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SOLARISE

Photovoltaic-Thermal (PV/T) Hybrid Systems

State-of-the-art technology, challenges and opportunities

Prof.dr.ir. Emilia Motoasca

PhD res. Clément de la Fontaine

PhD res. Baptist Vermeulen

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University of Picardie Jules Vernes, Amiens

Content

- PV/T in the energy context
- PV/T technology: state-of-the-art
- Typical PV/T applications
- Performance PV/T vs PV + T systems
- PV/T uptake: challenges and opportunities
- Future research on PV/T
- Conclusions

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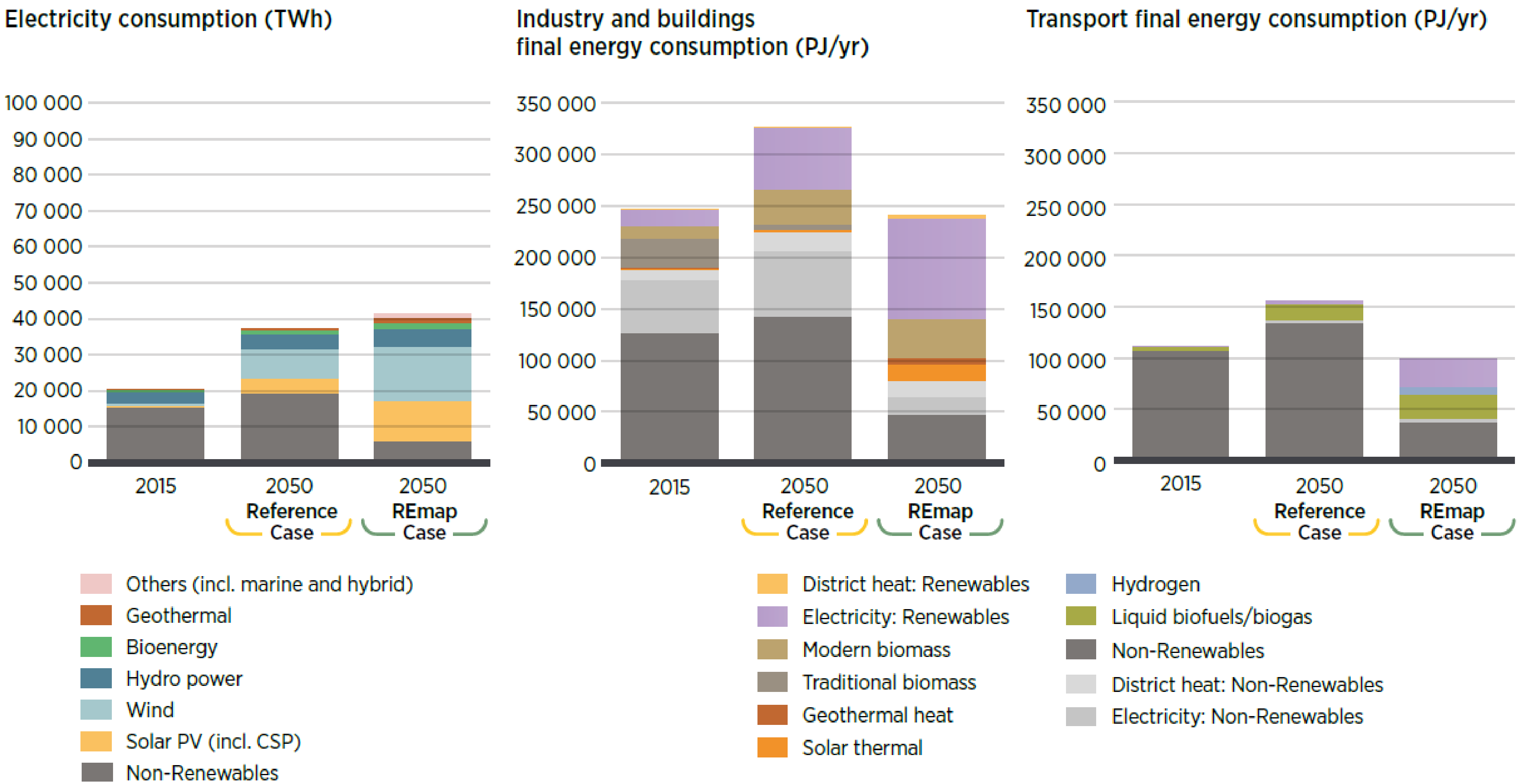
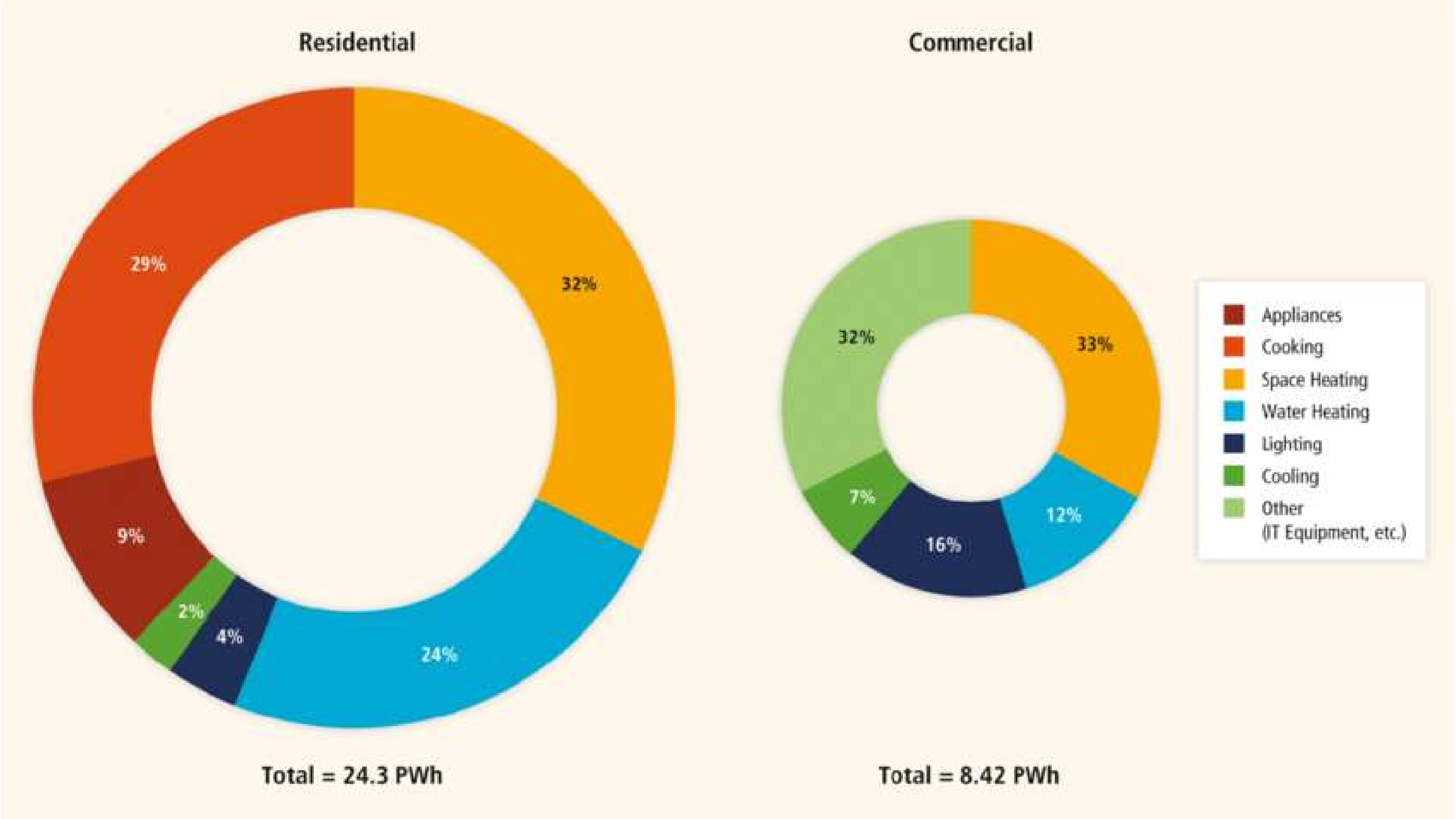
Global energy: a roadmap to 2050?



