FAKULTEIT INGENIEURSWESE
FACULTY OF ENGINEERING

IRRADIANCE MODELING FOR BI-FACIAL PV MODULES USING THE RAY TRACING TECHNIQUE.

Renewable Energy Postgraduate Symposium 2018

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Overview

1. Introduction
2. Bi-facial PV modules
    - Rear side irradiance
    - Electrical model
    - Bi-facial PV module characterisation
3. Simulation and modelling of bi-facial PV modules
4. Ray tracing
    - *RADIANCE* software
5. Proposed solution
    - Program flow
6. Simulation results
7. Conclusions and future work

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Introduction

- Active **rear side** leads to potentially higher power outputs.
- **Cost** difference: Mono-facial vs Bi-facial
- **Market** for bi-facial PV
- **Characterization** and simulation
- Existing simulation software: **inaccurate**
- **Ray tracing** can serve as the solution

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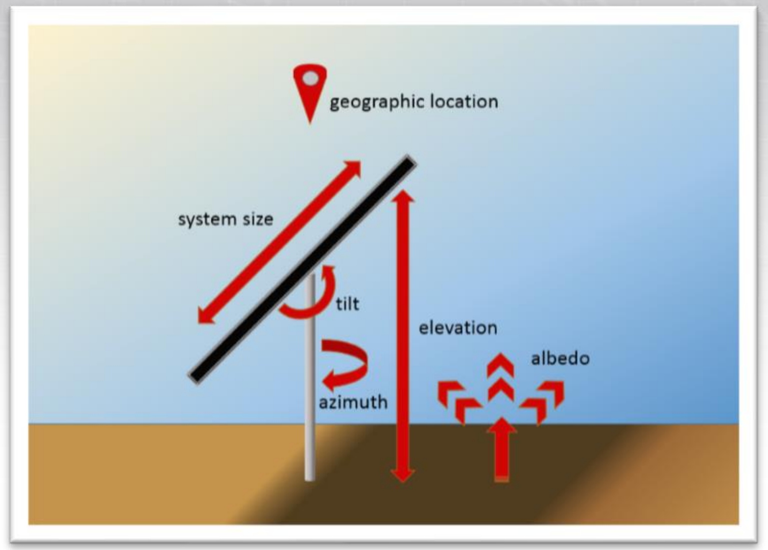
Bi-facial PV Modules
Rear side irradiance

Mounting height
- **Increased** irradiance between **0-1*m***

Albedo
- Ratio between **reflected** and **received** irradiance by **ground** surface

Mounting structure
- **Self-shading** severely **decreases** performance



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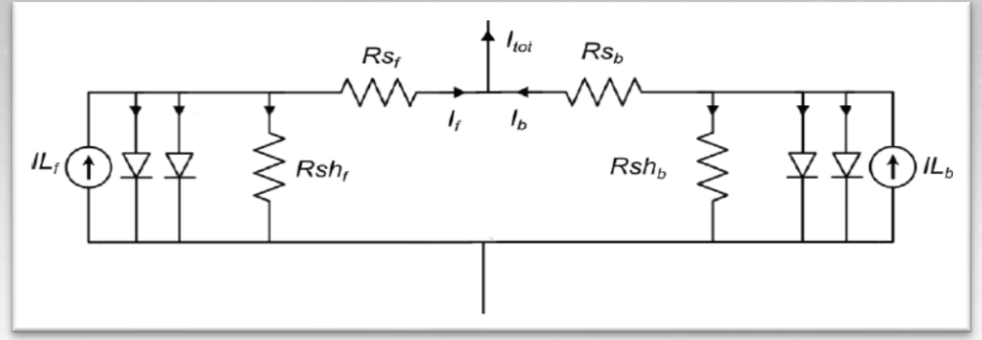
Bi-facial PV Modules
Electrical Model

- **Two-diode model**



- IL_f **and** IL_b **are dependent on received irradiance.**

- $I_{tot} = I_f + I_b$ **after shunt- and series resistances** $Rsh_f,\ Rs_f\ , Rsh_b$ **and** Rs_b **are taken into account.**

- **Rear side operates independently and only contributes to the total current output.**

