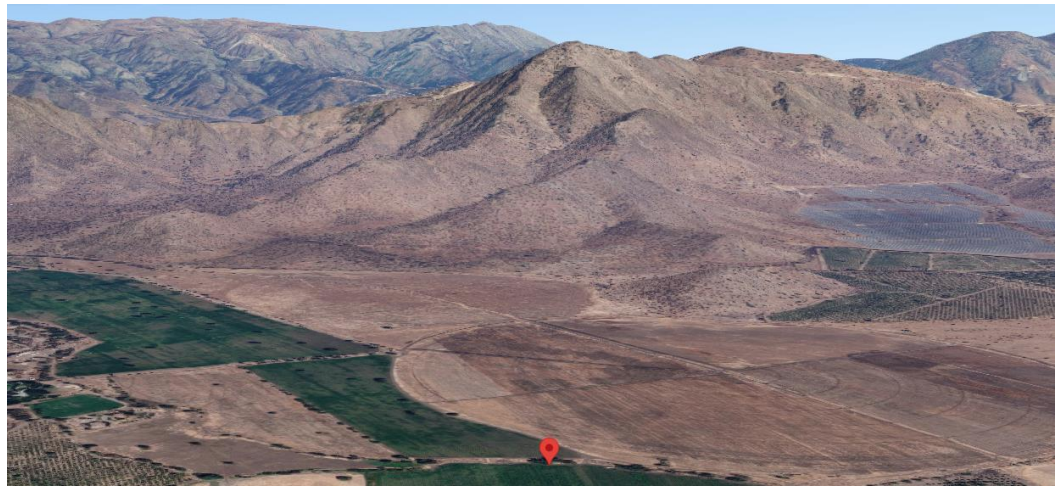



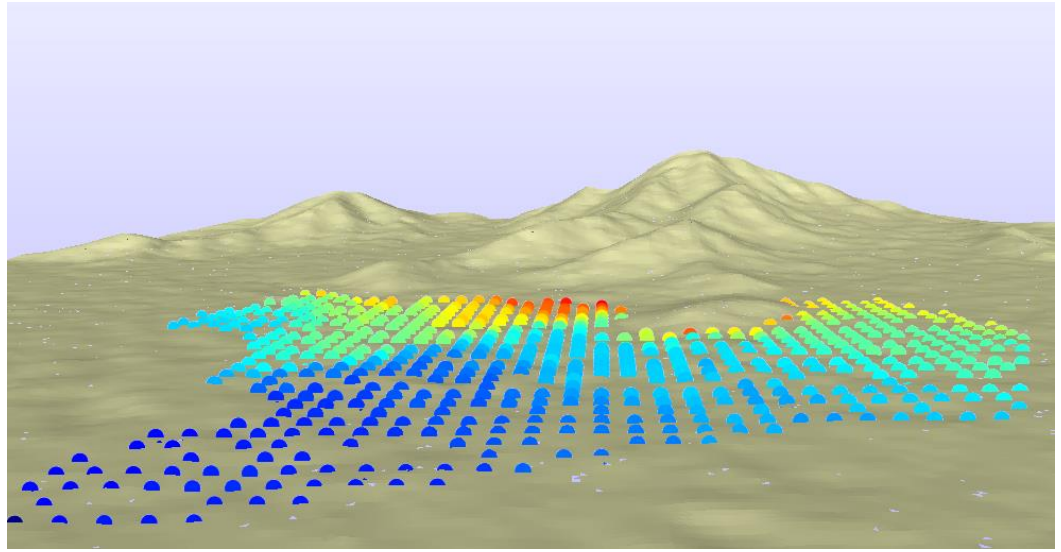






- Complex terrain – Detailed 3D analysis to evaluate installation constraints and create slopes histogram for further shading and bifacial analysis per sector
- Installation analysis based on height fixation points constraints – Evaluation of individual trackers' slopes and terrain movement needed
- Cost function generation of installable MW of trackers versus economic cost of terrain rework

