Performance Plus

Accurate optical-thermal-electrical modelling of PV modules

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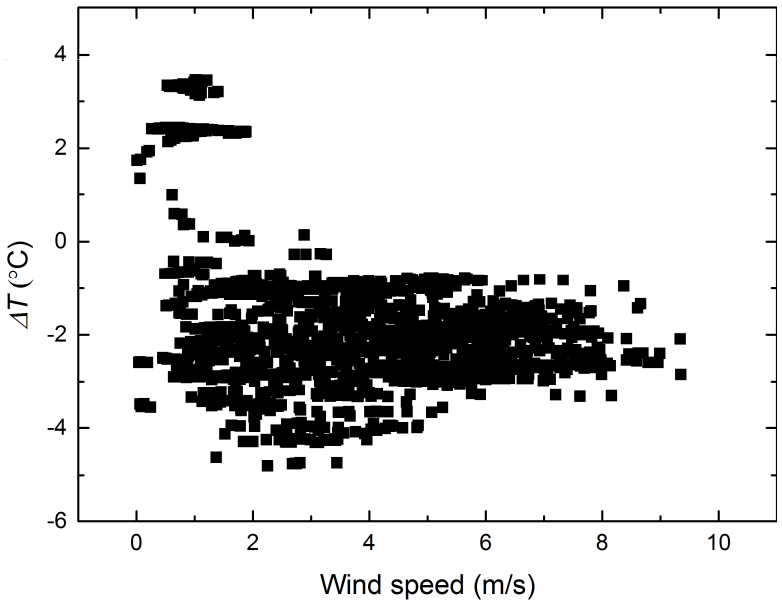
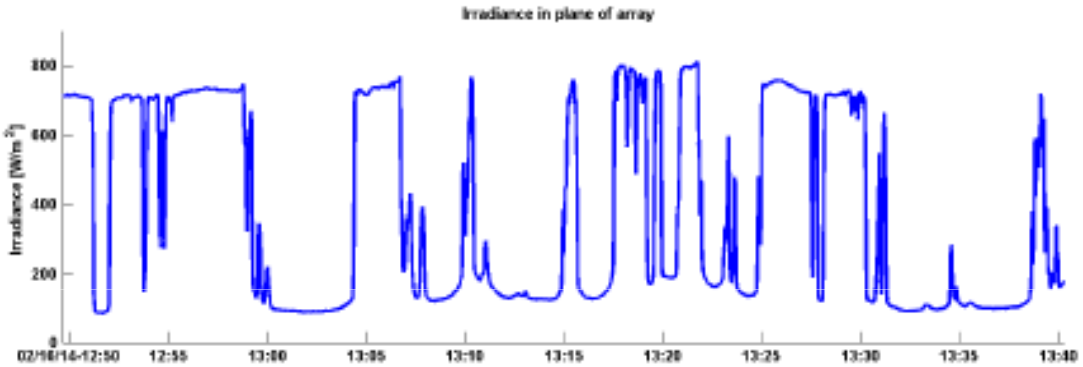
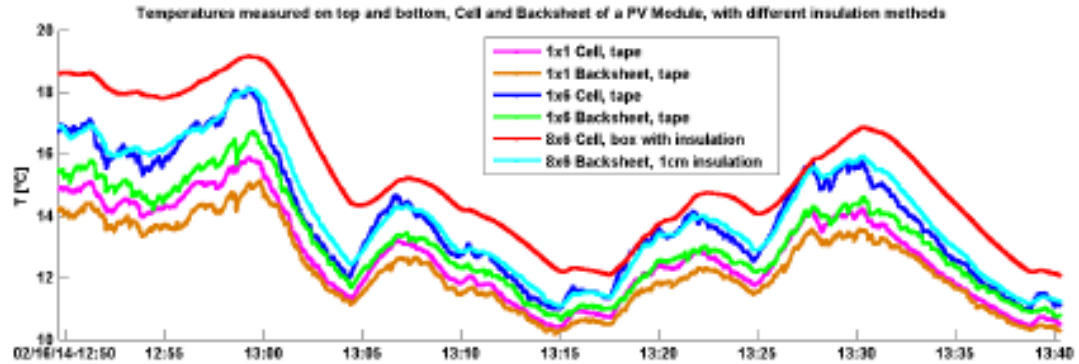
Motivation