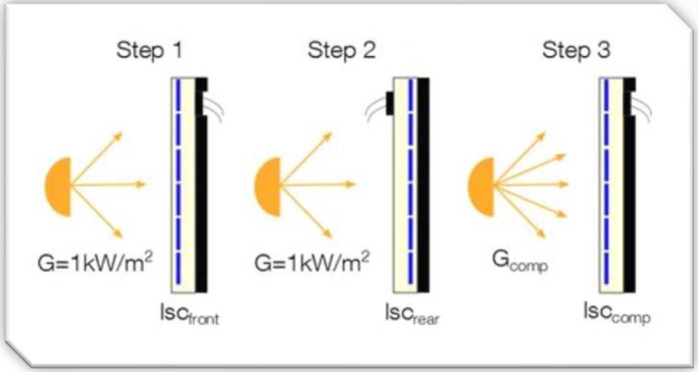
Bi-facial PV Modules **Characterization**

Shortcoming:

- **No** standardized characterization of bifacial modules
- **Standard Test Conditions** (STC) for mono-facial modules

Irradiance – **1000** $\mathbf{W}/\boldsymbol{m}^2$

Module temperature – **25** °$\boldsymbol{C}$



Current implementation (NREL):

1. **Cover** the **rear side** of the module.
2. **Illuminate** the **front side** and take power measurements.
3. **Turn** the **module around** with the front side now covered.
4. **Illuminate** the **rear side** and take power measurements.

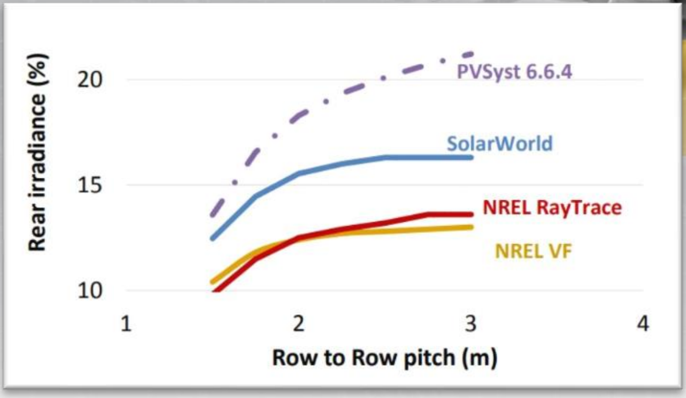
Bi-faciality factor

$$BF = \frac{P_{rear}}{P_{front}} \times 100\%$$

Simulation and Modelling

Shortage

- PVSyst from v6.6.4.
- SolarWorld

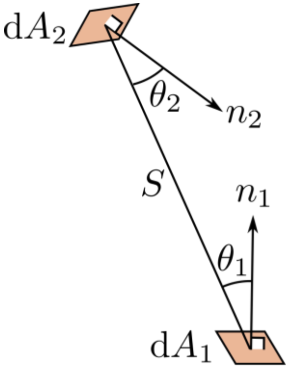


Inaccuracy

- 10% variations

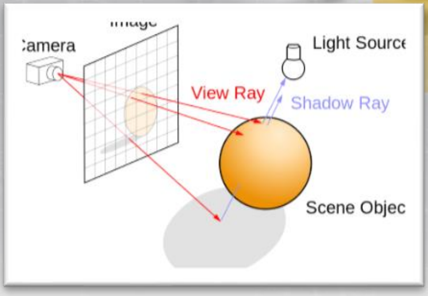
Irradiance modelling

- View Factor
- Neglect influences



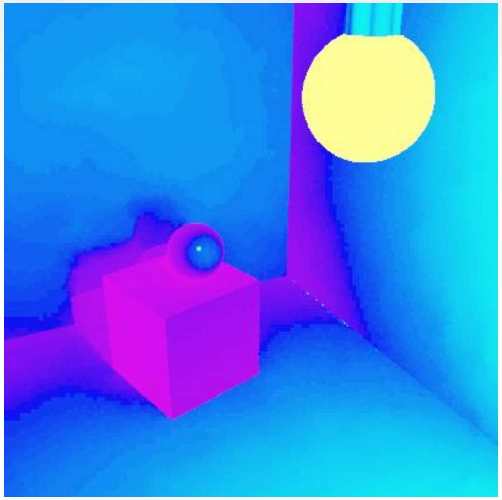
Ray Tracing
Radiance

- **UNIX** based
- Open-source toolkit
- Architectural lighting analysis
- **CAD** compatibility (.dwg -> .rad)
- Own geometric functionality (.txt -> .rad)

