Integrating 3D PV design and yield simulation: challenges and opportunities

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We are PVcase

Our focus on automation and accuracy from the earliest stages of planning, incorporating 3D topographical data points to simulate the actual location of the solar plant, allows our customers to be able to compete for and win more projects by delivering greater yields.

GROUND MOUNT PVcase

10GW+
Projects designed

500+
Clients

50+
Countries

Agenda

01 Digital interoperability

02 Process integration

03 PVcase Yield

04 Case studies

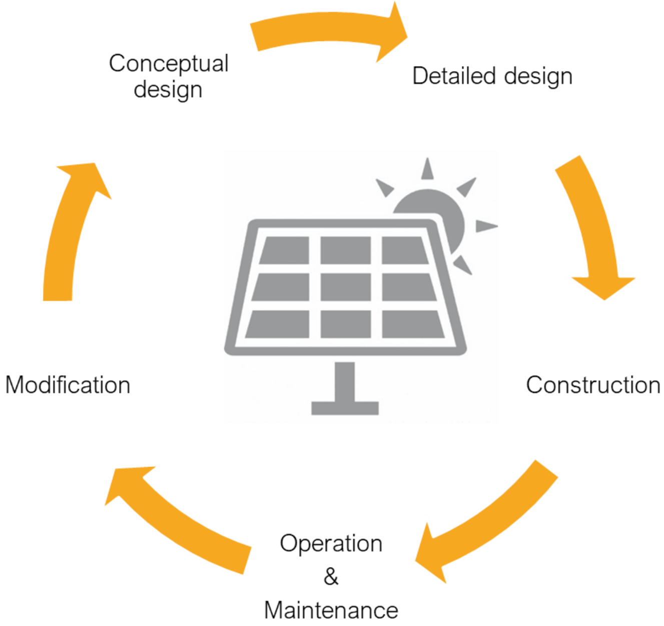
Digital interoperability in PV

PV project lifecycle

- TRUST-PV project:
  - reach a demonstrated increase in performance and reliability of solar PV components, solar PV systems, and in large portfolios of distributed and utility-scale solar PV

- Challenge: PV digital services focus on specific processes
  - Repeated, error-prone model re-creation
  - Inefficient transition between stages
  - Lack of *single source of truth*

