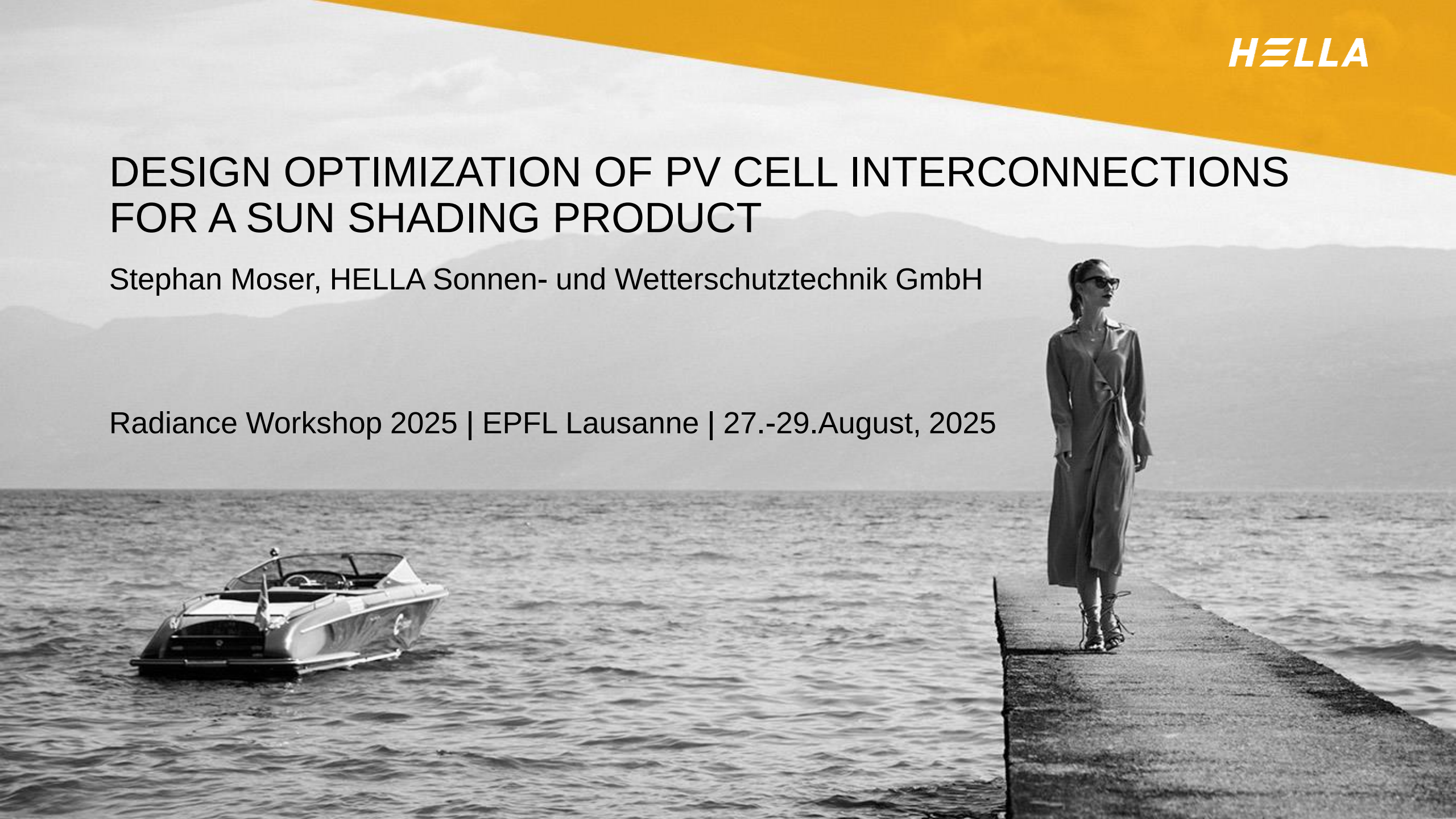


DESIGN OPTIMIZATION OF PV CELL INTERCONNECTIONS FOR A SUN SHADING PRODUCT

Stephan Moser, HELLA Sonnen- und Wetterschutztechnik GmbH

Radiance Workshop 2025 | EPFL Lausanne | 27.-29.August, 2025



CONTENT

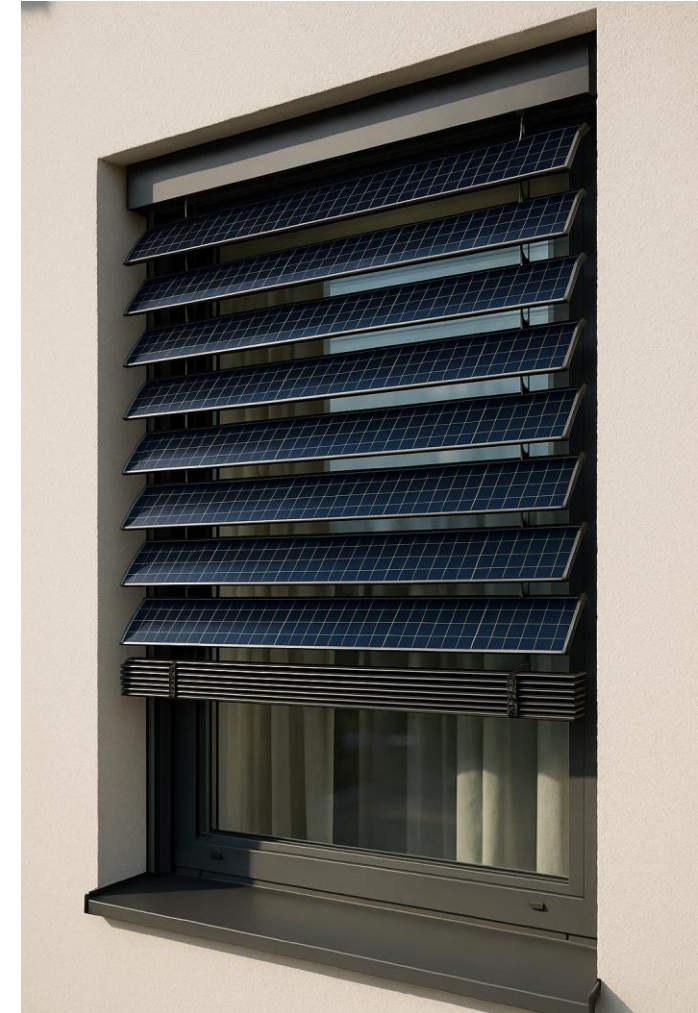
- Motivation
- Sunplugged - PV Technology CIGS
- Method
- Simulation
- Results
- Conclusion

MOTIVATION

- Integration of photovoltaic cells into sun-shading slats
- Enhancing the functionality of the sun-shading system
- Evaluation of various sun-shading product types
- Focus to thin-film technology
- Shading challenges from nearby buildings, trees, surrounding mountains and self-shading effects from the pergola's own structure
- Evaluation different PV module interconnections to mitigate the effects of partial shading

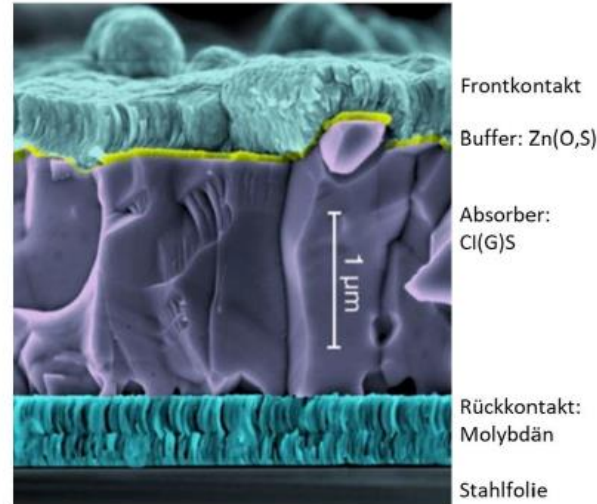


Generated by ChatGPT



SUNPLUGGED GMBH

- Sputter-Hybrid process
- Full Roll2Roll process at 300mm width
- In-house measurement equipment for analysis