- Temperature variation module (e.g. due to wind effects)
- Fast-varying illumination







B. Herteleer et al., EUPVSEC 2014, Amsterdam

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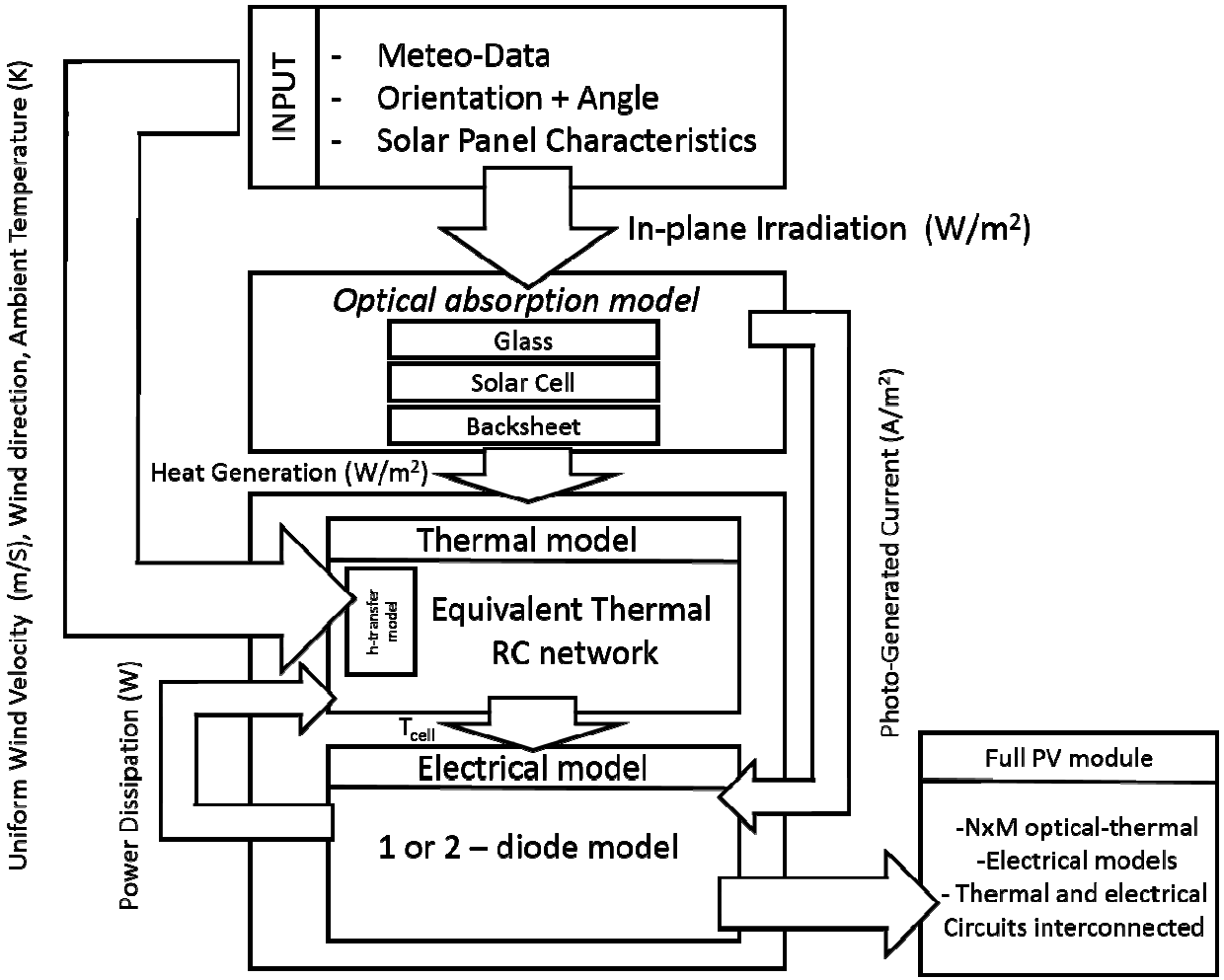
Overview Model