- Answer: interoperable information models



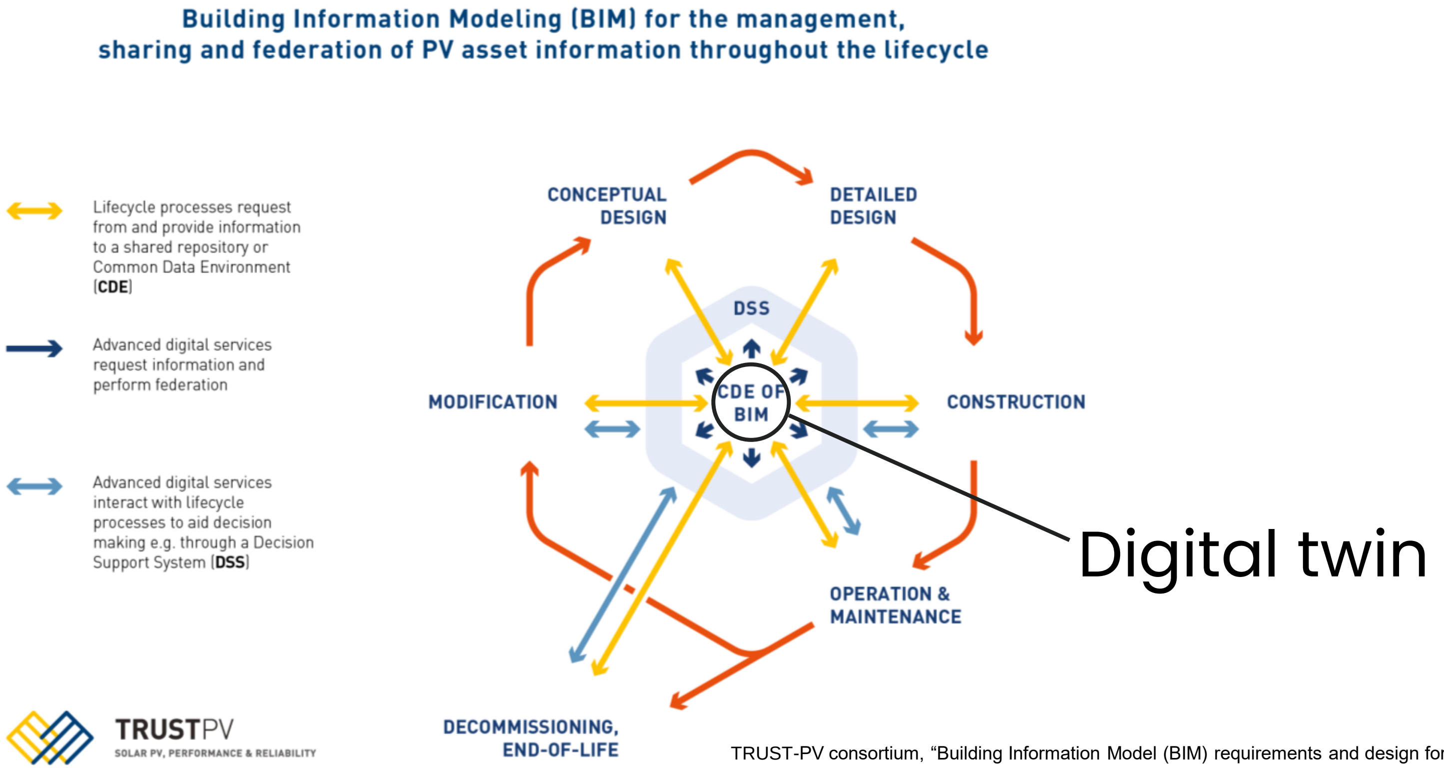
PV digital twin

- PV Digital twin in TRUST-PV
  - Parametrized (2D/3D) model of a PV system that contains all physical information needed to simulate the behavior and performance of its real counterpart.
- Excludes:
  - Operational data, Weather data, Ticketing data, ...

- There is a need for a standardized digital twin: generally valid for all lifecycle processes
  - Real-world geo-spatial context and PV module geometry (2D or 3D)
  - Real world functional connectivity (mechanical, electrical)
  - Real-world component properties and unique component identifiers
  - Change tracking using a versioning system
  - Standardized, open format