Layer Structure

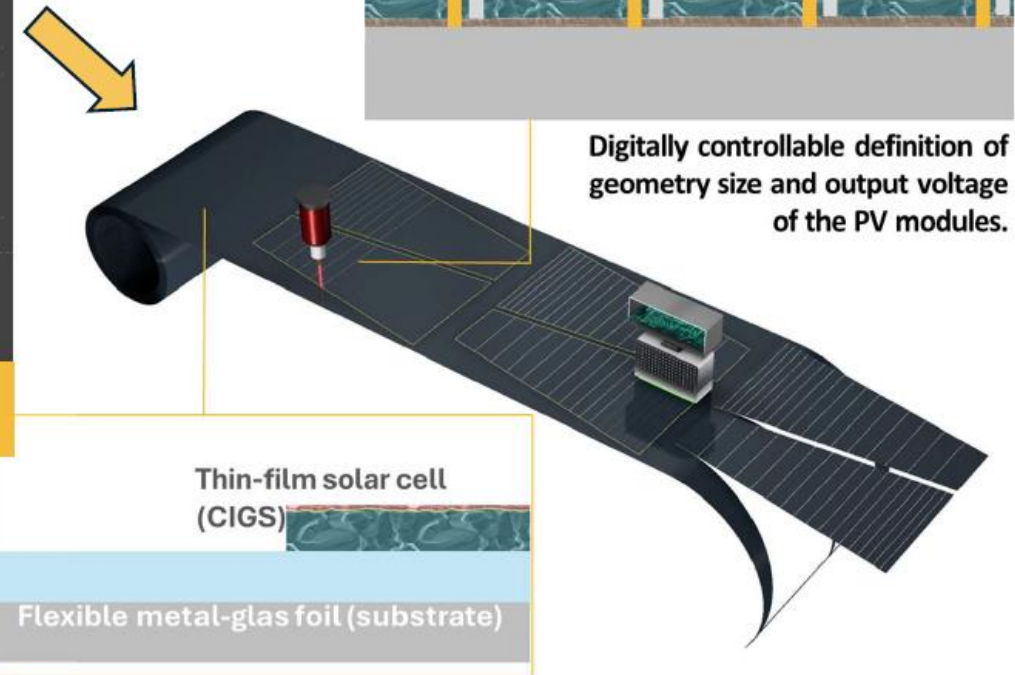
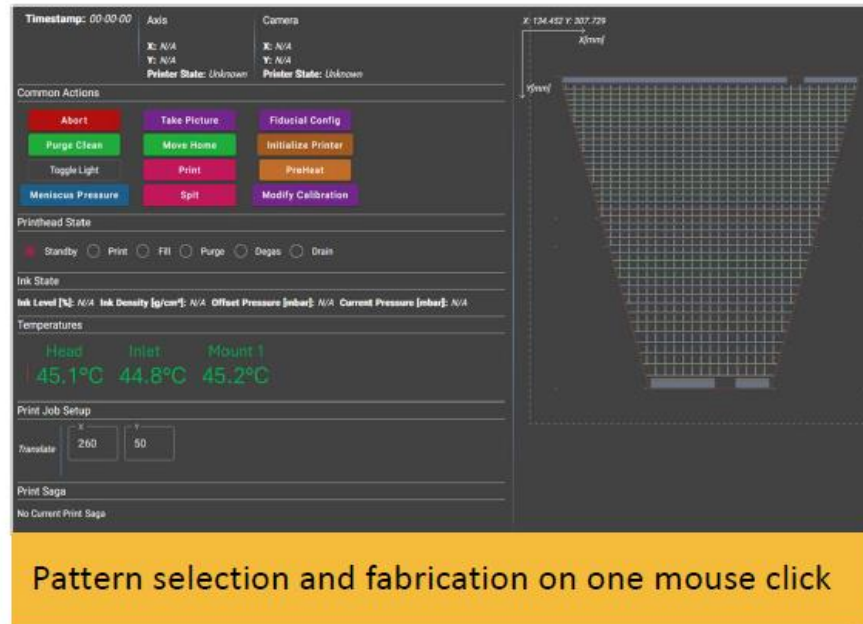
Link: (<https://www.zsw-bw.de/>)



Deposition of the absorption layer (CIGS)



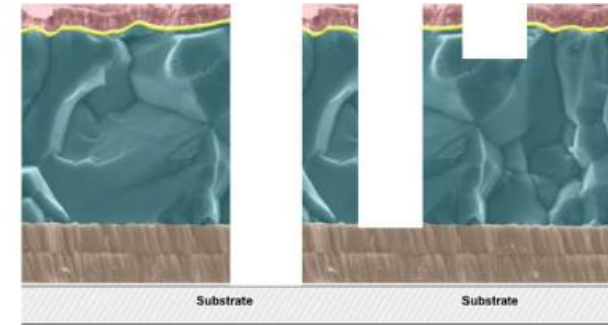
CUSTOMIZED MODULE INTERCONNECTION



CUSTOMIZED MODULE INTERCONNECTION LASER PROCESS

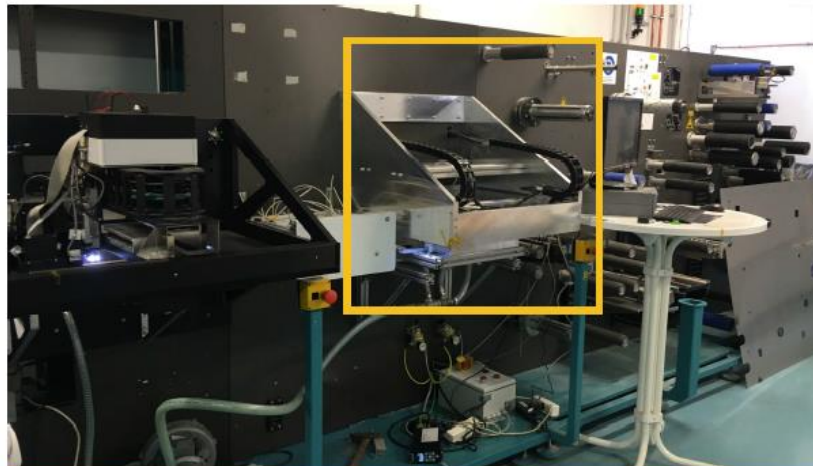


Roll-to-roll laser process

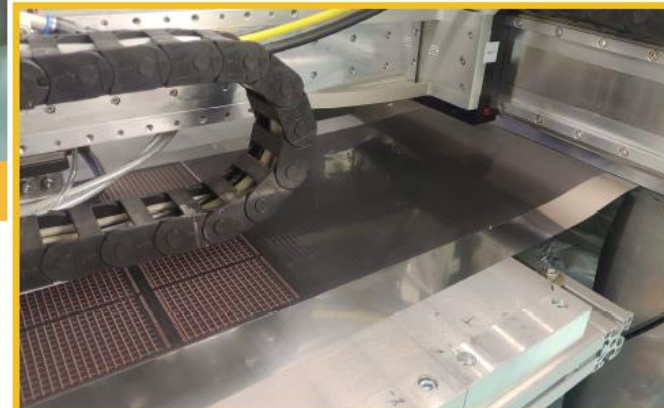
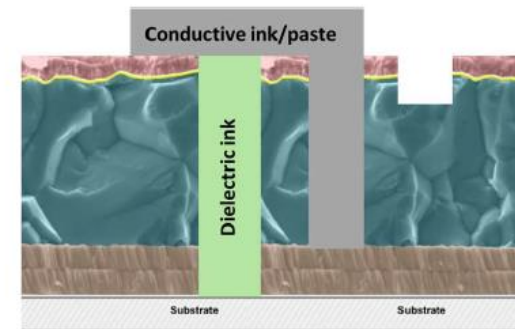


Number of cells defines the output
voltage

CUSTOMIZED MODULE INTERCONNECTION CONDUCTIVE PRINTING

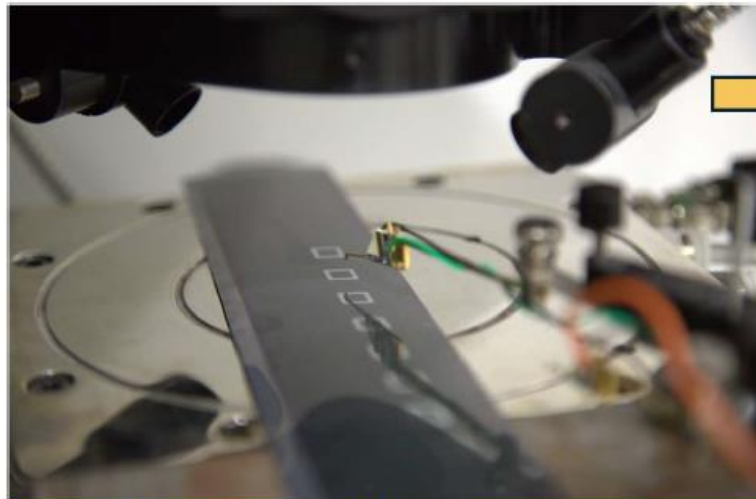


Fully automated roll-to-roll interconnection line

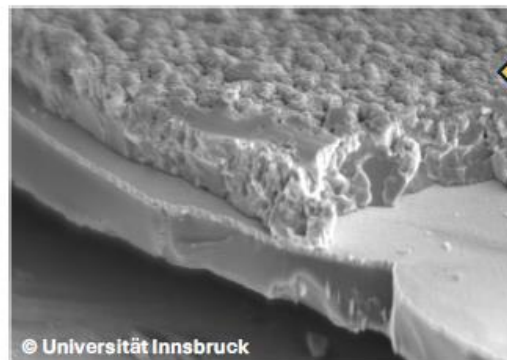
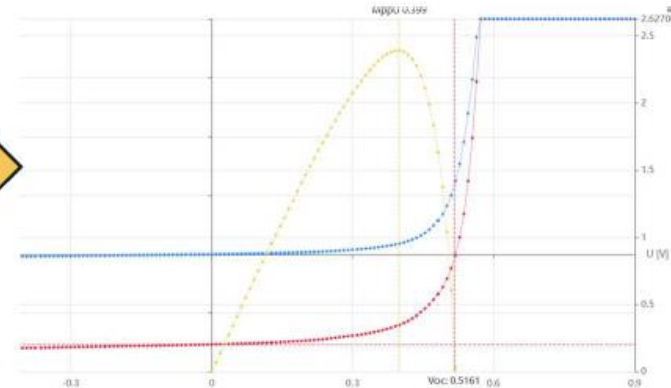