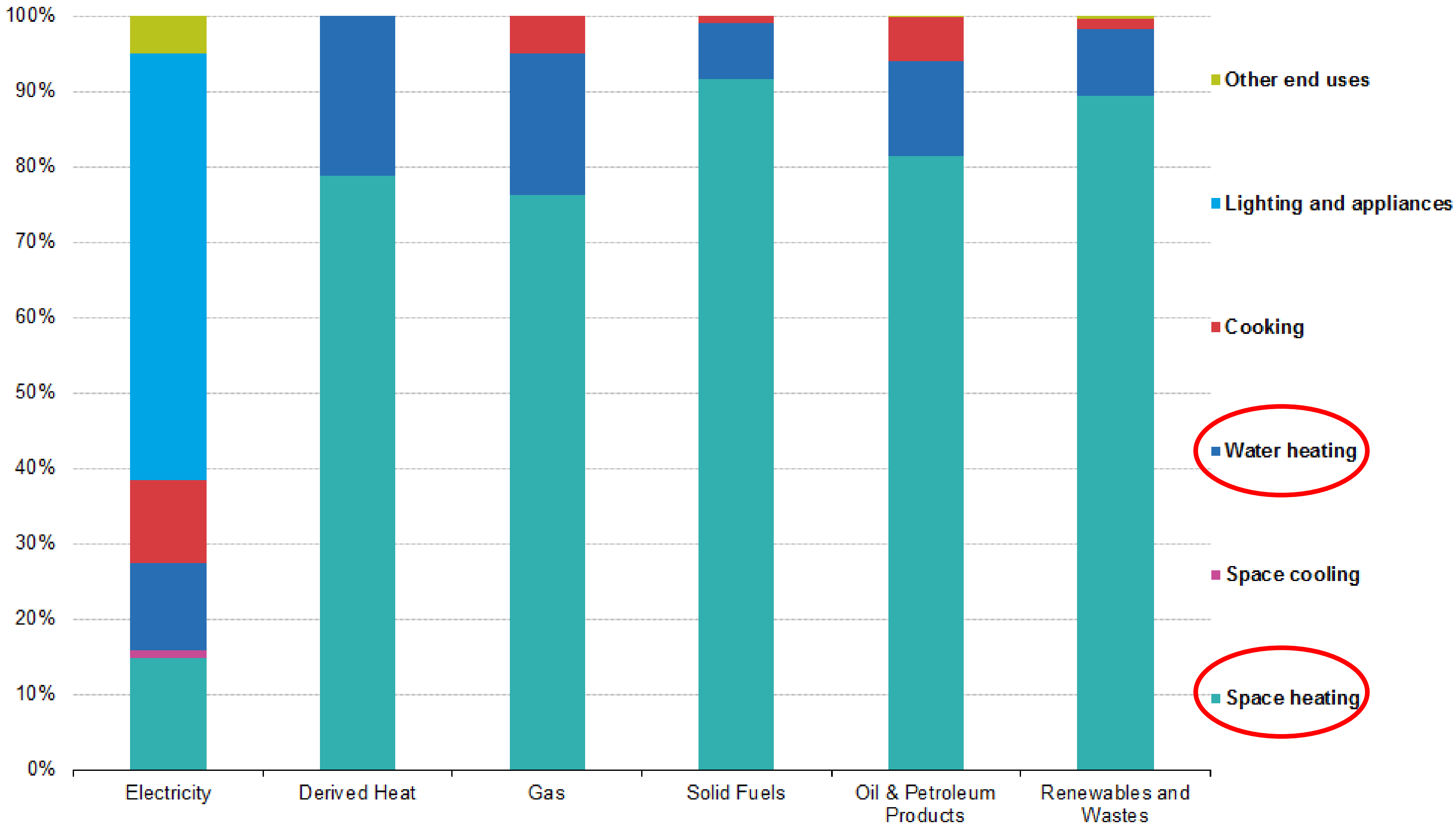
Source: IRENA 2018 'Global energy transformation: A roadmap to 2050'