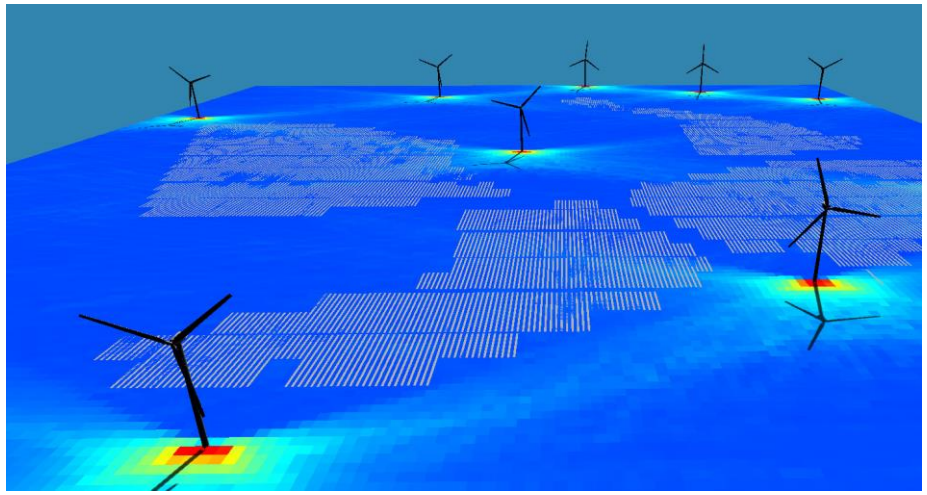
# Shading of near terrain

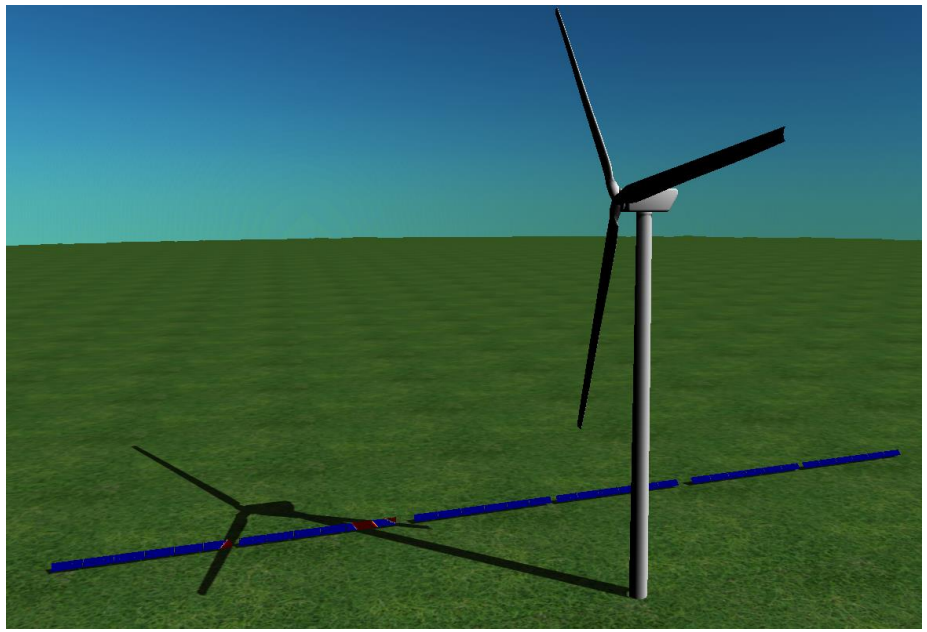




- Hybrid requirements for horizon (hill too close to be considered as far shading)
- 3D generation of the plant surroundings (5-10 km) from terrain radar data
- Heatmaps of different shading areas (direct irradiance and diffuse one) depending on tracker installation place for a complete year
- Detailed yearly analysis for each location of a 1 axis tracker including bifacial gains