Serial interconnection of modules

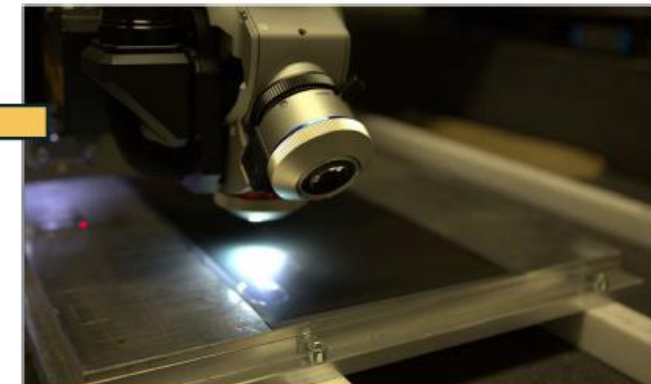
ANALYSIS OF THE FINISHED SOLAR CELL



IV characteristics to analyze performance

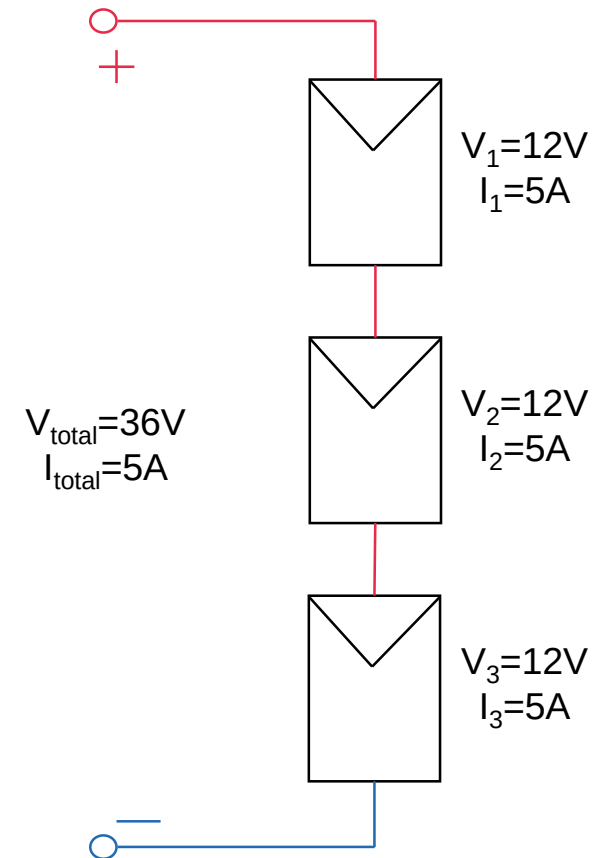
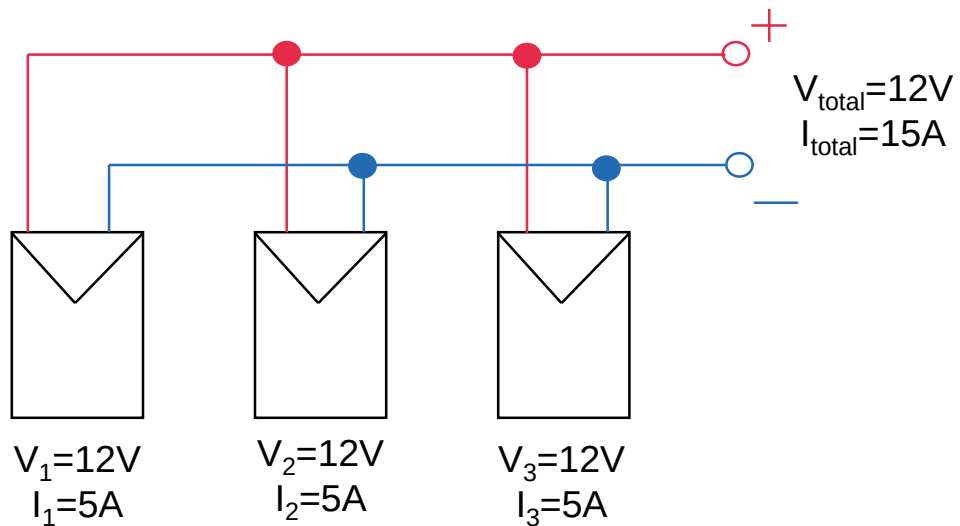


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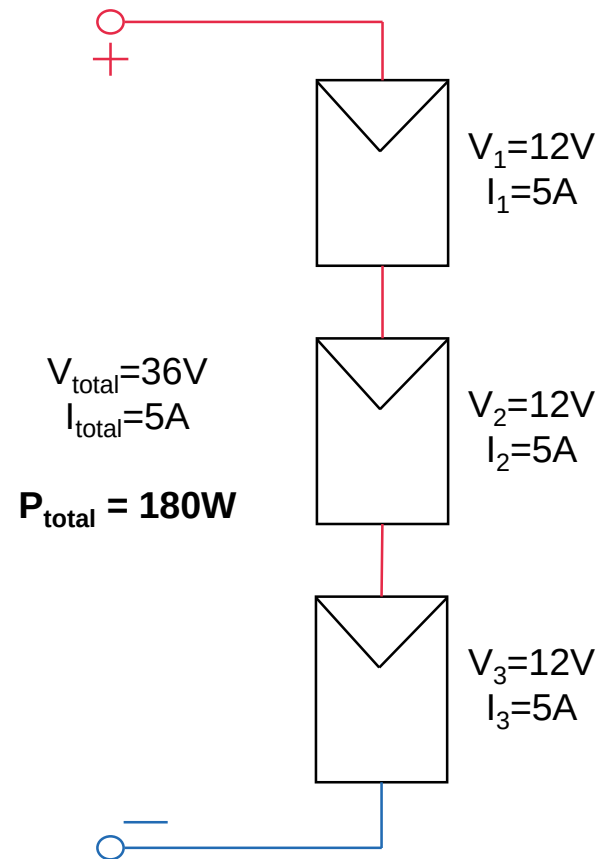


