Solar Cogeneration of Industrial Heat and Power by a Concentrating Hybrid Collector

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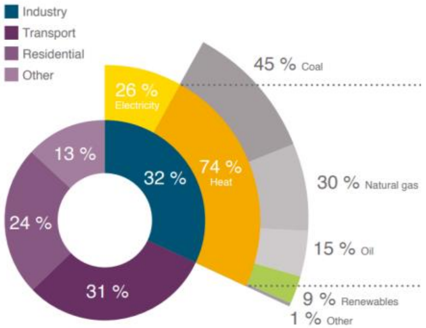
Introduction

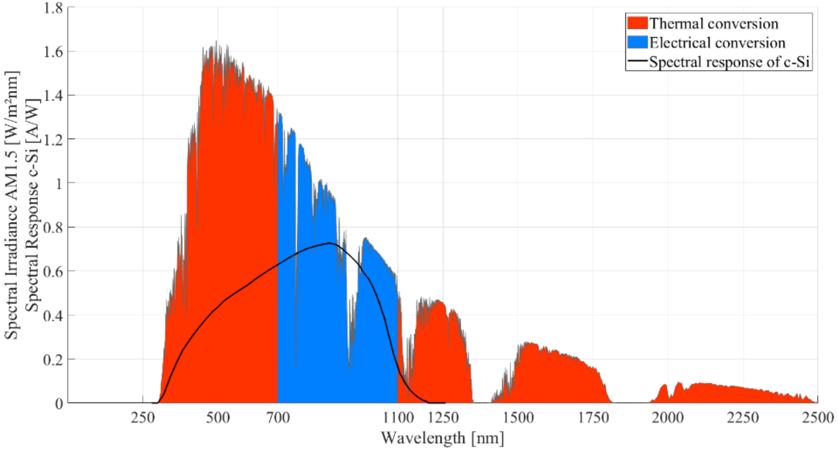
- Industrial sector plays important role for global energy demand:
  - One third of final energy required by industry
  - 74 % heat, 26 % electricity
  - 70 % of heat demand @ T > 150°C
- Contribution of renewables shows potential for improvement
- Suitable solar technologies basically available:
  - Concentrating solar systems
  - PVT collectors
- Challenge: Temperature limitation of conventional PVT-collectors to max. 85°C
- Research project for the development of a CPVT collector:
  - Providing solar heat up to 200°C and electricity
  - Based on Fresnel mirror field
  - Key approach: Spectral Splitting



Sources:
Epp, B. & Oropeza, M. (2017). Solar Heat for Industry, Solar Payback project
IEA SHC Task 64 (2024). Technology Position Paper - Solar Heat for Industrial Processes (SHIP)

The concept of Spectral Splitting

- Incident solar spectrum is split into several wavelength segments, depending on SR of PV cells
- Wavelength range of high spectral response (blue area) used for electrical energy conversion
- Range of low spectral response (red areas) used for direct thermal energy conversion
- Approach of selective absorption applied for CPVT receiver design: combination of solid and liquid absorption filter

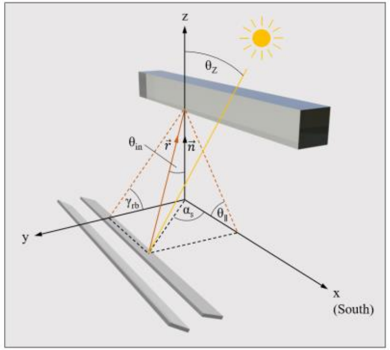


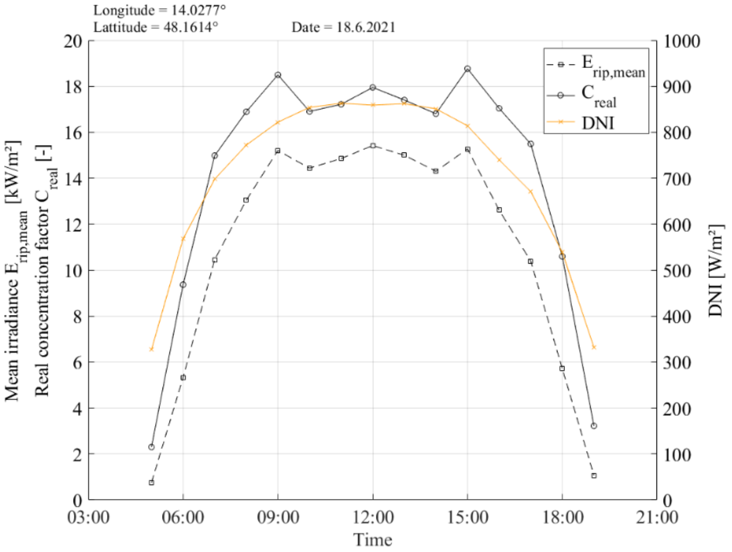
Sources:
Resch, A. and Höller, R. (2023). State-of-the-Art of Concentrating Photovoltaic Thermal Technology. Energies, 2023, 9, 3821. https://doi.org/10.3390/en16093821
Resch, A. and Höller, R. (2021). Electrical Efficiency Increase in CPVT Collectors by Spectral Splitting. Energies, 2021, 14, 8128. https://doi.org/10.3390/en14238128