# Wind farm dynamic shading

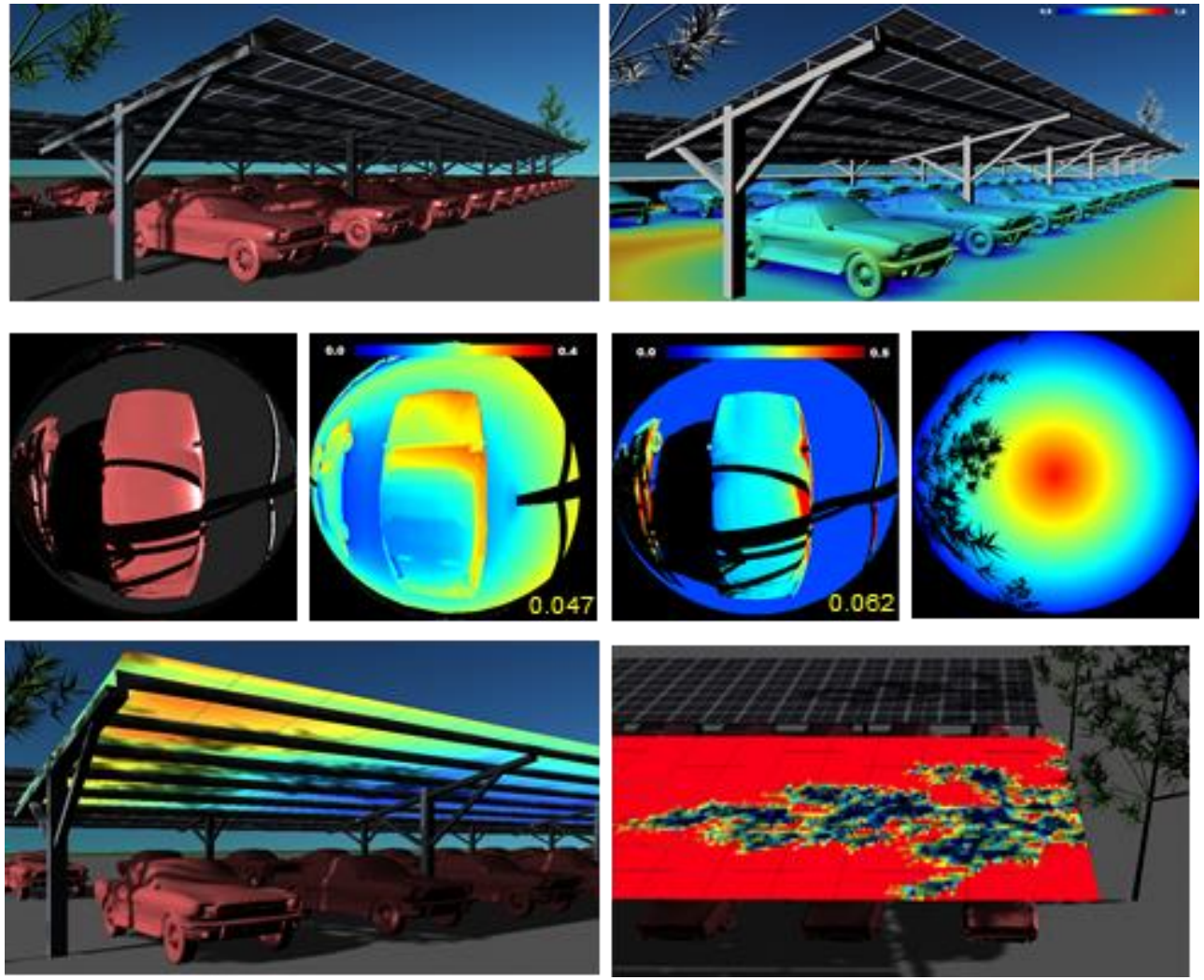




- Shading analysis from static (wind towers and pole) and dynamic elements (blades)
- Cumulative shading through a Monte Carlo analysis
- Cost function – Yearly energy loses on trackers as a function of relative position and distance to the nearest wind turbine
- Study presented in PVSEC 2021

*PVSEC 2021 – Dynamic simulation of the shading cast by a wind farm on an adjacent photovoltaic plant*