Optical inspection

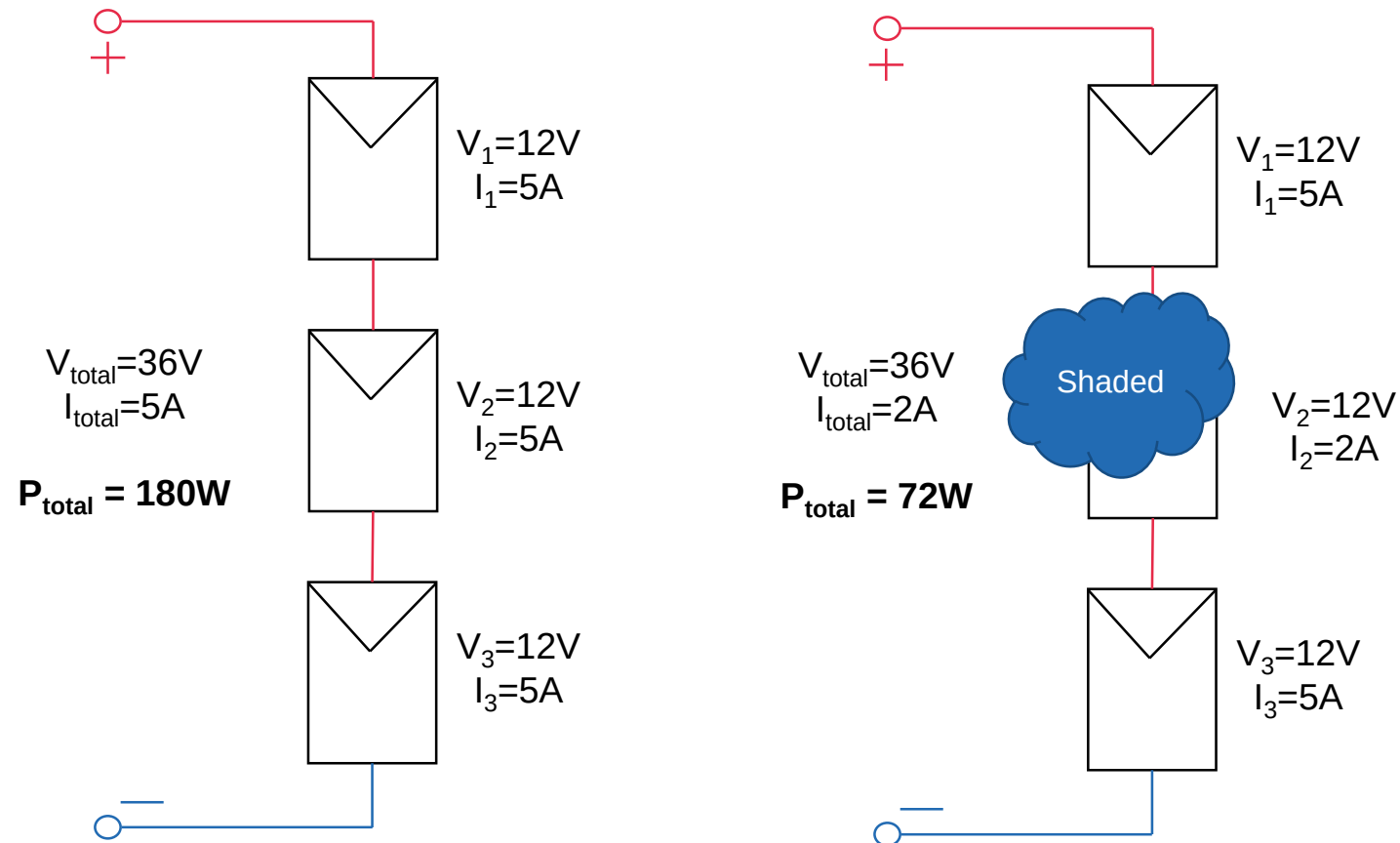
SERIAL AND PARALLEL CONNECTION



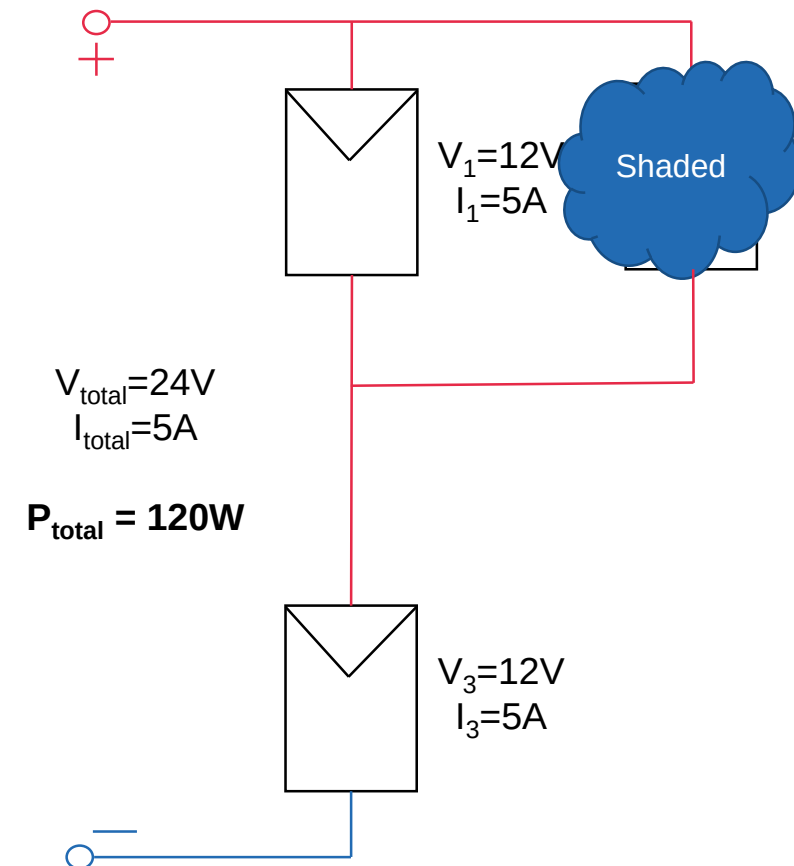
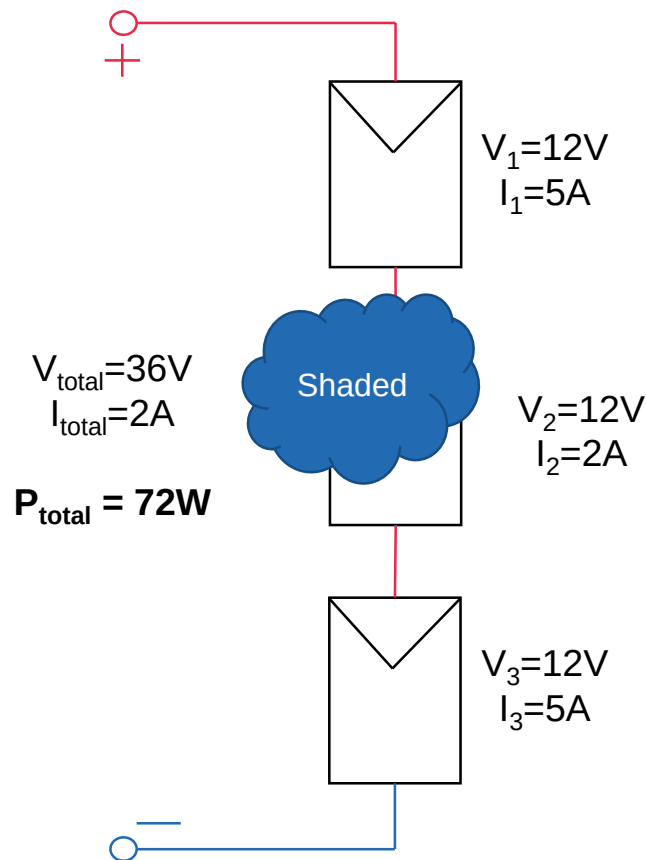
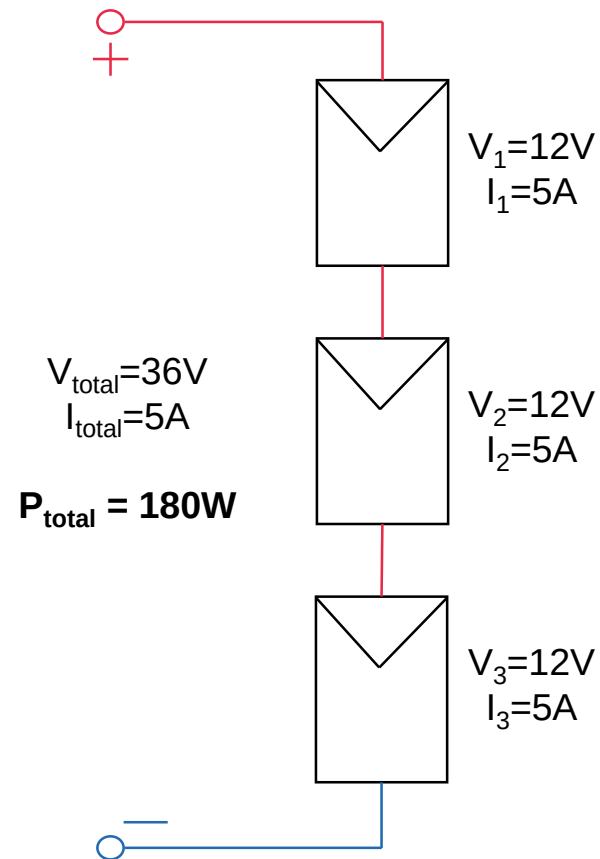
SHADING LOSSES OF PV MODULES WITH SERIAL CONNECTION