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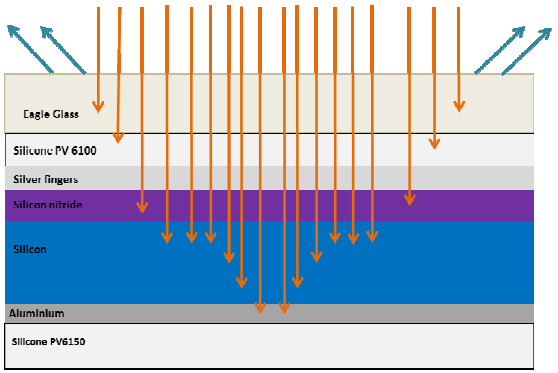
Optical Modelling

- Layer-by-layer absorption model
- Physical properties solar cell and PV module
- Ray-tracing

  → *Calculate electrical and thermal generation*



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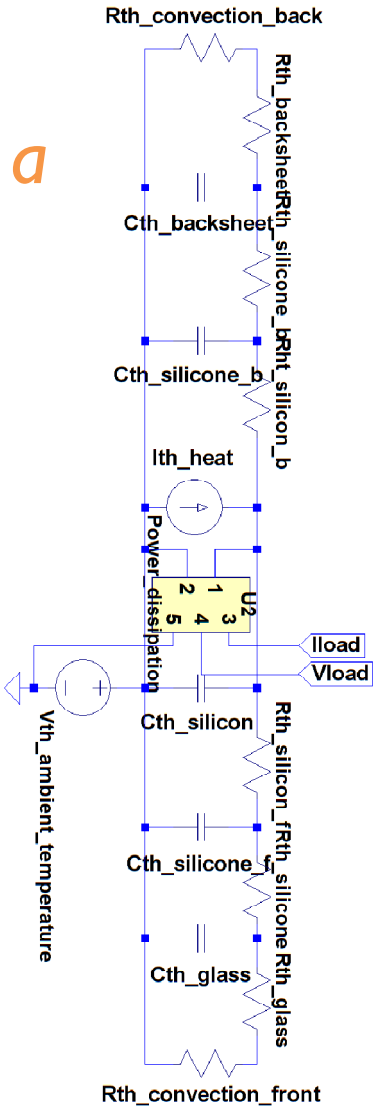
Thermal Modelling

→ Calculate solar cell temperature using a thermal equivalent circuit ←

- Bottom-up thermal equivalent circuit
  - Thermal resistances and capacitance
  - Generated heat
  - Heat losses
    - → *Radiation*
    - → *Convection*
    - → *Conduction*
  - Electrical dissipation