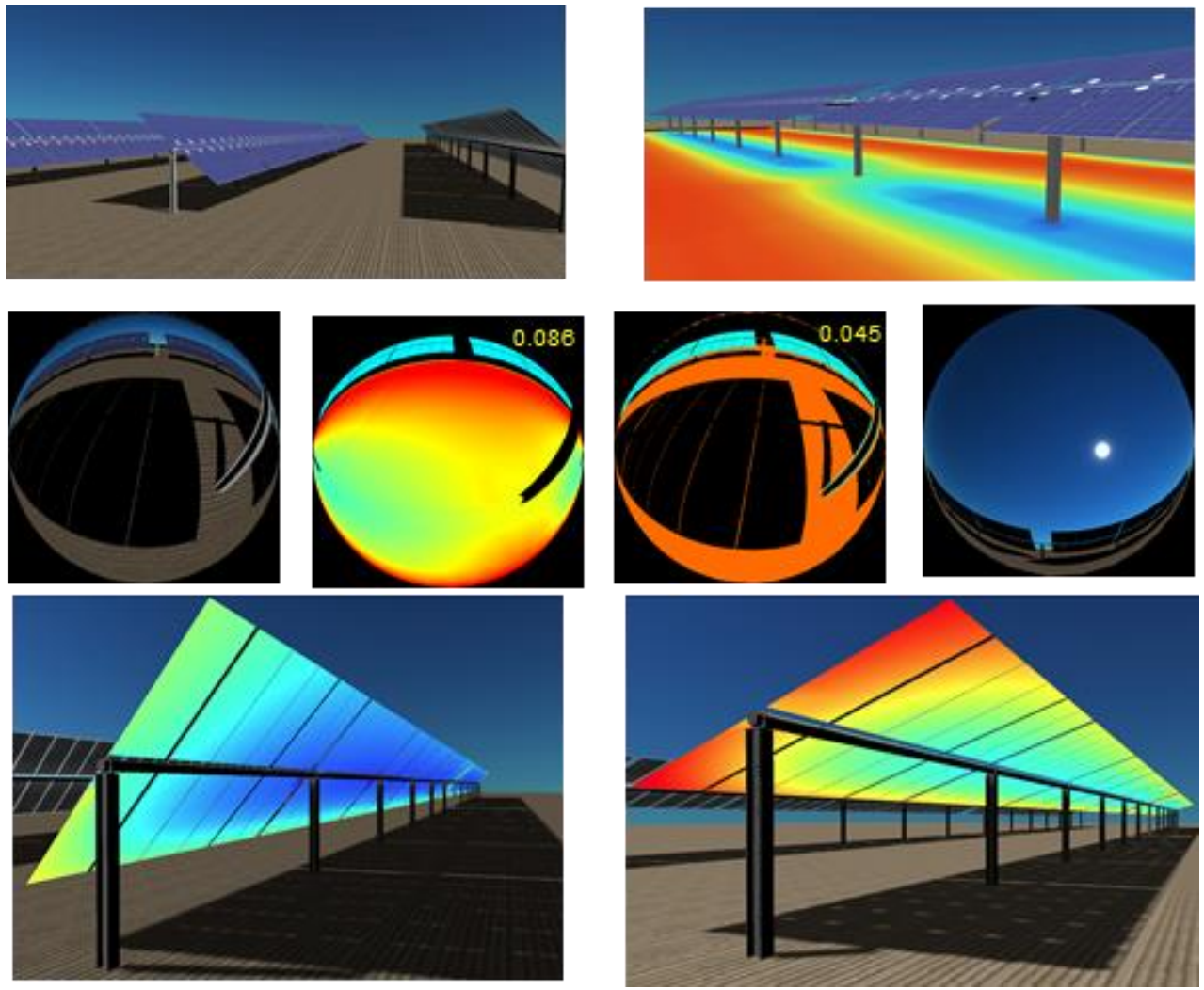
# Bifacial – Fixed structures and obstacles




- Rear irradiance affected not only by albedo variety (different from ground or obstacles), but also by geometry of the obstacle
- Irradiance decomposition on diffuse contribution (depends on material diffuse albedo and sky visibility) and direct sun light reflections (affected by posible shading effects)
- Property methodology using GPU rasterization of 180º spheric views
- Methodology presented at PVSEC 2021