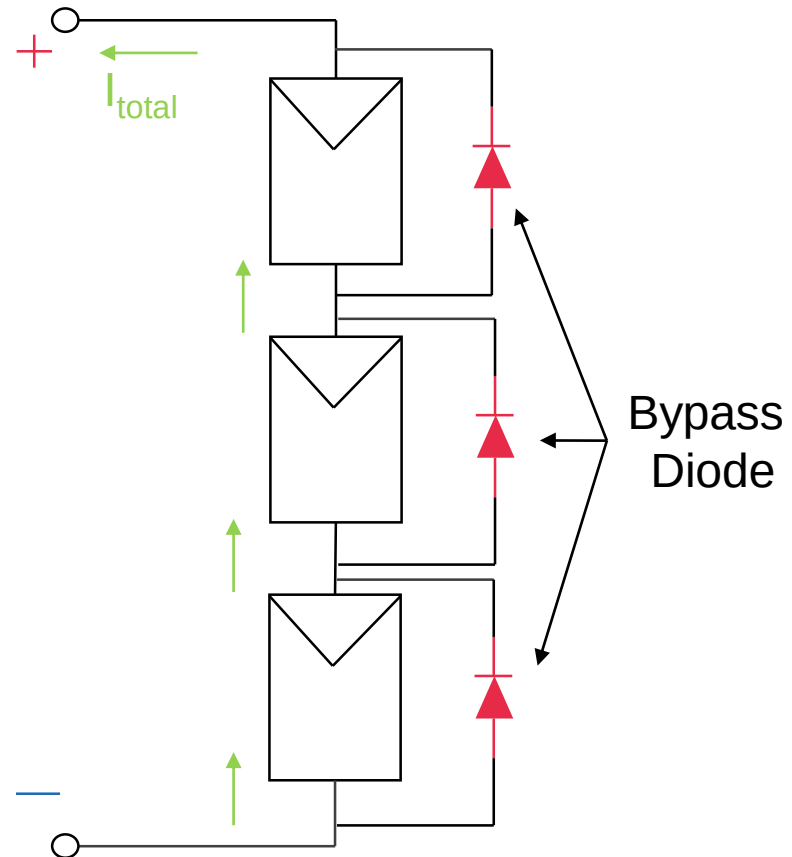
SHADING LOSSES OF PV MODULES WITH SERIAL CONNECTION



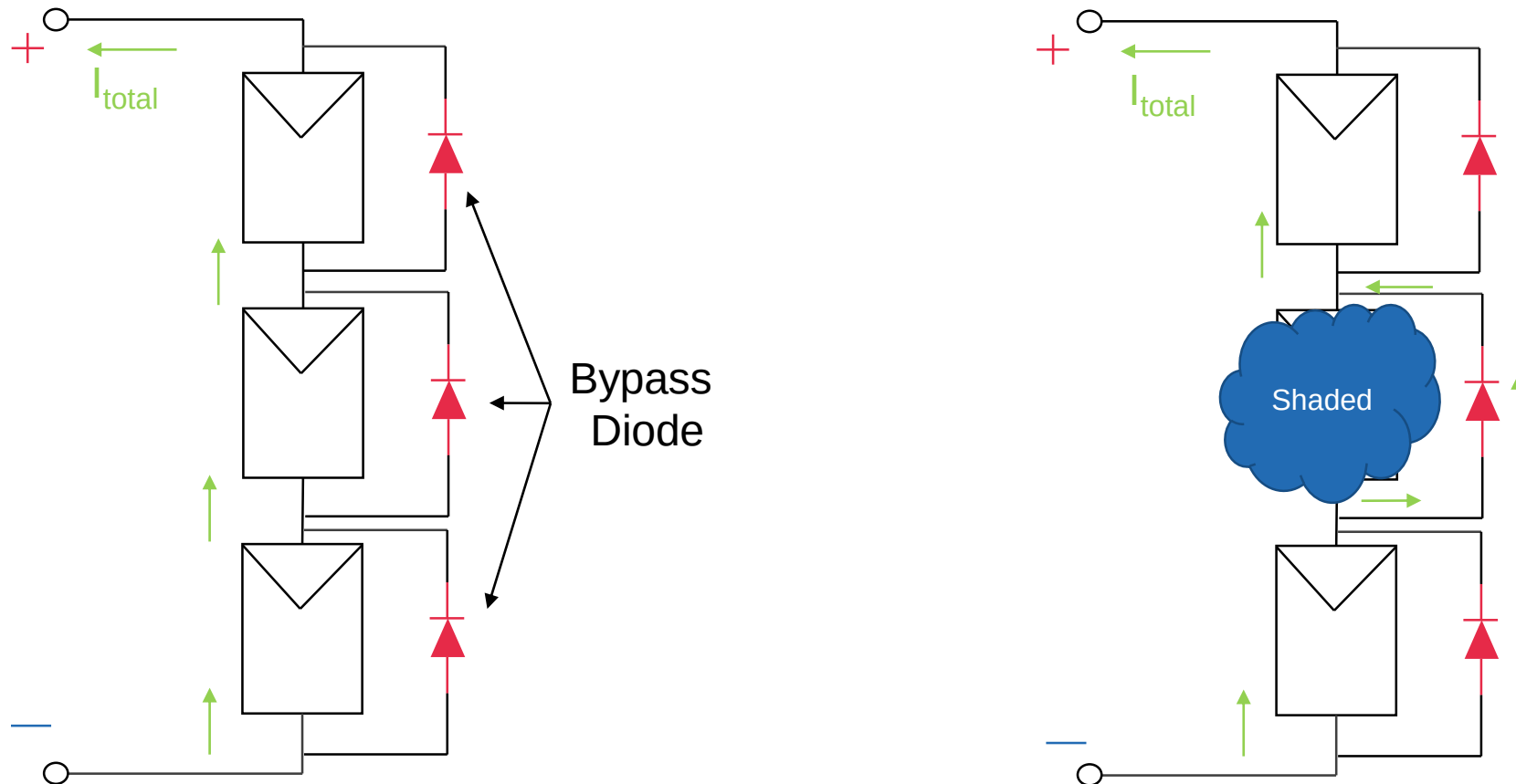
SHADING LOSSES OF PV MODULES WITH SERIAL CONNECTION



OPTIMIZATION INDUSTRY: BYPASS DIODE

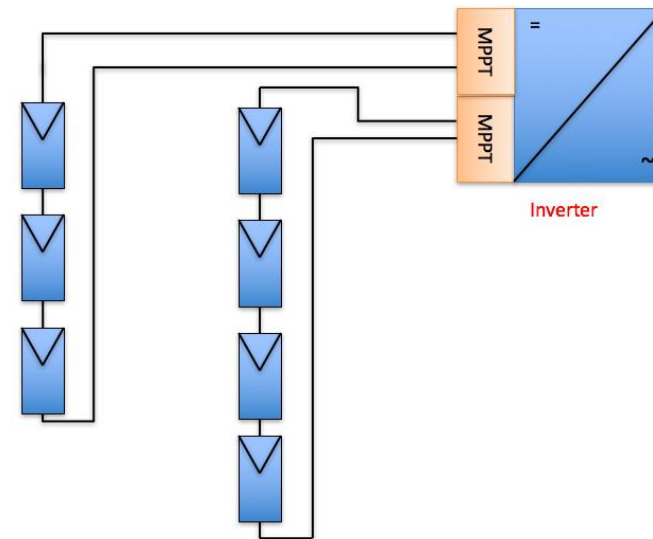


OPTIMIZATION INDUSTRY: BYPASS DIODE



OPTIMIZATION INDUSTRY: STRING INVERTER

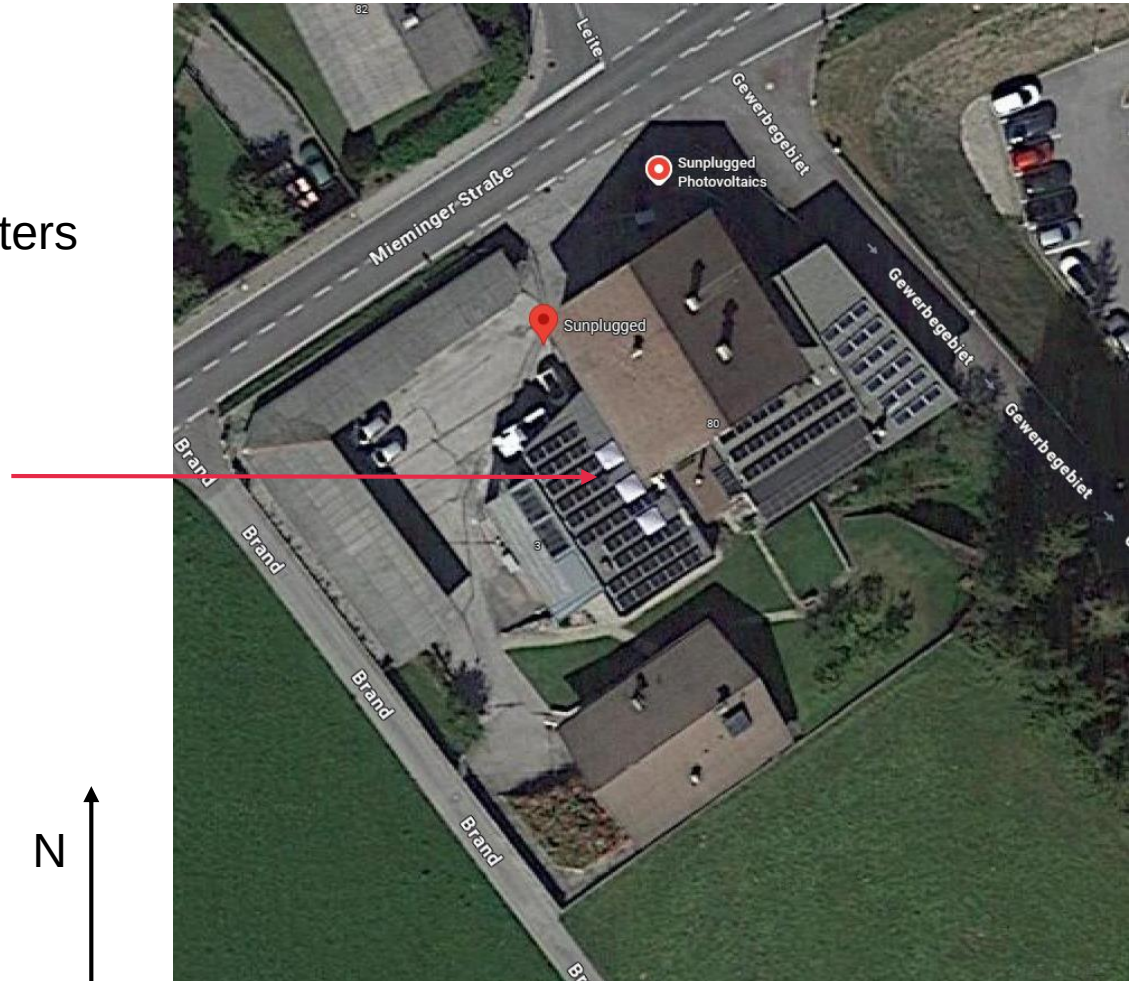
- PV installations with string inverters
- Each group of panels in series is called a string
- Each string is connected into a separate input on the inverter



<https://www.solarquotes.com.au/blog/an-eastwest-split-of-solar-panels-on-a-single-string-can-work-well/>

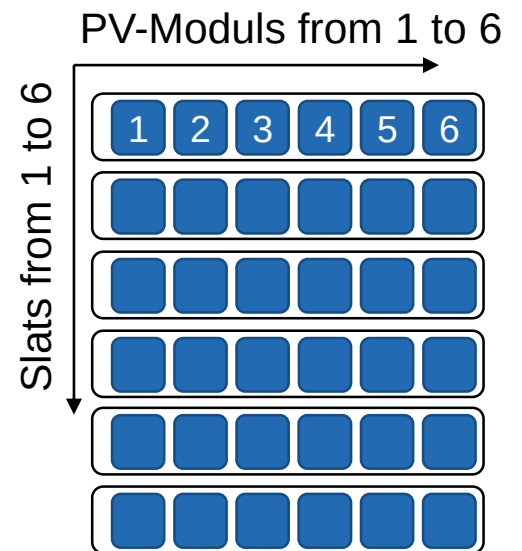
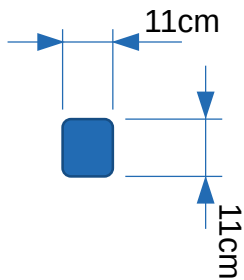
METHOD