Parameters thermal equivalent circuit extracted from experiments and FEM models



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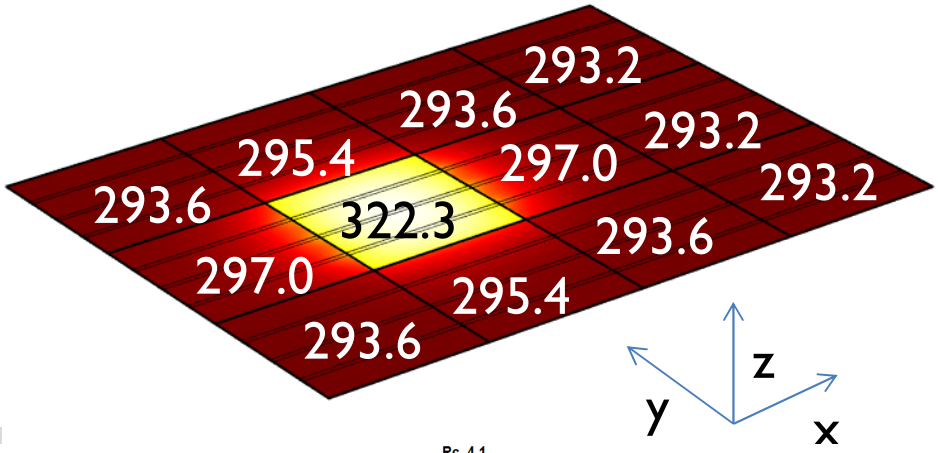
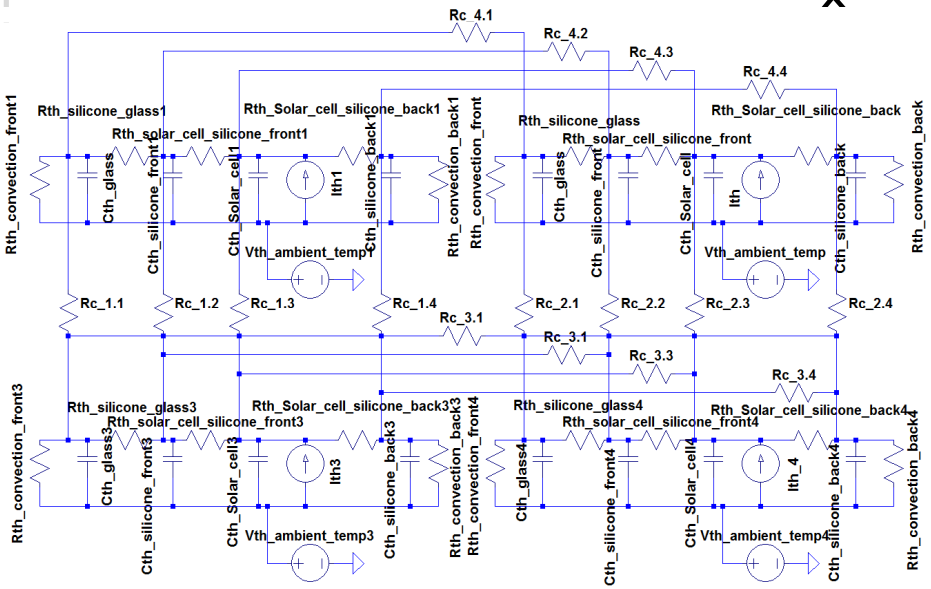
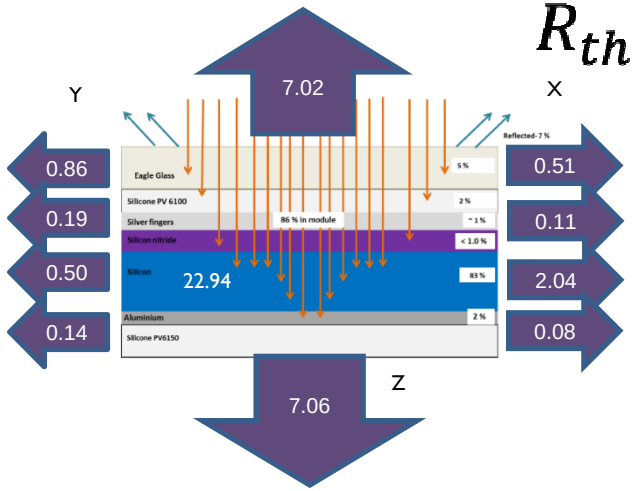
Conduction of heat FEM model





- 3D FEM model constructed to investigate inter-module heat conduction
- 1 solar cell illuminated at 1000 W/m^2
- Analyse heat flow
- Calculate thermal resistance