TRUSTPV
SOLAR PV, PERFORMANCE & RELIABILITY

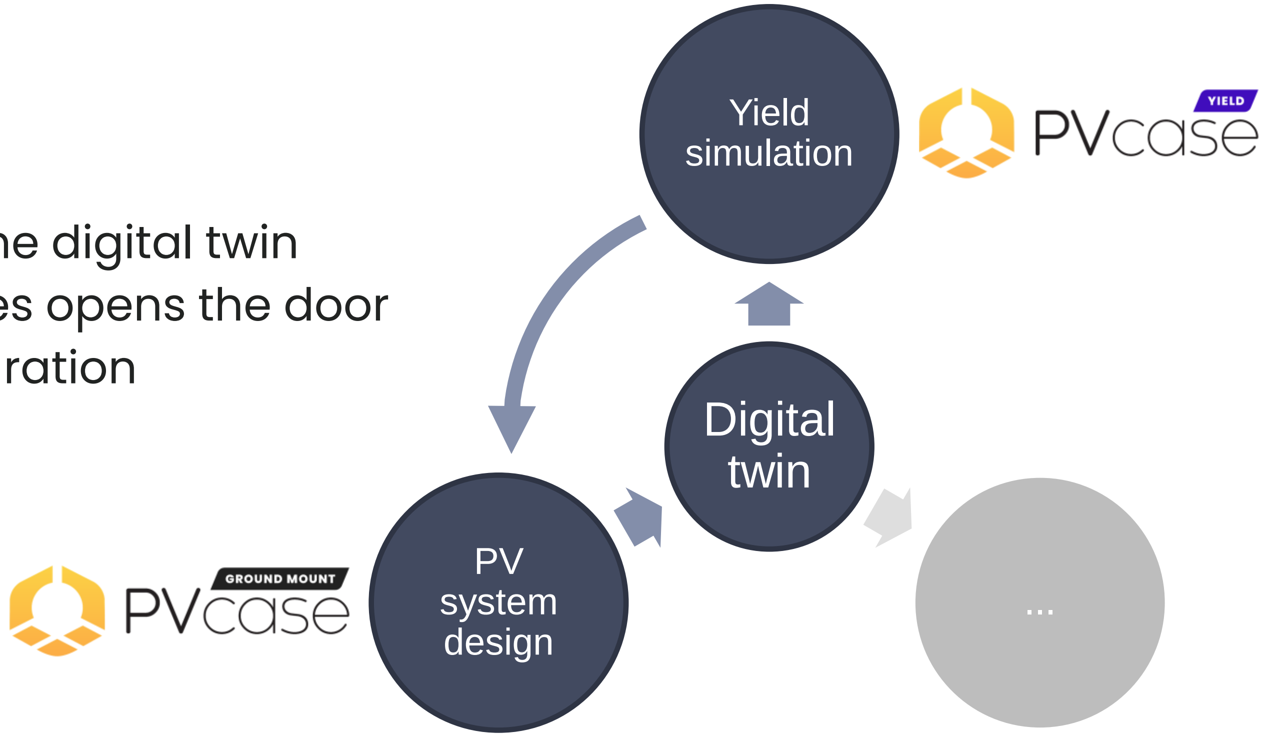
BIM for PV in the TRUST-PV project



TRUST-PV consortium, "Building Information Model (BIM) requirements and design for the operational phase," Deliverable report, 2021. [Online]. Available: https://trust-pv.eu/wp-content/uploads/2021/10/TRUST-PV_T3p4_report_Final.pdf

PVcase: from design to Yield

- Sharing the same digital twin across processes opens the door to process integration



Goals of integration

- Easy access to energy yield assessment in the engineering & design phase:
    - **Unlock *energy yield* as a quantitative design variable**

- Technology agility, software to drive PV technology innovation
    - Physics-based models (as opposed to empirical ones) have a large range of validity
        - Ability to simulate something that has never been done before