Energy final use in buildings



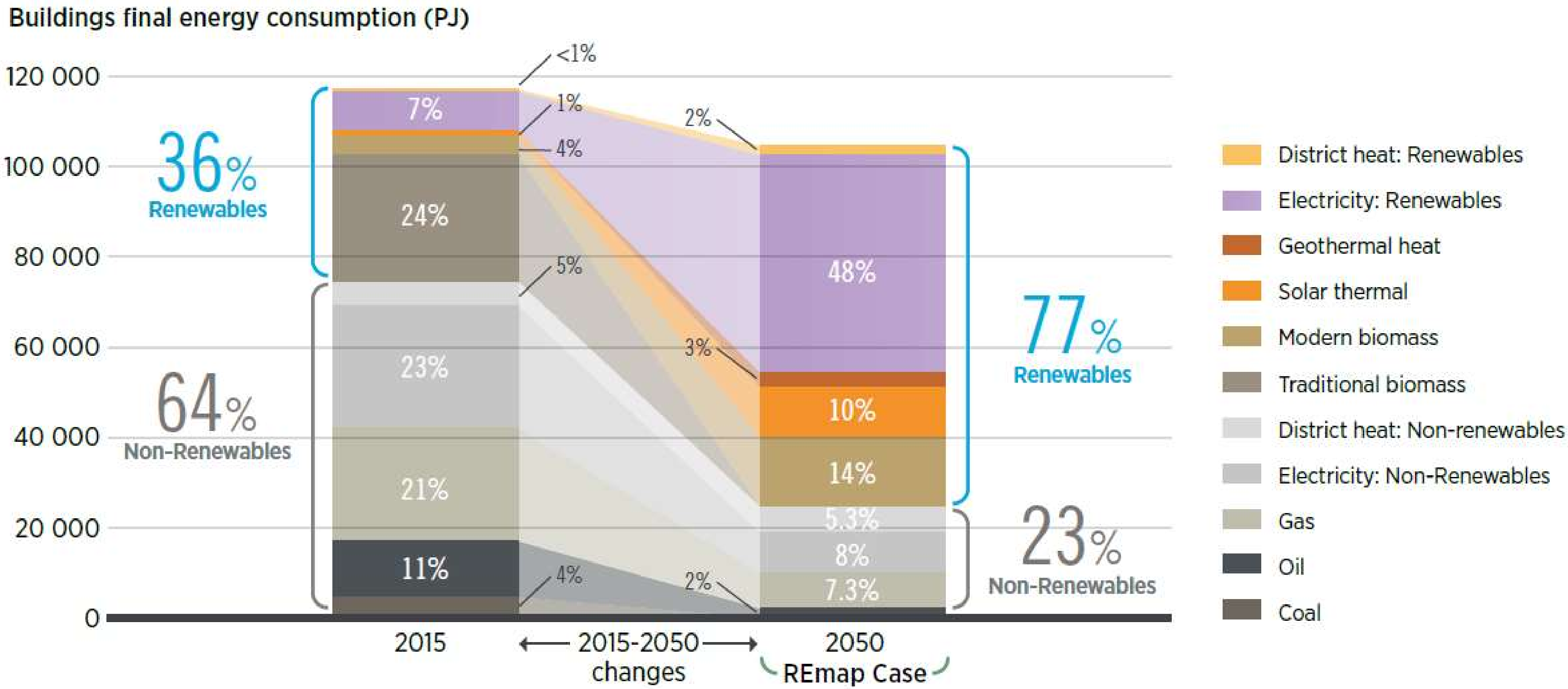
Source: World building final energy consumption by end-use in 2010, IEA (2013).