- Simulation and construction of a small-scale pergola demonstrator with photovoltaic slats at the headquarters of Sunplugged GmbH, Wildermieming, Tyrol
 - Latitude: 47.312 Longitude: 11.005



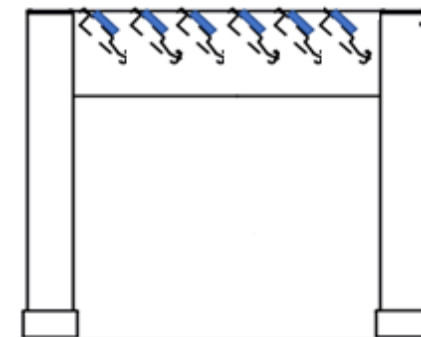
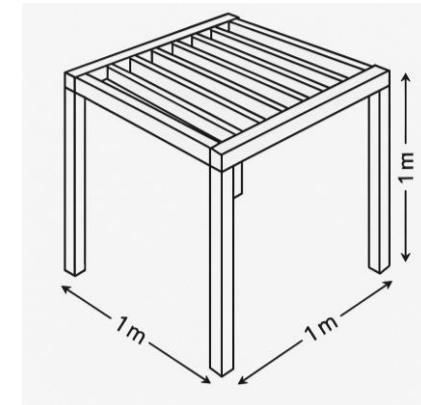
DEMONSTRATOR

PV-modules size:



Grid of 36 modules

Schematic sketch:

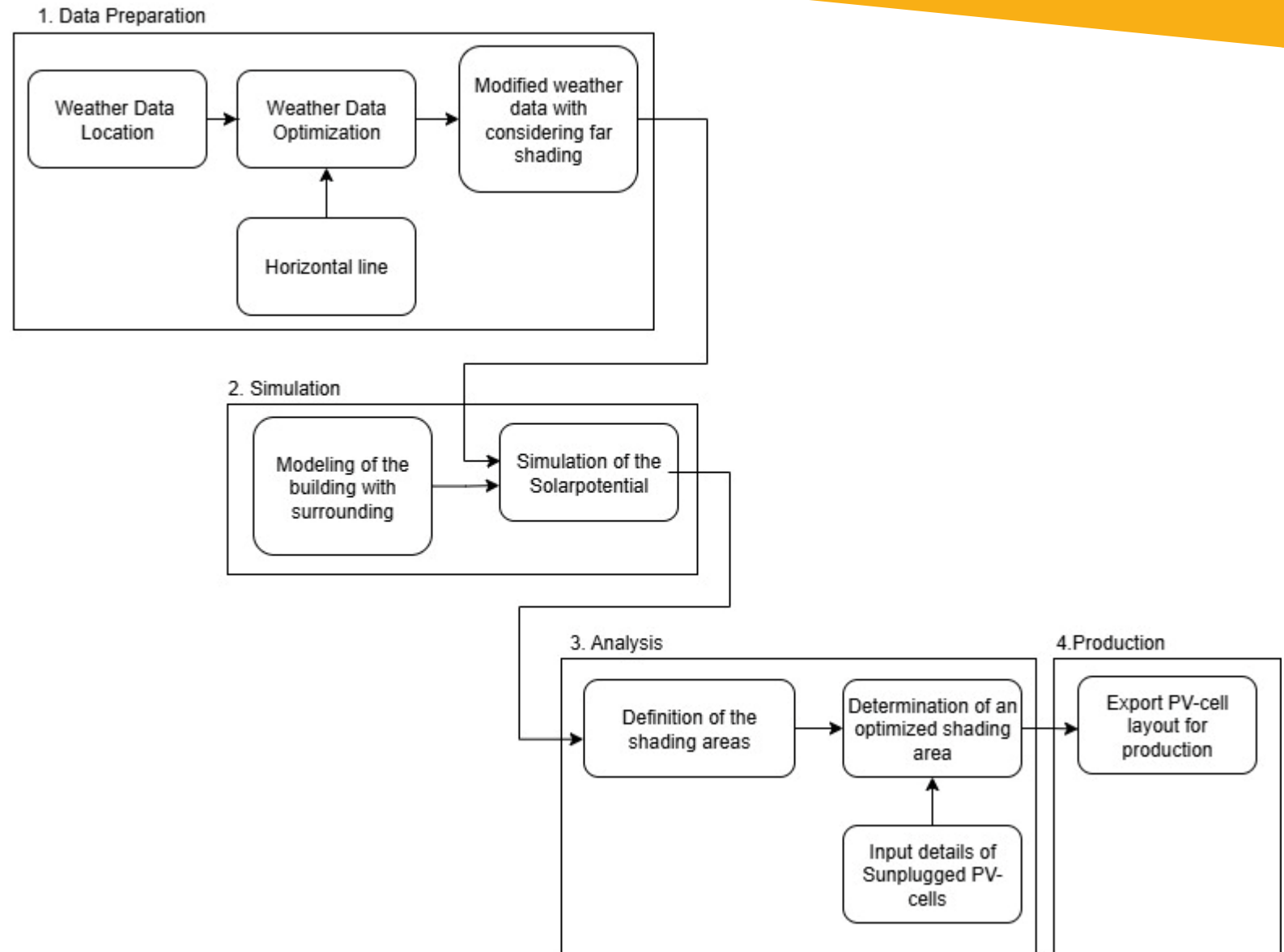


GOAL

Which PV modul interconnection using Sunplugged CIGS moduls is most effective at reducing the impact of partial shading without the use of bypass diodes?

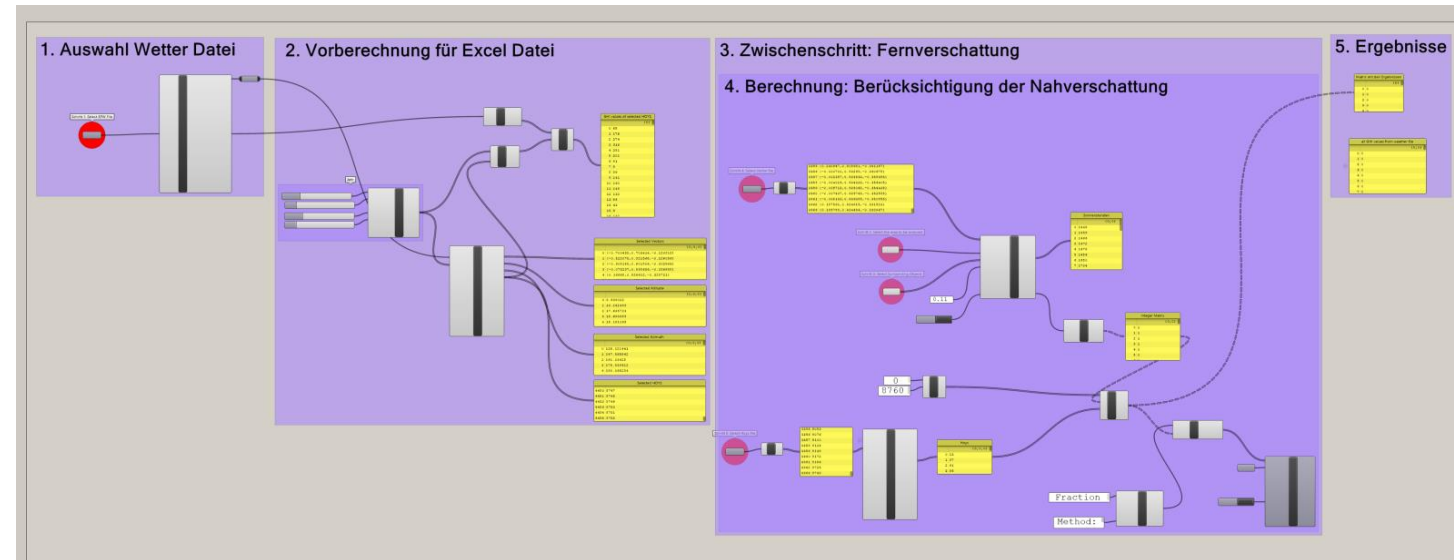
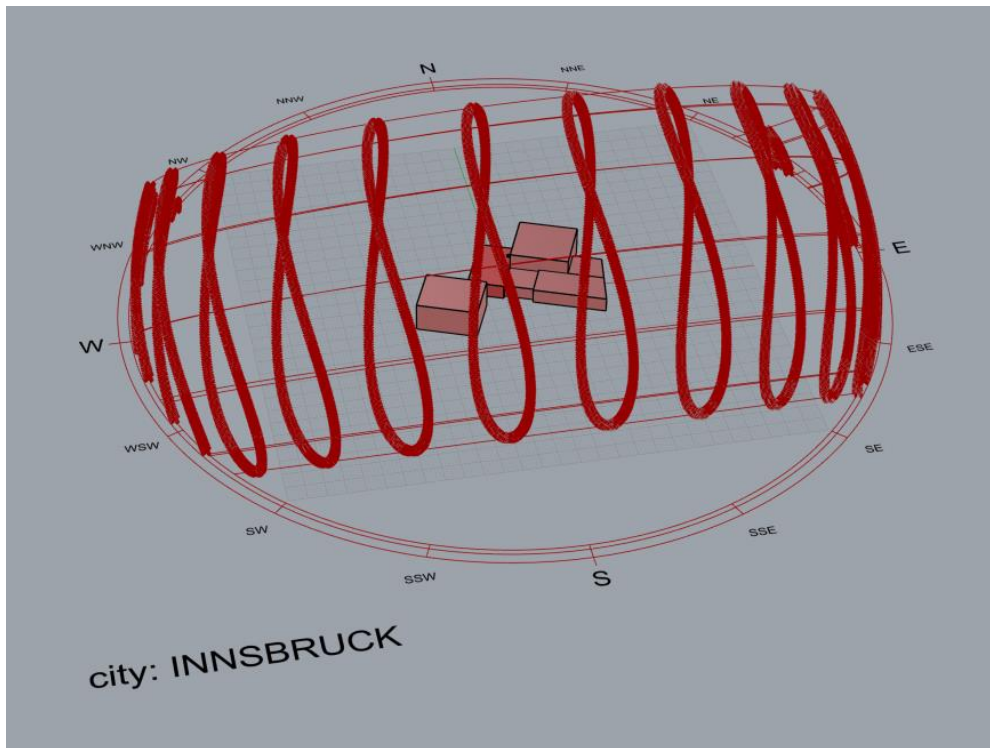
WORKFLOW