Optical Modeling of a Fresnel Concentrator

How much solar radiation is impinging the CPVT receiver?

- Development of MATLAB model
- Depending on concentrator construction, location, date and time:
  - Calculation of single mirror angles
  - Consideration of internal shading losses
  - Calculation of longitudinal cosine losses
- Validation by measurements on Fresnel concentrator



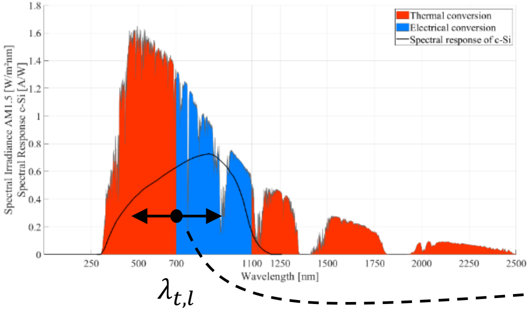


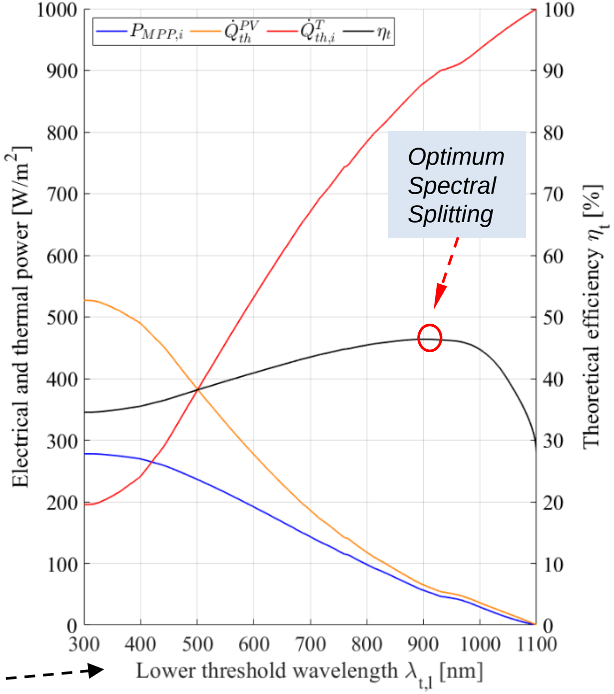
Source:
Resch, A. and Höller, R. (2023). Optical Modelling of a Linear Fresnel Concentrator for the Development of a Spectral Splitting Concentrating Photovoltaic Thermal Receiver. Energies, 2023, 14, 5373. https://doi.org/10.3390/en16145373

Modeling of Electrical Efficiency Increase by Spectral Splitting

What is the optimum Spectral Splitting configuration to maximize the electrical efficiency?

- MATLAB model for electrical energy conversion with PV cells
- Consideration of three PV technologies: c-Si, CIGS, CdTe
- Variation parameter: lower threshold wavelength $\lambda_{t,l}$
- Validation of MATLAB model with full spectrum results
- Increase of theoretical efficiency from 28.3 % (full spectrum) to 46.4 % (Spectral Splitting with $\lambda_{t,l}$ = 902 nm) with c-Si
- 91 % reduction of waste heat dissipation within the PV cells