Final energy consumption: EU-28, 2016



EUROSTAT: Final energy consumption in the residential sector by type of end-uses for the main energy products, EU-28, 2016

The potential of solar thermal by 2050



Source: IRENA, Global Energy Transformation 2018

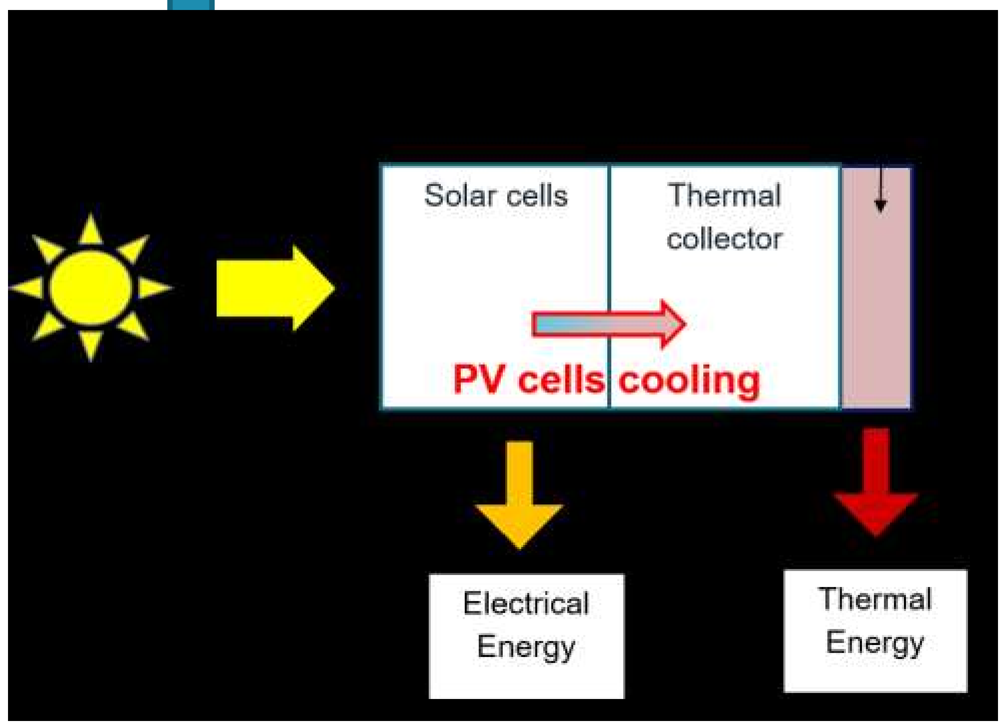
EU target of 1 m2 of solar-thermal installations per person