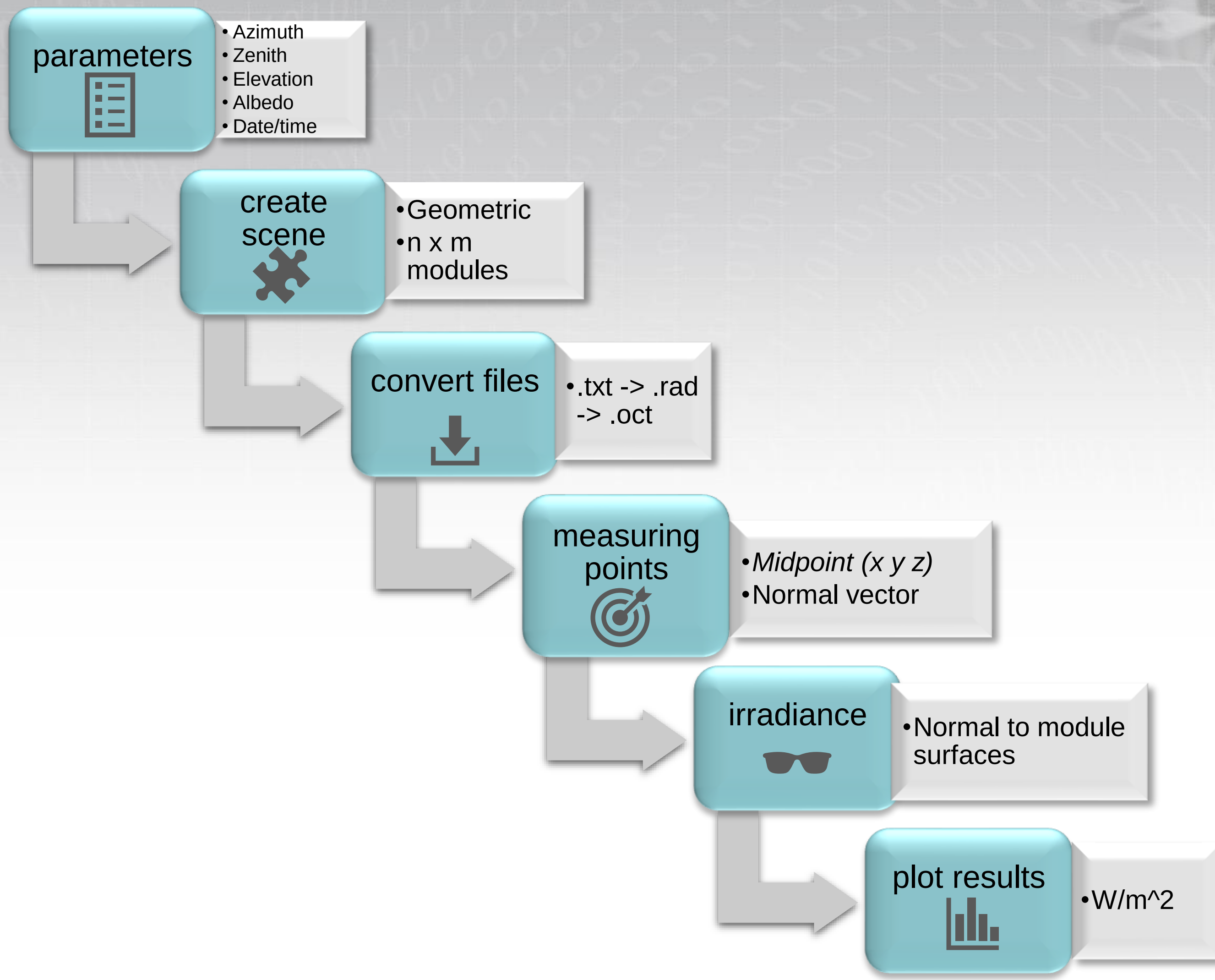


Basic scene rendering

Irradiance mapping



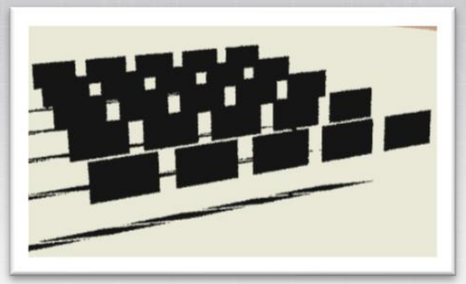
Proposed Solution



Simulation Results
Tilt optimization

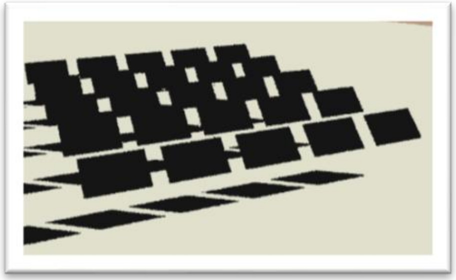
Non-optimized