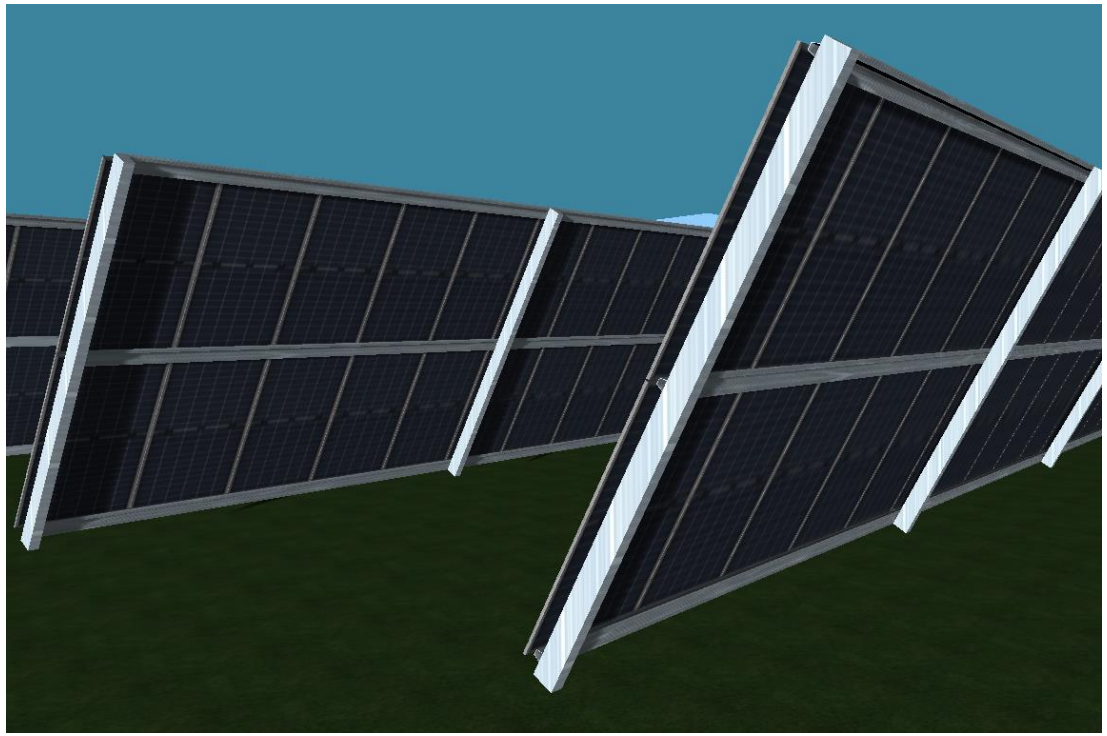
*PVSEC 2021 – Dynamic and visual simulation of bifacial energy gain for photovoltaic plants*

# Bifacial – 1 axis trackers



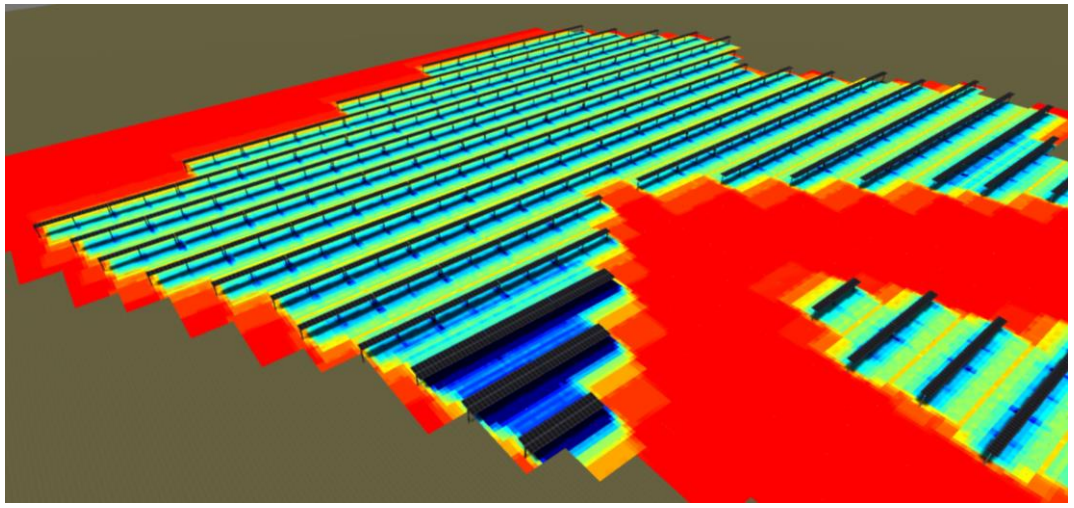

- Identical methodology, but trackers movement changes the field of view from each point from one instant to another
- Ground and objects diffuse capability potential is time dependent (due to trackers rotation)
- Rear structures and module layout has an influence in the rear irradiance (details under study)
- Non homogeneity in the rear side variable with time has a mismatch effect (detailed evaluation on going)