$$R_{th} = \frac{\Delta T}{Q}$$



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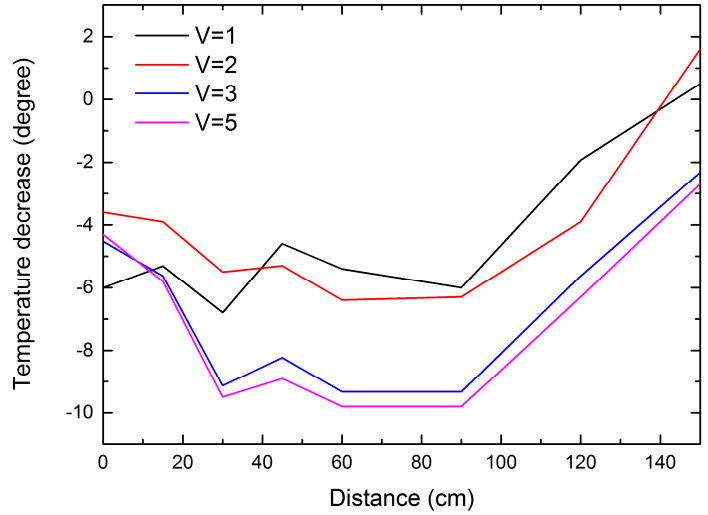
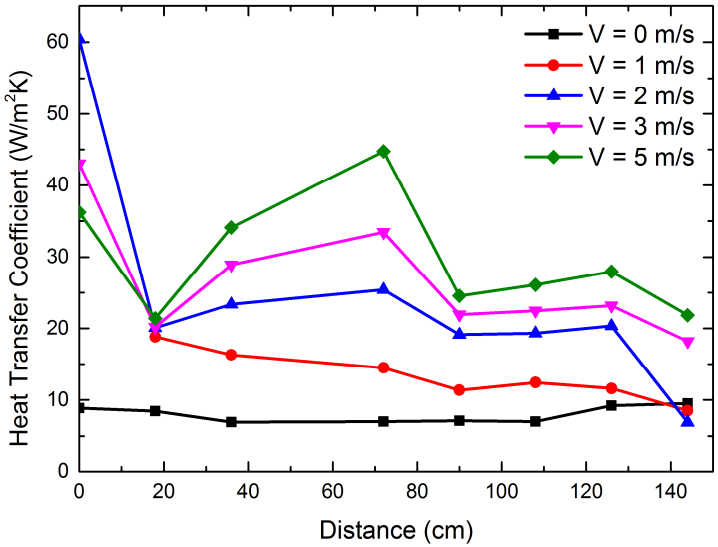
Free and forced convection wind tunnel experiment





- Module temperature decreases due to increase forced convection
- Forced convection increases at higher uniform wind speeds
- Spatial temperature variation due to wind effect
  - Reduction wind speed
  - Transportation hot air
- Extraction *h*-coefficient
  - *h* coefficient reduces along the module