Introduction to PVcase Yield

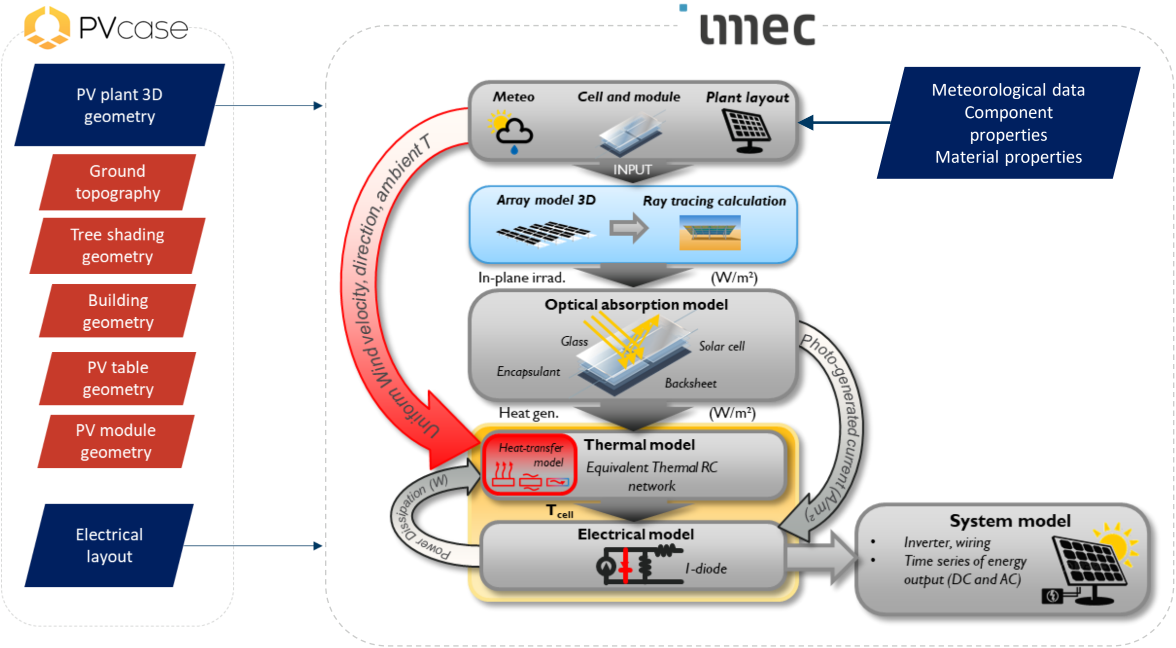
Software requirements

- Capable of processing CAD design files of varying readiness
  - Preliminary layout
  - Optimized, detailed layout in 3D
  - Detailed layout + electrical design
- Using physics-based models in order to
  - Relate design variables and energy yield
  - Minimize additional assumptions and empirical inputs, human effort
  - Reduce uncertainty, improve traceability of yield assessment

YIELD PVcase

Technology background

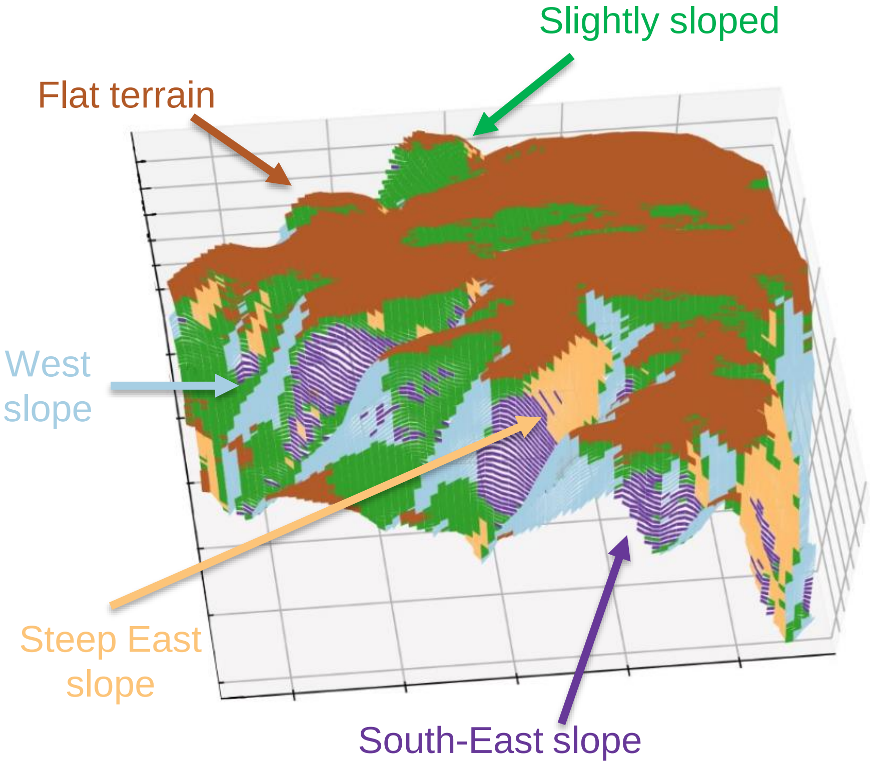
- PV energy yield simulation software based on Imec's technology



- Optical simulations: ray tracing
- Thermal-electrical simulations: coupled, equivalent RC network
- ML-based model reduction algorithm

Model reduction algorithm

- Reduction → simulation → upscaling
    - Group strings with similar irradiance patterns:
        - Technology, tilt, azimuth, shading conditions, reflection conditions
    - Perform simulation on each group
    - Combine results, scale to original plant
- Large reduction in computing time
- Limited impact on end-result (yield)