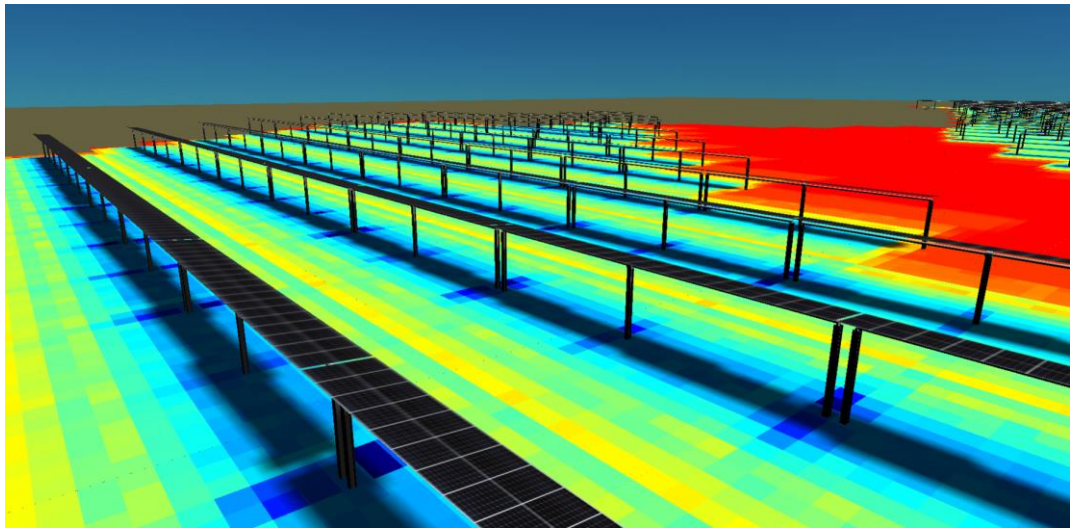
# Bifacial - Rear structure influence (on going)



- Different studies showed that losses of irradiance gain on the back side could be reduced up to 30% due to the structure
- Different parameters as beam thickness, width, distance to modules, layout… has a variable influence
- Trade off for different configurations under study and planned to be presented in next PVSEC 2022 conference

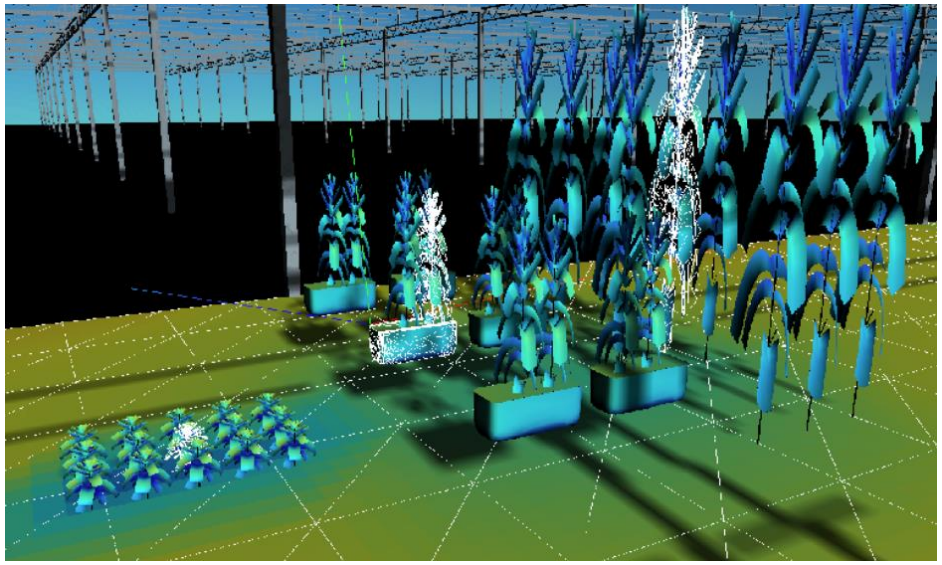
# Agrivoltaics – Terrain shading





- Demands of tradeoffs for ground coverage versus cumulated irradiance over the ground for plants grow potential
- Dynamic analysis of direct and diffuse irradiance over a complete year
- Different parameters analyzed as trackers ground distance, arm length, pitch distance between trackers, orientation…

# Agrivoltaics – Greenhouses



- Geometric effect of greenhouse structure both in diffuse and direct components impacting both to the reflected irradiance to the rear side of the modules and the plants growth potential
- Different configuration of plants studied, in terms of shape, distance, separation between them, type of growth…
- Effect of transmissivity and diffusion of light through greenhouse glass walls
- Spectral effects analysis on going
- Study to be presented at next PVSEC conference

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# Thanks for your time!

# Any questions?