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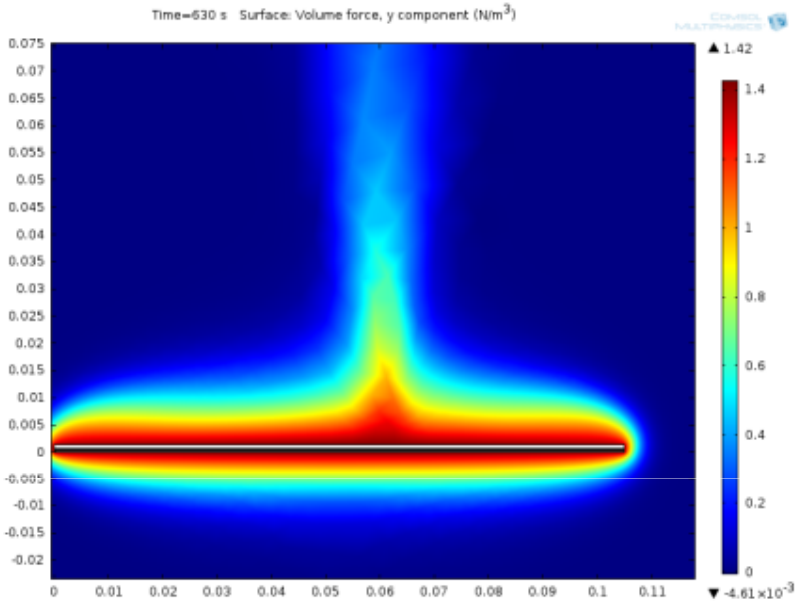
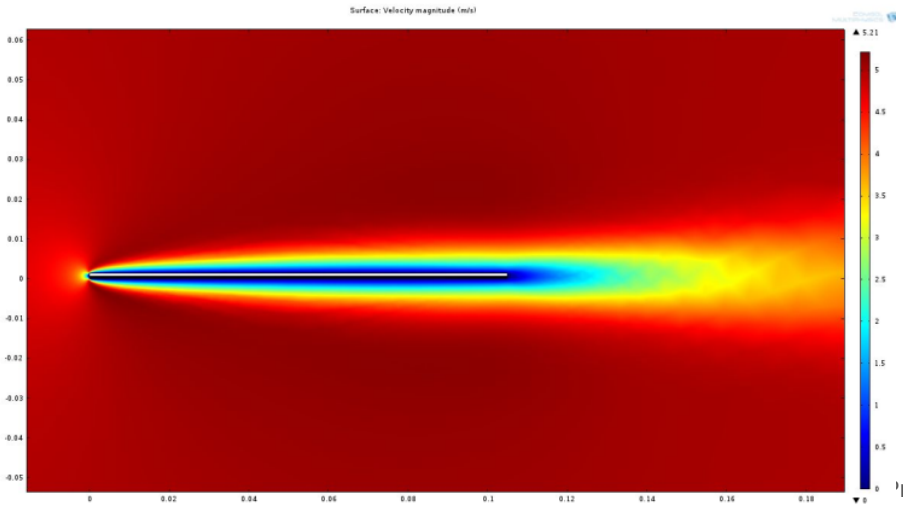
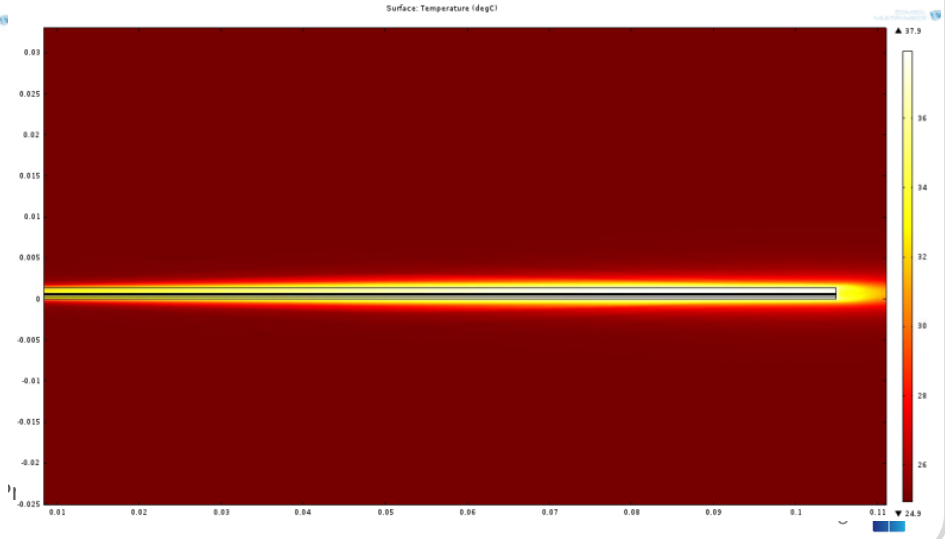
Free and forced convection FEM model



- 2D FEM model of PV module in free uniform wind field constructed
- Heat transfer model coupled to CFD model
- Wind tunnel experiments used to validate simulation results