Content

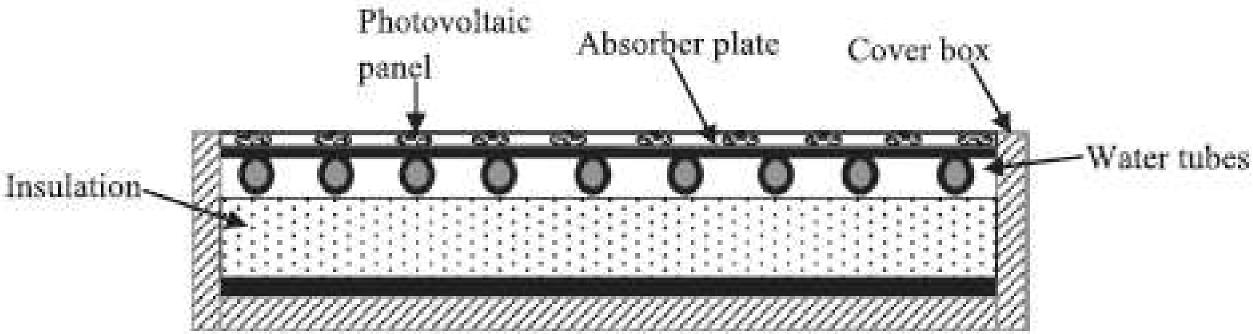
PV/T: working principle

PV-array

Solar thermal collectors

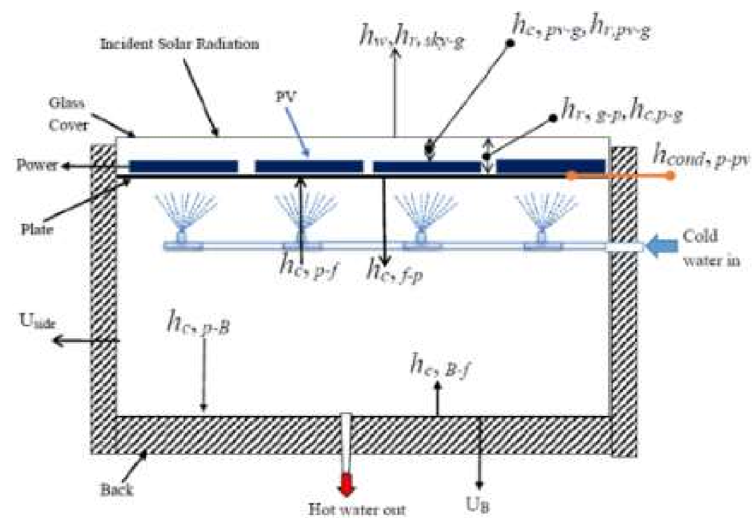


Water-based PV/T systems



Flat-plate water collector

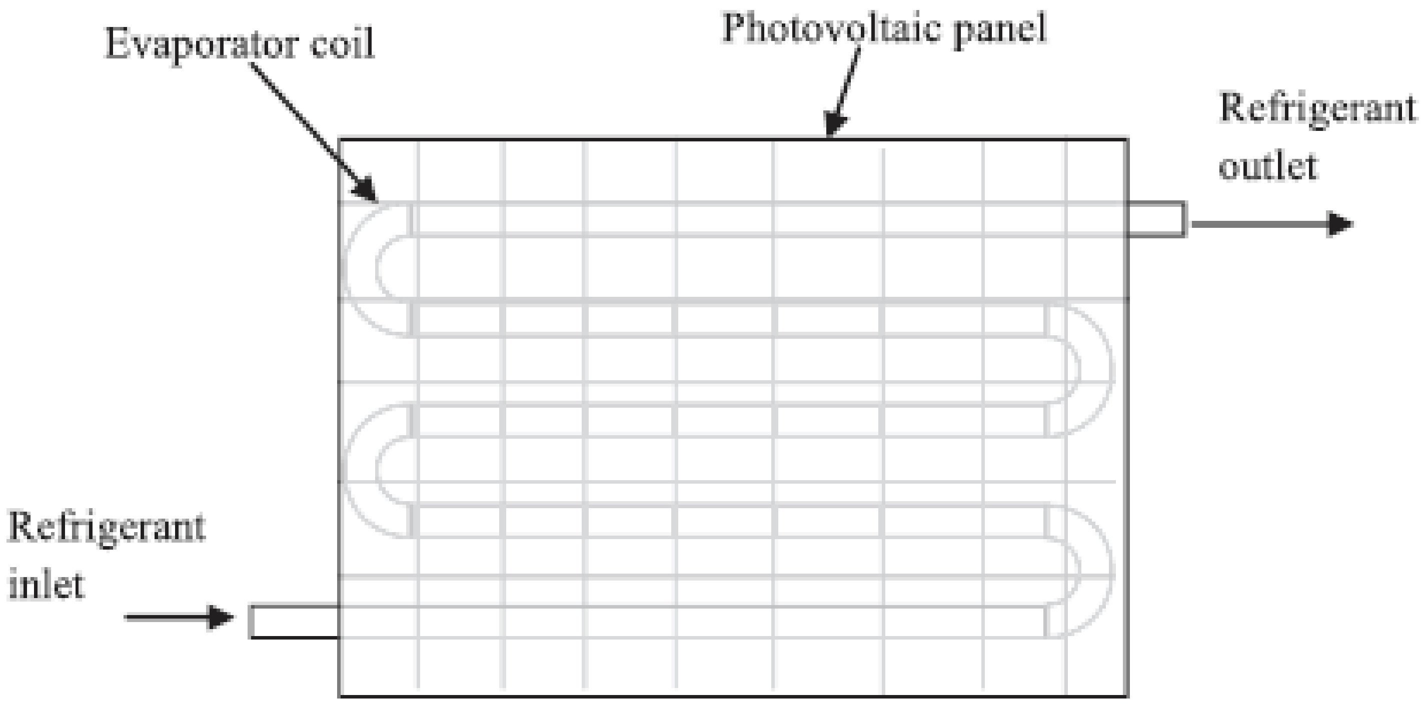
Source: Abdelrazik et.al, 2017



Source: H.A. Hasan et.al, 2018