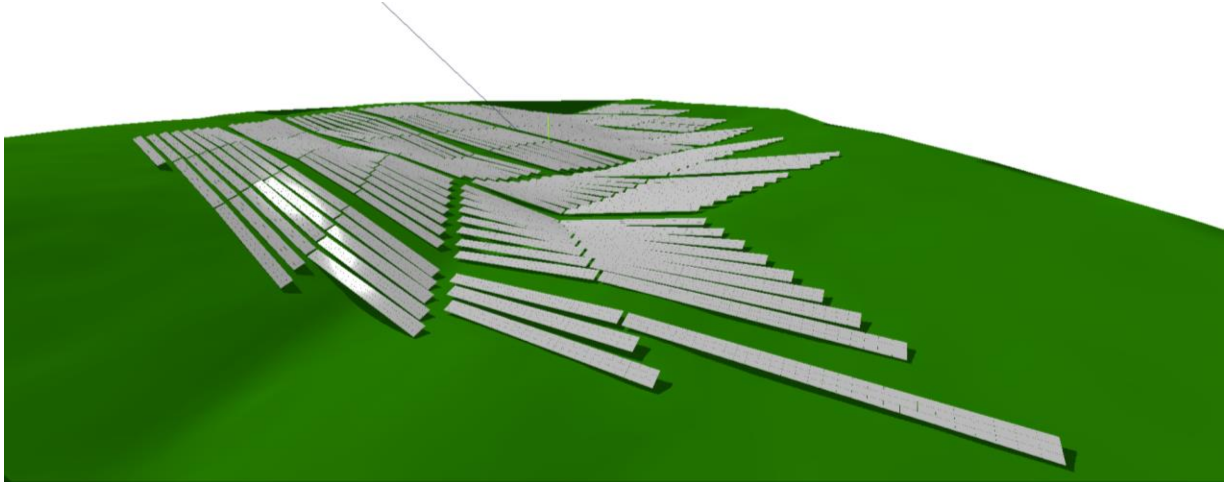


PVcase Yield main features (1/3)

- Import 3D PV plant models directly from PVcase Ground Mount
    - Varying readiness and detailing

PVcase Yield main features (2/3)

- Lighting simulation using 3D ray tracing
  - Effects of 3D frames, 3D terrain, arbitrary shading objects, reflection (bifacial)
  - First in industry for large-scale PV systems

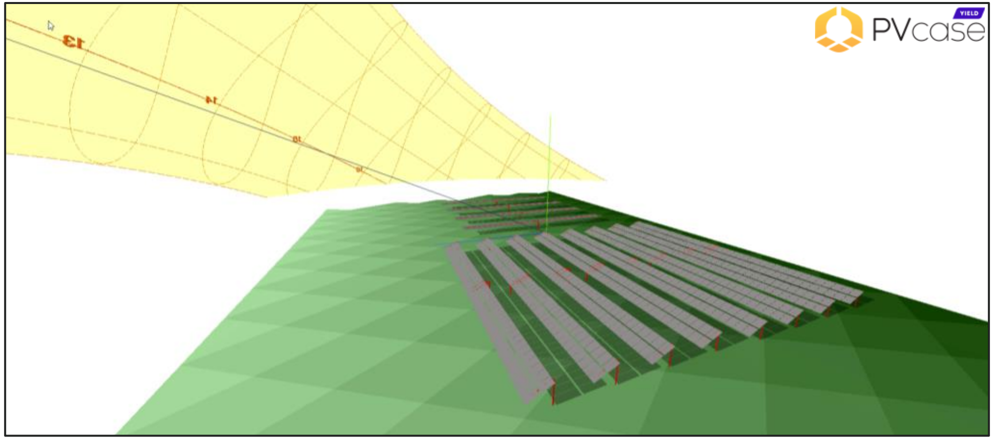


PVcase Yield main features (3/3)

- Thermal-electrical modelling at module-level resolution
  - Using electrical information (incl. cabling) designed in CAD
  - Or proposing optimal arrangements
  - Solved for each individual inverter and MPPT
    - Providing spatio-temporal performance and loss insight
- Cloud-based computing
  - No need for user-side supporting hardware resources and infrastructure
- Convenient user interface
- Product status: user trials