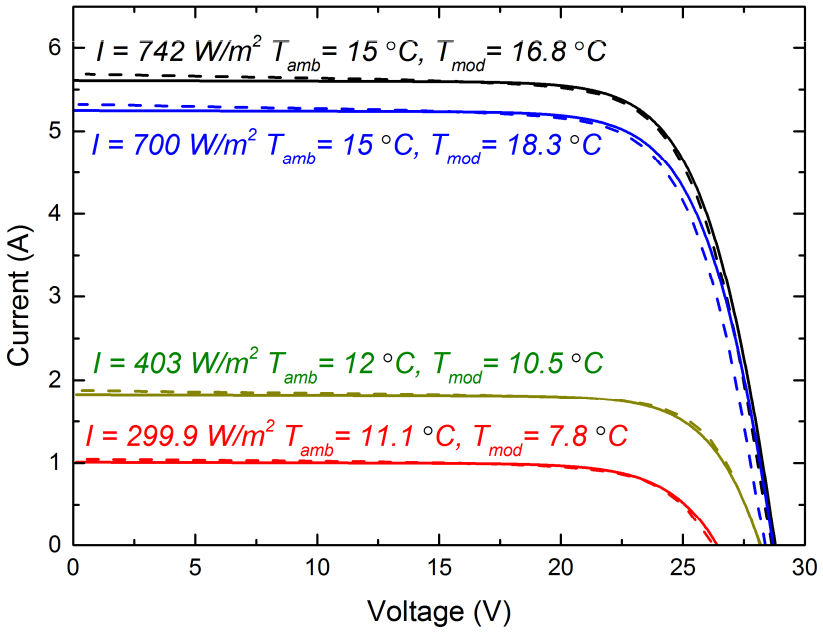


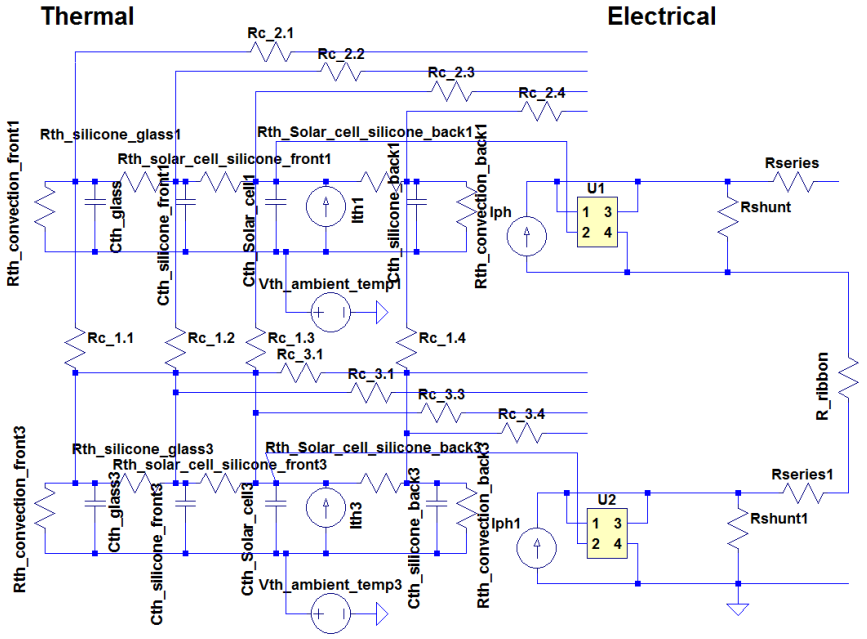


and demonstration under grant agreement No 308991.

Electrical model PV module

- Temperature dependent 1-diode model of PV cell
  - *Vary J_0 and V_t*
- Parameters 1-diode model extracted from IV measurement
  - *Flash/steady-state IV test*
- Interconnect PV cells for full PV module