1. Data preparation
2. Simulation
3. Analysis
4. Production

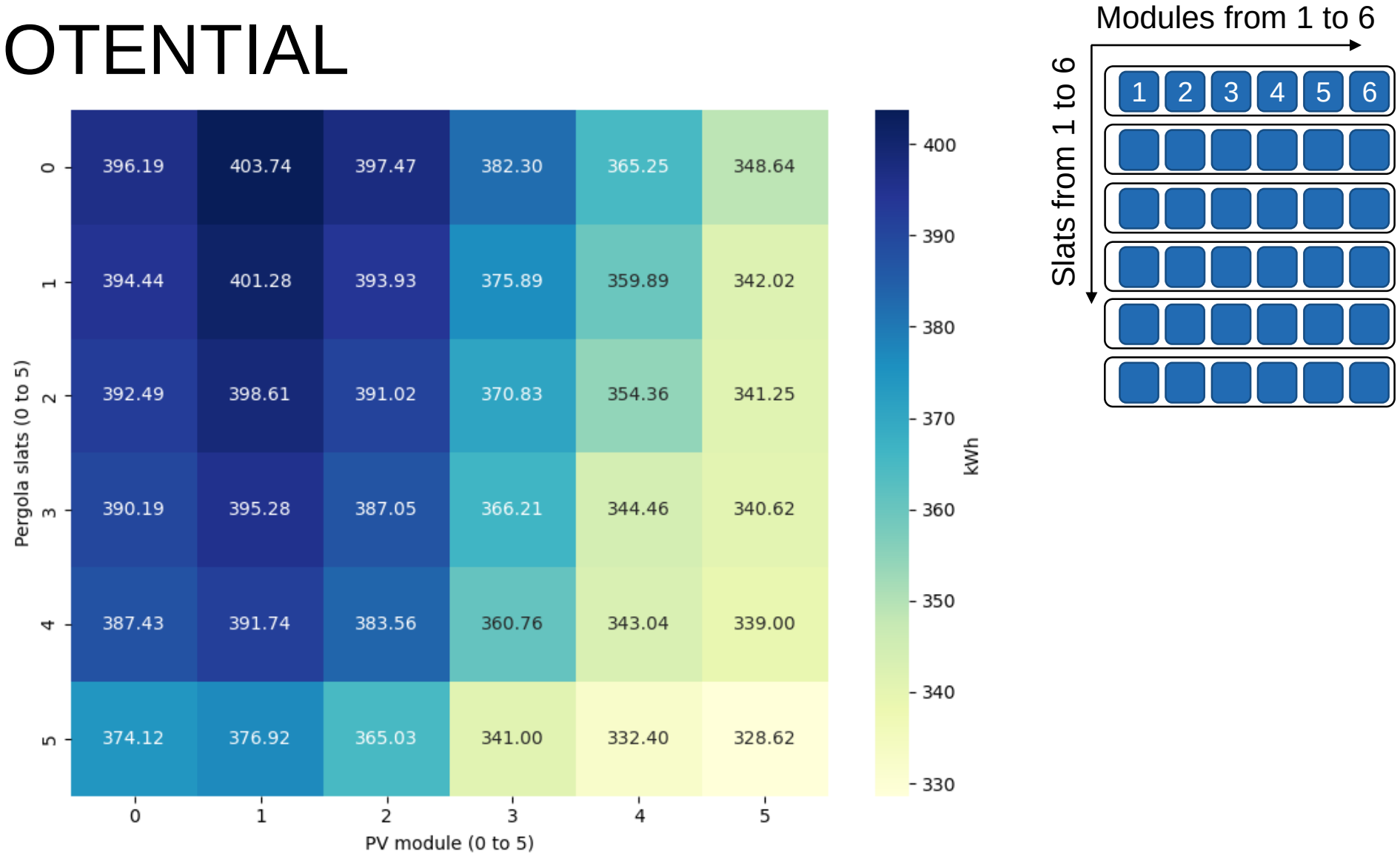


MODELLING

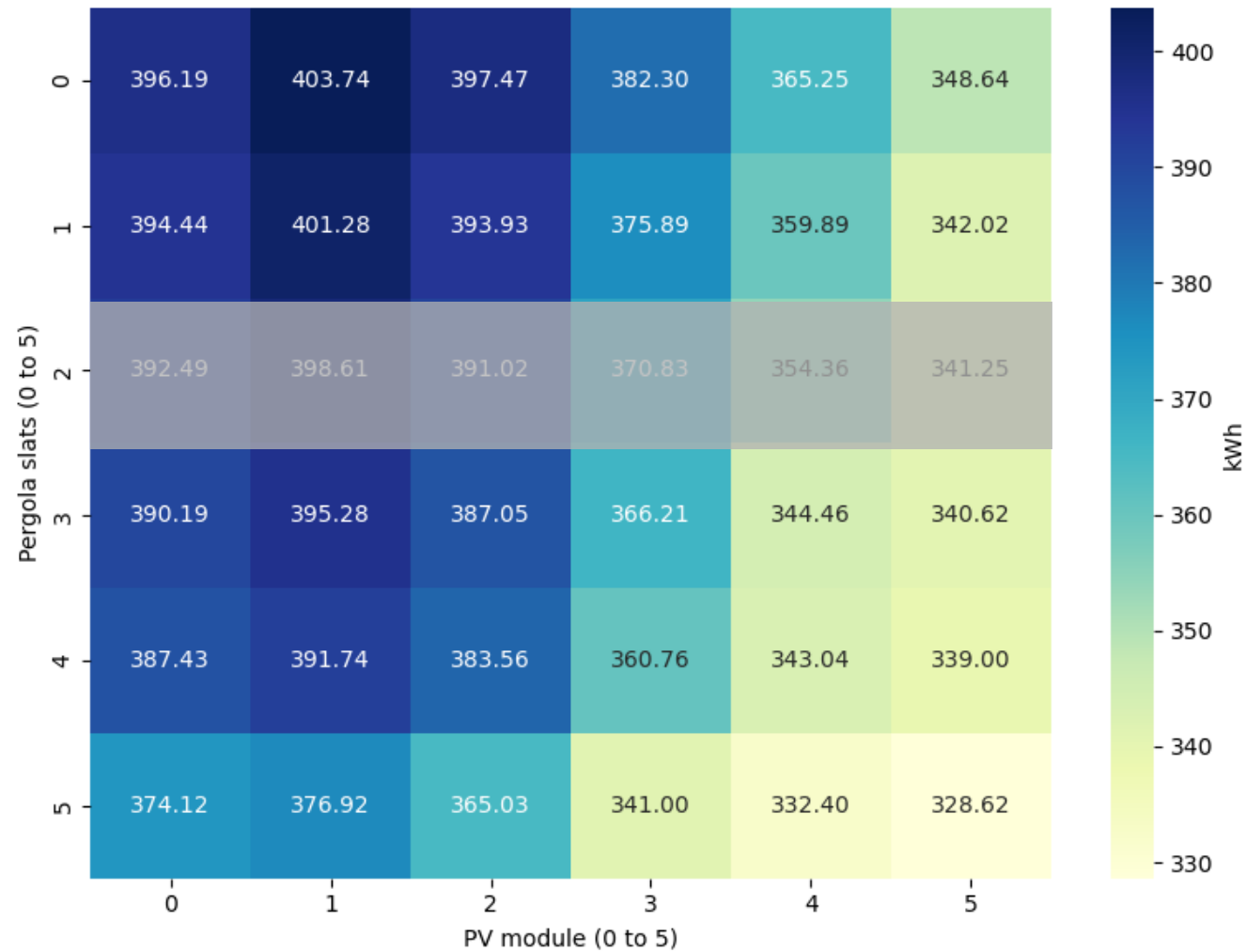
- Modelling of the main building with environment (neighboring building)
- Implementation in Grasshopper with Ladybug/Honeybee Tools