Module tilt angle = 90°

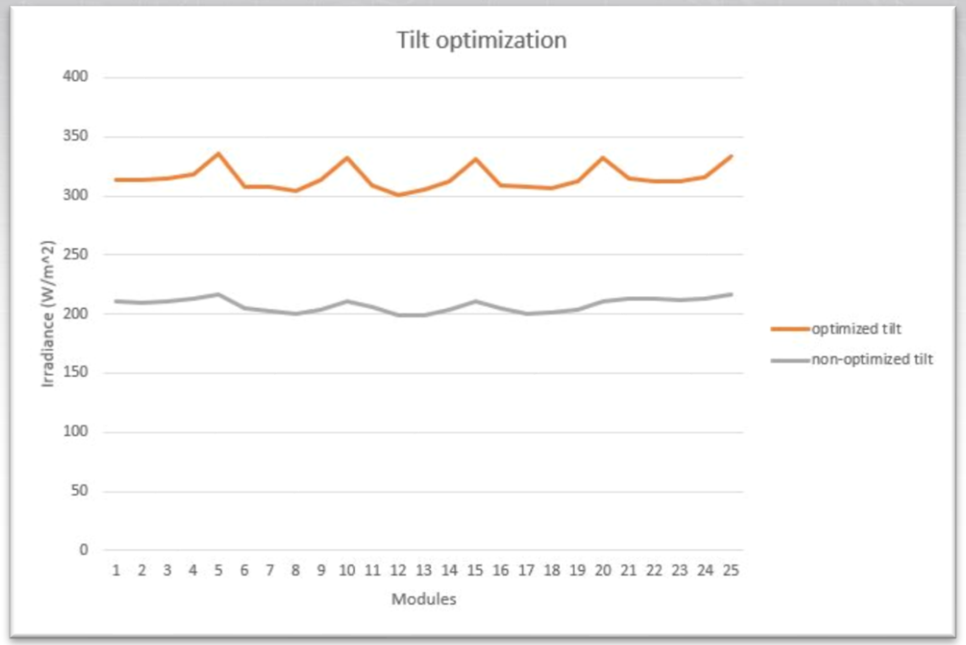


Optimized

Module tilt angle = 45°



Solar altitude = 30 °



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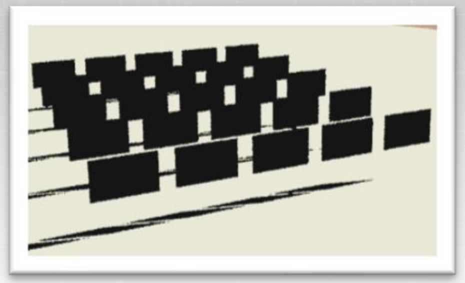
Simulation Results
Effect of albedo