Validation

- Publicly available PV performance dataset thanks to PEARL-PV WG3 [1]
- Bifacial, monofacial, fixed-tilt and HSAT, utility PV-type construction
- Used for: internal due diligence study, validation, improvements

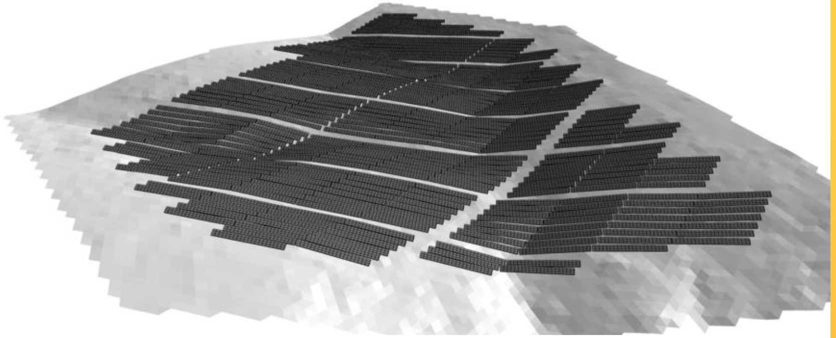


[1] Riedel-Lyngskaer et al. *Validation of Bifacial Photovoltaic Simulation Software against Monitoring Data from Large-Scale Single-Axis Trackers and Fixed Tilt Systems in Denmark*, 2020

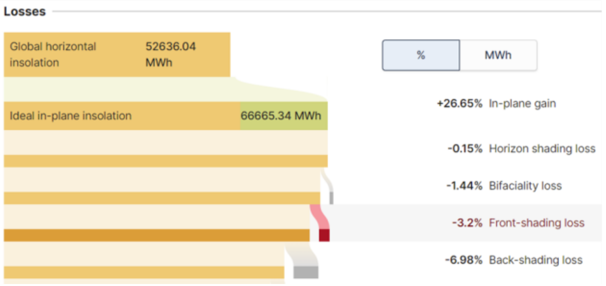
Case studies

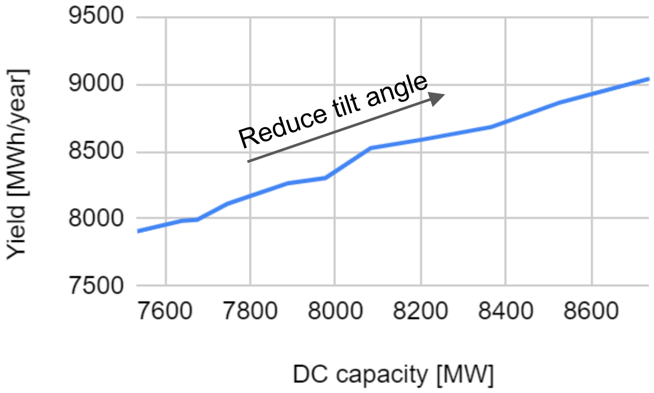
Optimize 3D layout on real terrain

- Try different frame arrangements
    - Ground Mount: Smart and quick layout generation, respecting design criteria e.g. shading limit angle



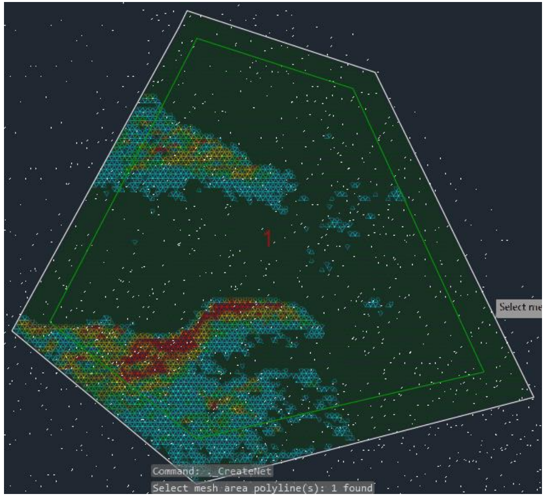
- Maximize capacity, yield, limit shading