Water collector with a jet collision system

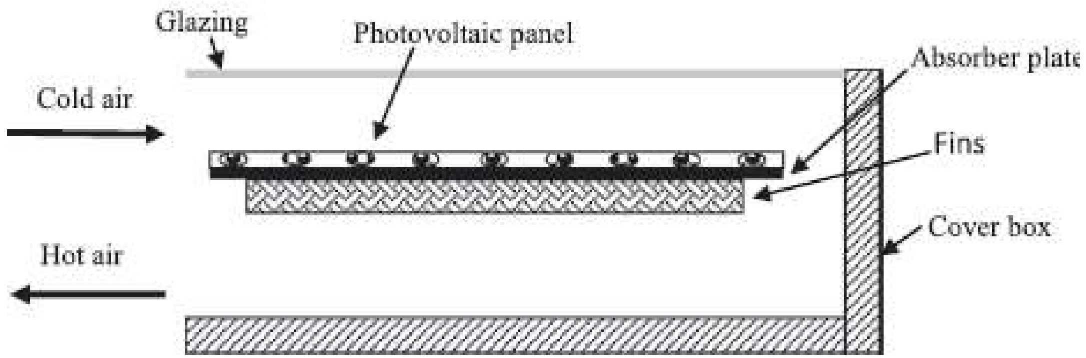
Refrigerant-based PV/T systems



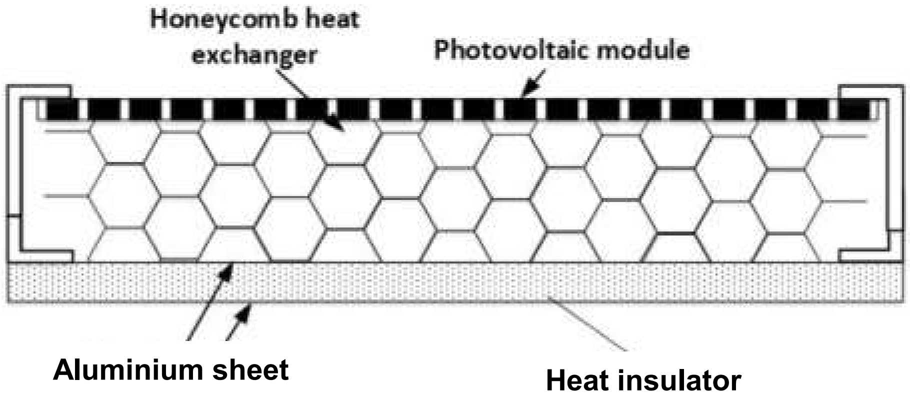
Refrigerant based PV/T system

Source: Abdelrazik et.al, 2017

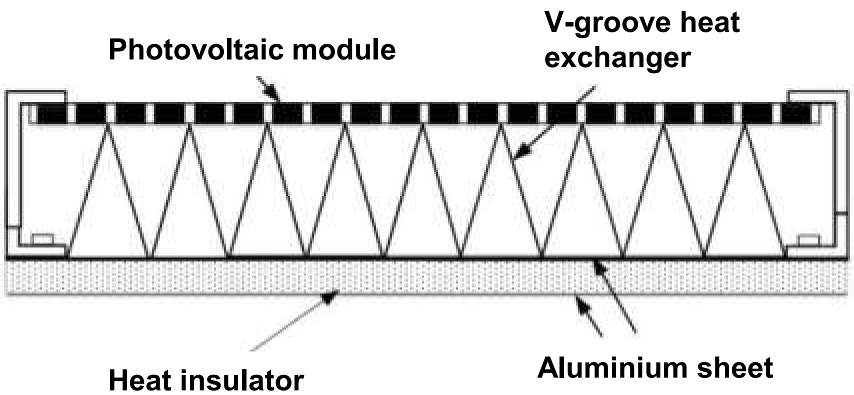
Air-based PV/T systems



Two-passes heat exchanger with fins