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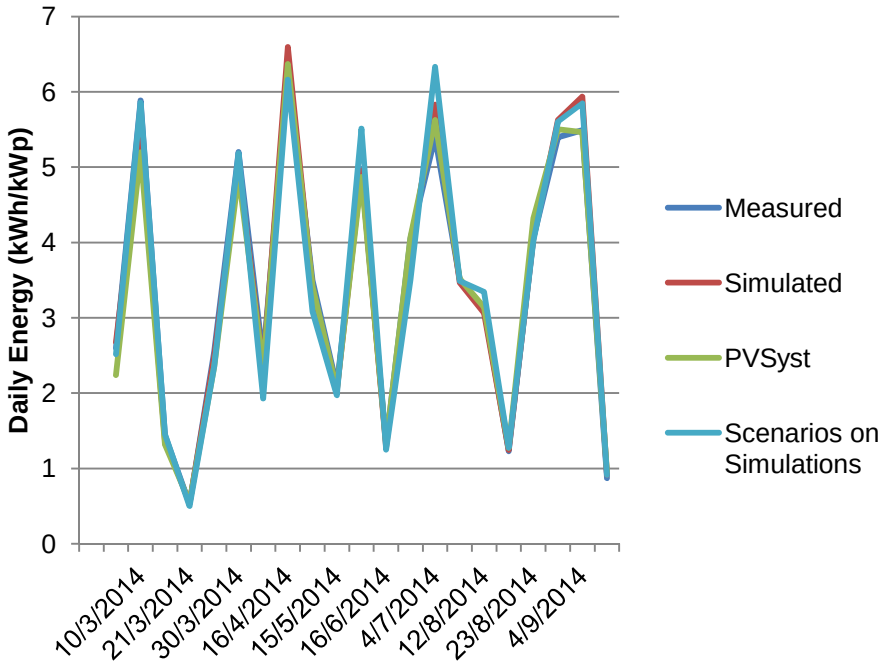
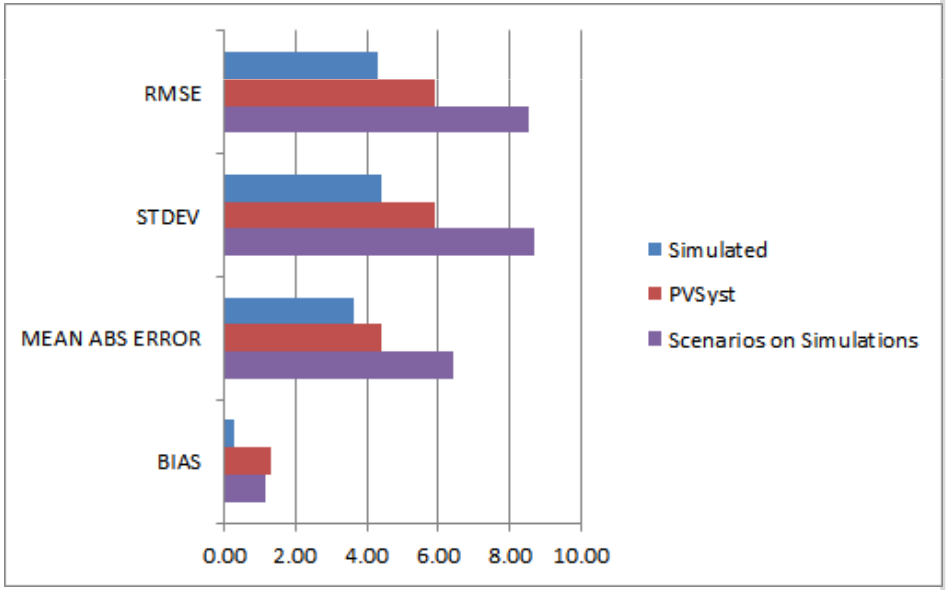
Comparison with other methods

- Cross-validation with other methods of daily energy yield estimation
- University of Oldenburg: high resolution weather and energy yield data
- The presented results focus on comparison with PVsyst 6





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Conclusion

- E-yield model suitable for non-steady state and non-uniform conditions
- Optical, thermal and electrical properties PV module integrated
- System scenario principles used to reduce computational effort while maintaining accuracy around applicable levels
- Model successfully validated against outdoor setup UOL

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References

- **Optical-Thermal-Electrical Model for a Single Cell PV Module in Non-Steady-State and Non-Uniform Conditions Built in SPICE,** H. Goverde, J. Govaerts, J. Baert, F. Catthoor, J. Driesen, J. Poortmans, 28th European Photovoltaic Solar Energy Conference and Exhibition, 2013, Paris
- **Energy Yield Prediction Model for PV Modules Including Spatial and Temporal Effects,** H. Goverde, B. Herteleer, D. Anagnostos, G. Köse, D. Goossens, B. Aldaladi, J. Govaerts, K. Baert, F. Catthoor, J. Driesen, J. Poortmans, 29th European Photovoltaic Solar Energy Conference and Exhibition, 2014, Amsterdam
- **Presentation of a Verilog-AMS Model for Detailed Transient Electro-Thermal Simulations of PV Modules and Systems,** D. Anagnostos, H. Goverde, F. Catthoor, D. Soudris, 29th European Photovoltaic Solar Energy Conference and Exhibition, 2014, Amsterdam
- **Spatial and temporal analysis of wind effects on photovoltaic module performance**, H. Goverde, D. Goossens, J. Govaerts, V. Dubey, F. Catthoor, Kris Baert, J. Poortmans and J. Driesen, submitted to Sustainable Energy Technologies and Assessments, 2014

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