SOLAR POTENTIAL

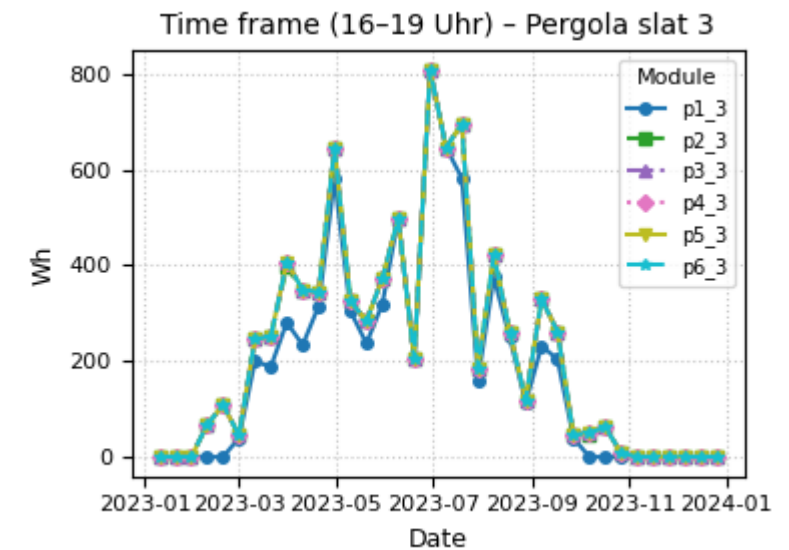
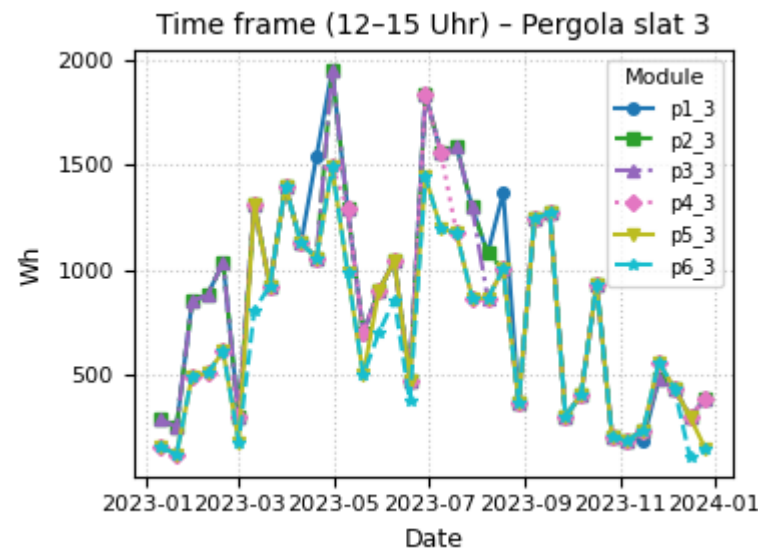
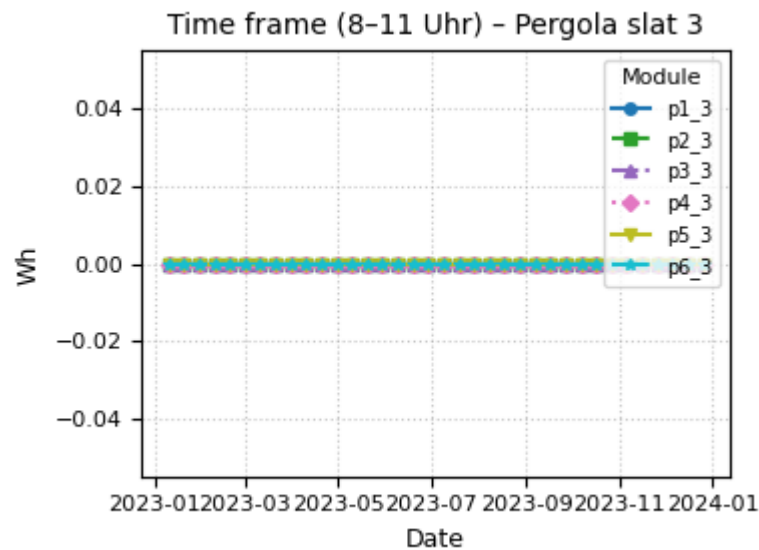


SOLAR POTENTIAL



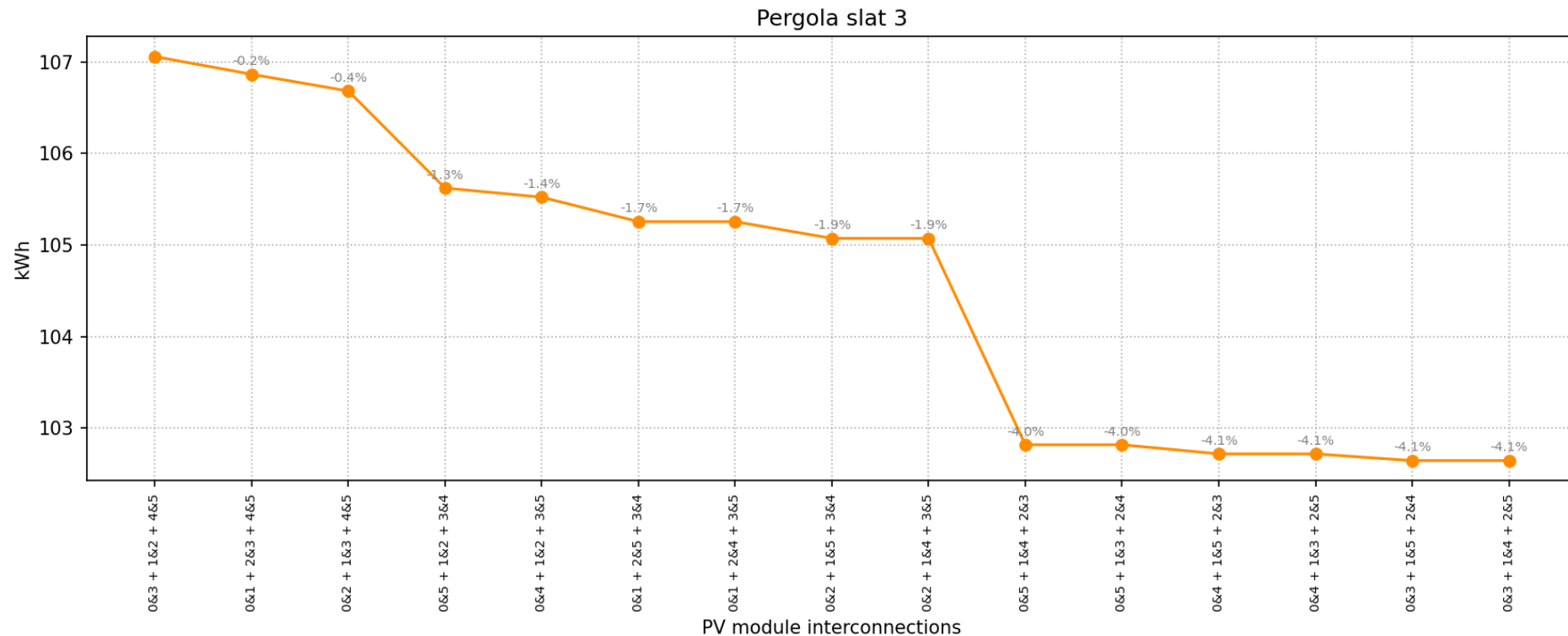
RESULTS – ANALYSE OF THE TIME SERIES

- Time series analysis at 10-day intervals through the year



PV MODULE INTERCONNECTIONS

Because of the required output voltage, two PV modules must always be connected in series. This leads to 15 possible pairing combinations per pergola slat.



PV MODULE INTERCONNECTION LAYOUT

Slat-1	S1-PV-1	S1-PV-2	S1-PV-3	S1-PV-4	S1-PV-5	S1-PV-6
Slat-2	S2-PV-1	S2-PV-2	S2-PV-3	S2-PV-4	S2-PV-5	S2-PV-6
Slat-3	S3-PV-1	S3-PV-2	S3-PV-3	S3-PV-4	S3-PV-5	S3-PV-6
Slat-4	S4-PV-1	S4-PV-2	S4-PV-3	S4-PV-4	S4-PV-5	S4-PV-6
Slat-5	S5-PV-1	S5-PV-2	S5-PV-3	S5-PV-4	S5-PV-5	S5-PV-6
Slat-6	S6-PV-1	S6-PV-2	S6-PV-3	S6-PV-4	S6-PV-5	S6-PV-6
	PV-module 1	PV-module 2	PV-module 3	PV-module 4	PV-module 5	PV-module 6

CONCLUSION

- The shadow cast by the edge of the house is clearly visible
- The upper row of slats reveals shading caused by the pergola frame
- The size of the pergola, optimizing the wiring has little impact on energy yield
- PV analysis indicates only minor losses

OUTLOOK

- Integration of the solar potential analysis into a HELLA digital tool
(Link: <https://fabricfinder.hella.info/>)
- Evaluation of existing tools to calculate the solar potential

ACKNOWLEDGMENT

Stephan Moser acknowledges funding by the Austrian Research Promotion Agency (FFG) through project (893504):

Sophokles - Sun protection slats with photovoltaic coating for climate neutral, energy-efficient structures

 Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology



PARTNERS

Special thanks to our partners for the excellent cooperation:

- Sunplugged GmbH, Tirol, Austria
- Polymer Competence Centre Leoben GmbH, Leoben, Austria



THANK YOU FOR YOUR ATTENTION QUESTIONS?



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