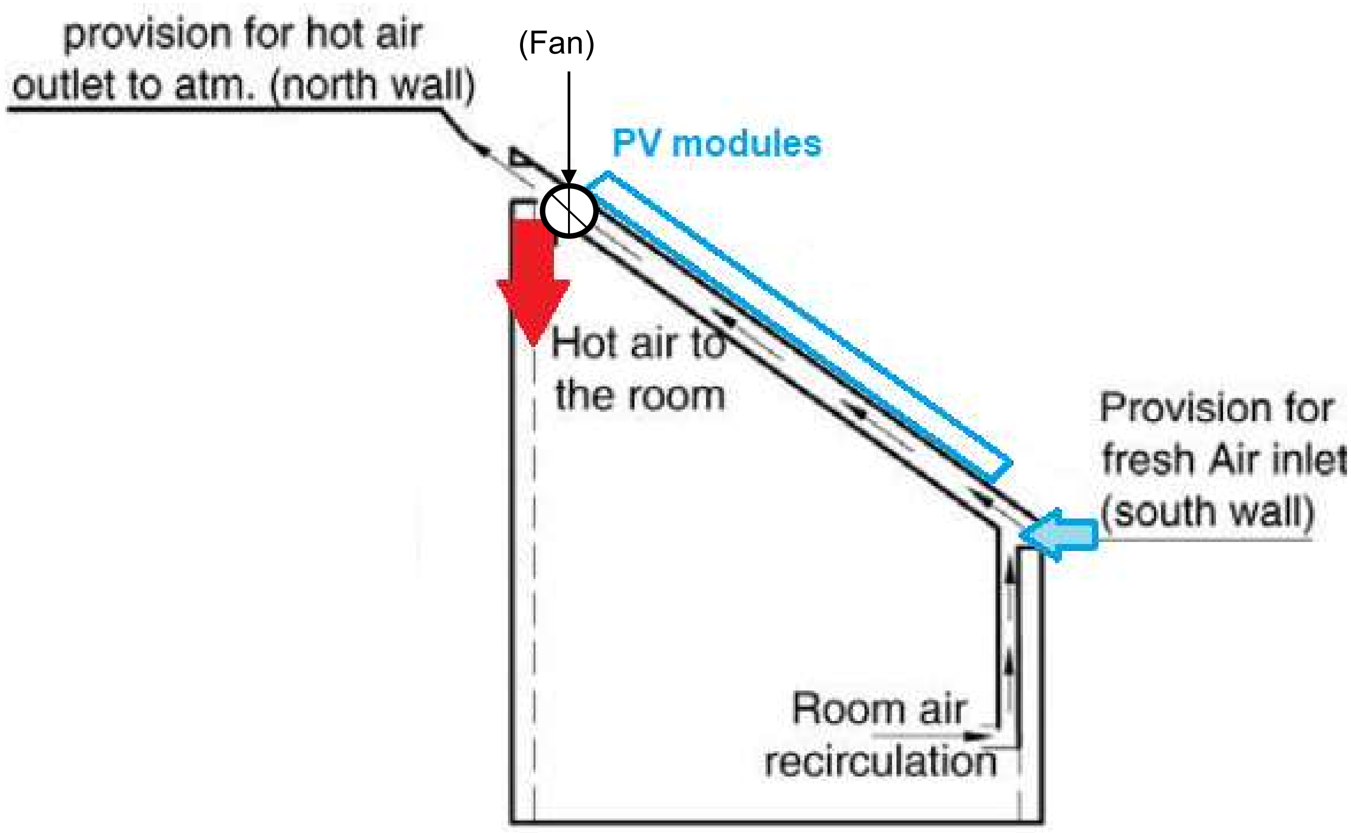
Honeycomb heat exchanger



V-groove heat exchanger

Source: Abdelrazik et.al, 2017

Air-based PV(T) system for space heating

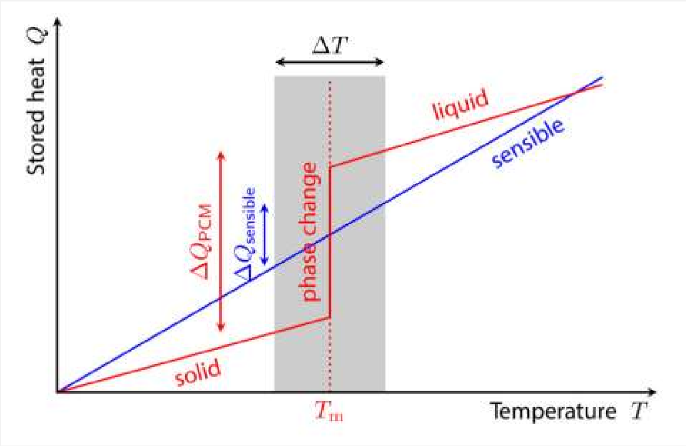


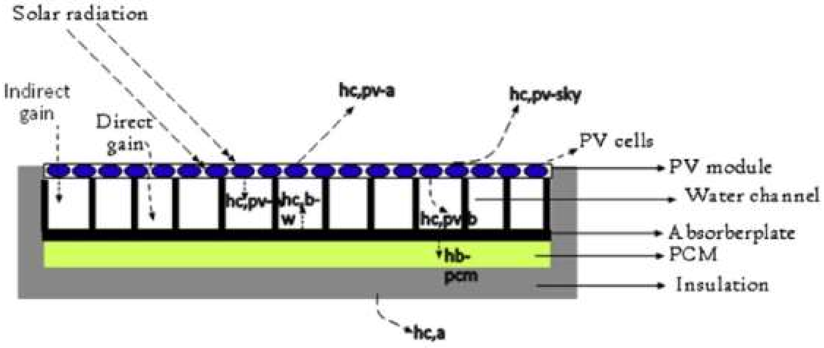
Bulding Integrated PV/T system (BIPVT) for space heating