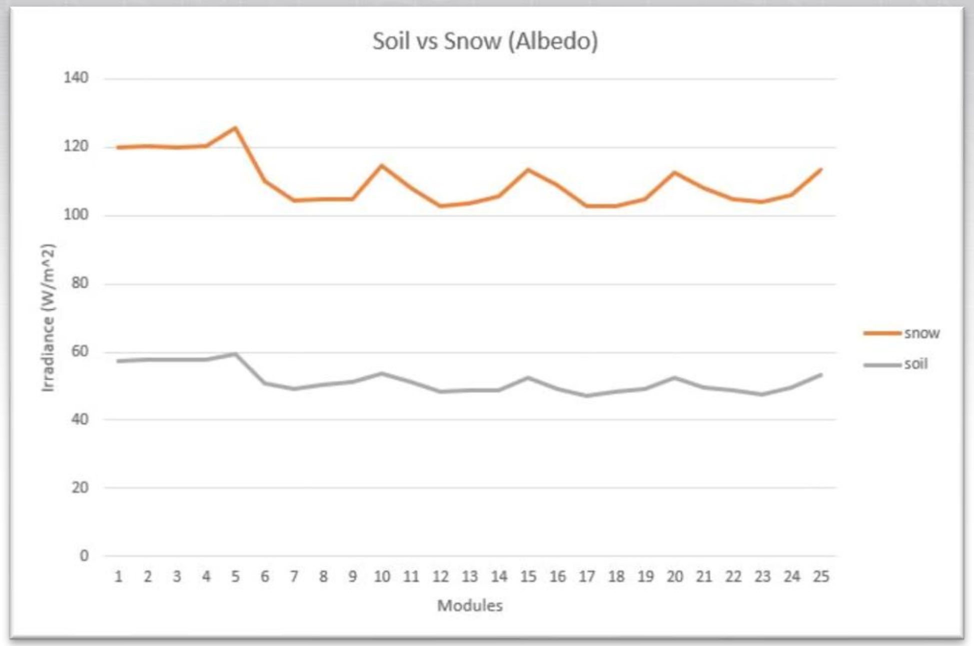
Soil

Albedo = 0.45



Snow

Albedo = 0.85



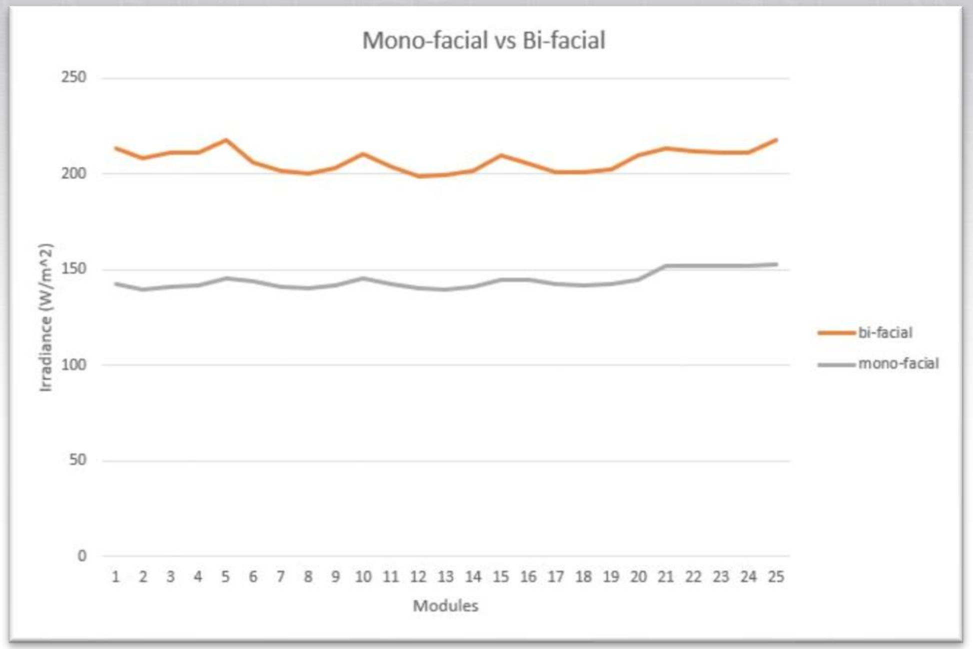
Simulation Results
Mono-facial vs Bi-facial

Mono-facial

Total irradiance = Front

Bi-facial

Total irradiance = Front + Rear



Conclusions

Bi-facial PV technology

- Benefits
- Unpredictable
- Characterization

Simulation software

- Shortage
- Optimization
- 10% variation
- View factor

Simulation results

- Interface for *Radiance*
- Various design parameters
- Results correlate

Ray tracing

- Powerful tool
- Lighting analysis
- Rear side modelling

Future Work

- Electrical model
- Annual energy yield
- Max/Min voltage and current ratings
- Test various sky models
- Optimization algorithms

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Thank you!
Questions?

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