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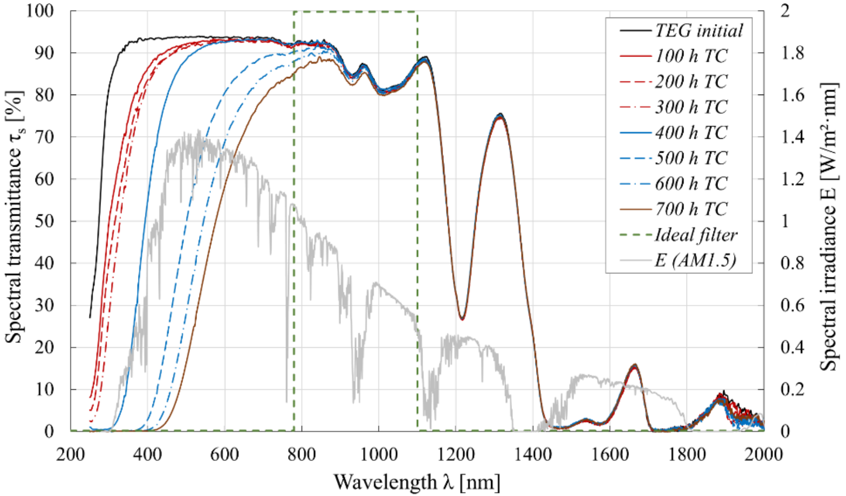
Investigation of a Novel Heat Transfer Fluid

Which fluid is suitable for the present application?

- Fluid serves as liquid part of spectrum filter and as HTF
- Various requirements in terms of optical and thermodynamic properties
- Triethylenglycol appeared as suitable candidate
- Comprehensive investigation confirmed its feasibility:
  - Transmittance measurements
  - Exposure to UV light: 50 kWh/m² < 400 nm
  - Temperature cycling test: 180 cycles, 45…210°C
  - High temperature test: 700 h @ 210°C



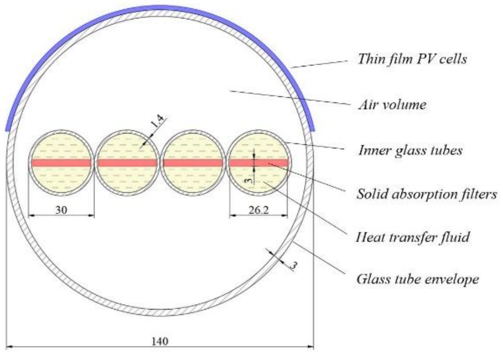
Source:
Resch, A., Thalhammer, T., Angerer, P., and Daborer-Prado, N. (2021). *Triethylenglycol as Novel Heat Transfer Fluid for CPVT Collectors with Spectral Splitting*. Conference Proceedings Solar World Congress. https://doi.org/10.18086/swc.2021.15.01

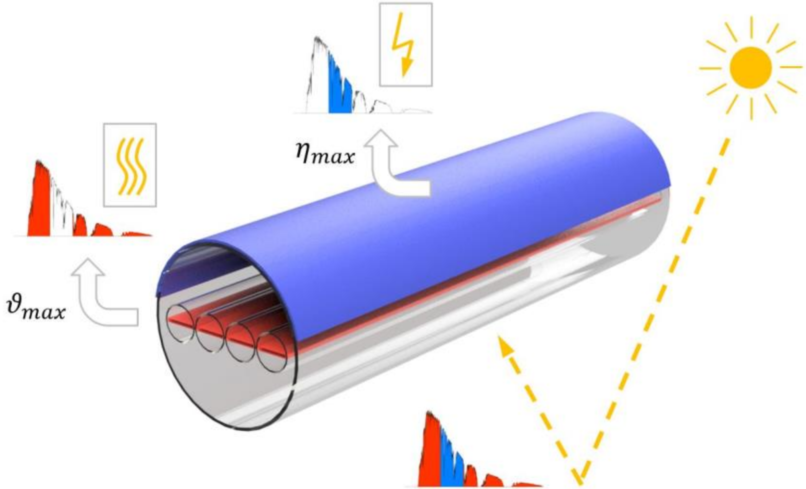
Design of a CPVT Receiver

What are possible receiver designs to realize a concentrating hybrid collector?

Receiver design phase based on the following premises and requirements:

- Output temperature of 200ºC, PV module temperature < 85°C
- Spectral Splitting by combined solid and liquid filters
- Compact and affordable construction
- Feasibility for prototype implementation





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Prototyping and performance measurements

- Implementation of CPVT receiver prototype (length of 1.5 m) was successful
- Prototype installed on 11 m² Fresnel mirror field at the university in Wels, Austria
- First results of performance measurements under validation
- Thermal decoupling (PV vs. T) works

Next steps

- Customization of utilized CIGS PV modules to concentrated irradiation
- Cost reduction: solid spectral filter causes 70 % of total material costs
- Improvement of hydraulic connections (glass-to-metal interface)

Relevant publications

Resch, A. and Höller, R. (2020). *Design Concepts for a Spectral Splitting CPVT Receiver*. Conference Proceedings EuroSun 2020, Athens, Greece. https://doi.org/10.18086/eurosun.2020.05.07

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Thank you for your attention!

Questions?

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