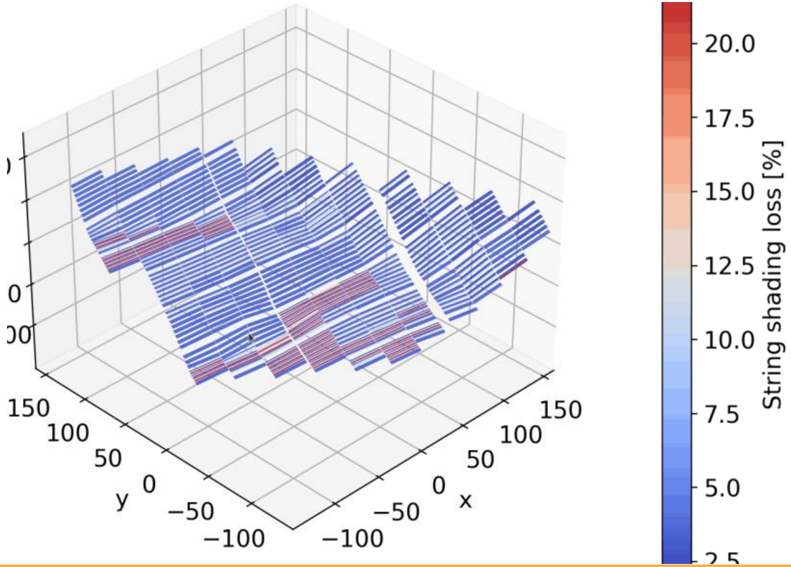




Problematic areas: quantify losses

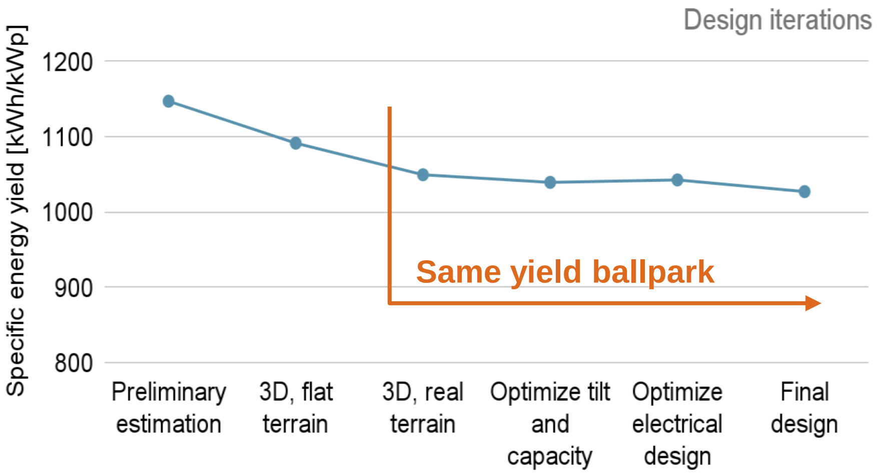
- Ground Mount: civil analysis → identify problematic areas (north slope)
- Yield: quantitative, 3D analysis of losses thanks to 3D ray tracing
- Confirm problematic areas, estimate cost-benefit of eliminating problems
    - excluding area? ground grading?





Early stage yield estimation accuracy

- Coupling 3D design and energy yield simulation
  - Information-rich models available from an early stage: more realistic preliminary yield estimates



Conclusions

- PVcase Ground Mount
    - Better PV plant designs, more accurate cost estimates, accelerated engineering process
- PVcase Yield
    - Energy yield simulation based on 3D ray tracing and physics-based models
- Integrating PV plant design and yield simulation through digital twin
    - Enable energy yield as design variable, provide quantitative inputs for decisions
    - Improve early-stage yield estimation accuracy
    - Step towards interoperable PV software
- Next up
    - 3rd party due diligence, **we are looking for partnerships**

Thank you

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