Source : Agrawal et. al, 2010

Phase Change Materials (PCM) PV/T

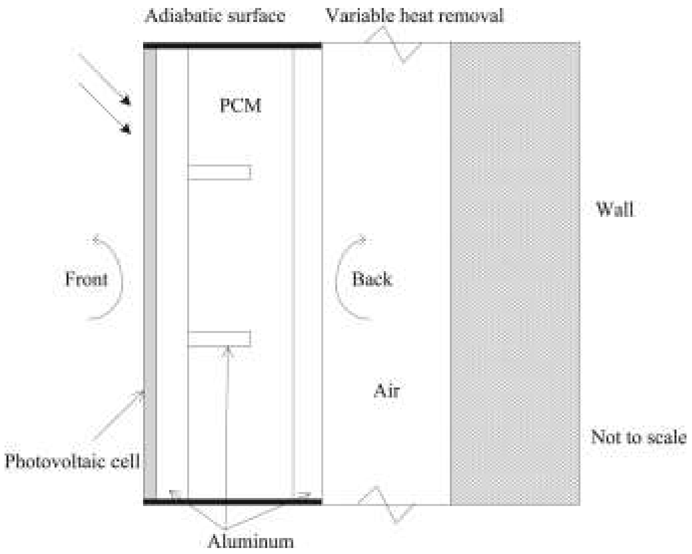
PCM can store large amounts of energy at a constant temperature :

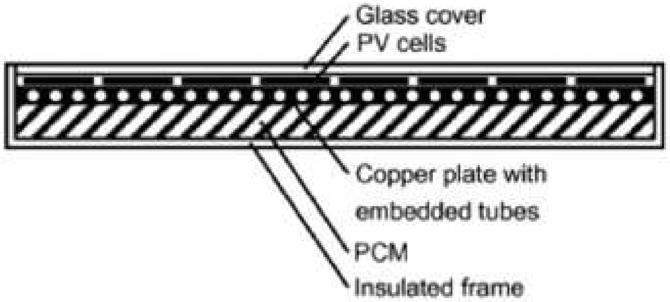




Source: *Joshi et. al, 2018*

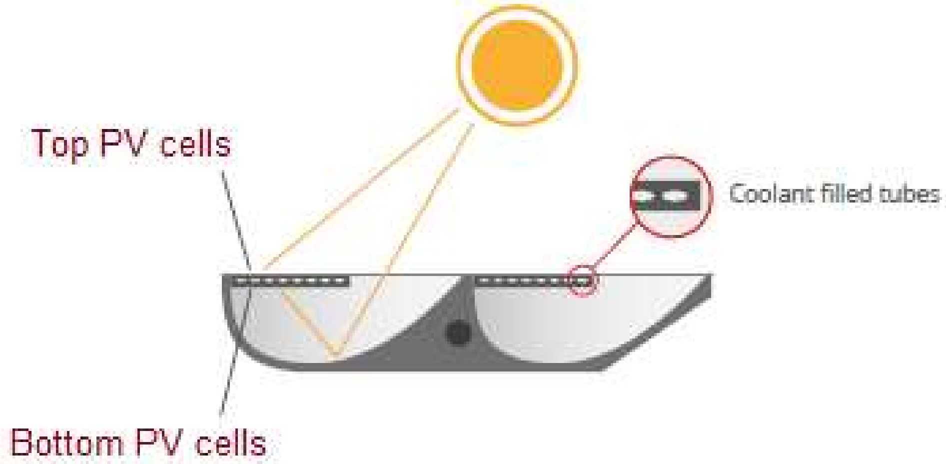
Different topologies of PV-PCM panels :





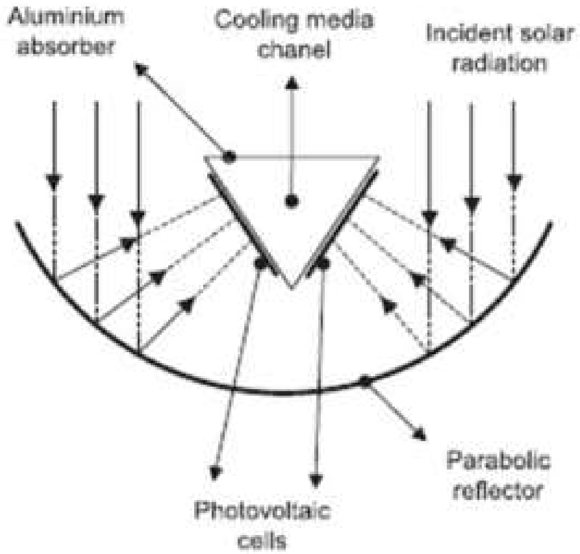
Source: *Maria C. Browne et. al, 2015*

Concentrated (C) PV/T



CPVT with parabolic trough and bifacial PV

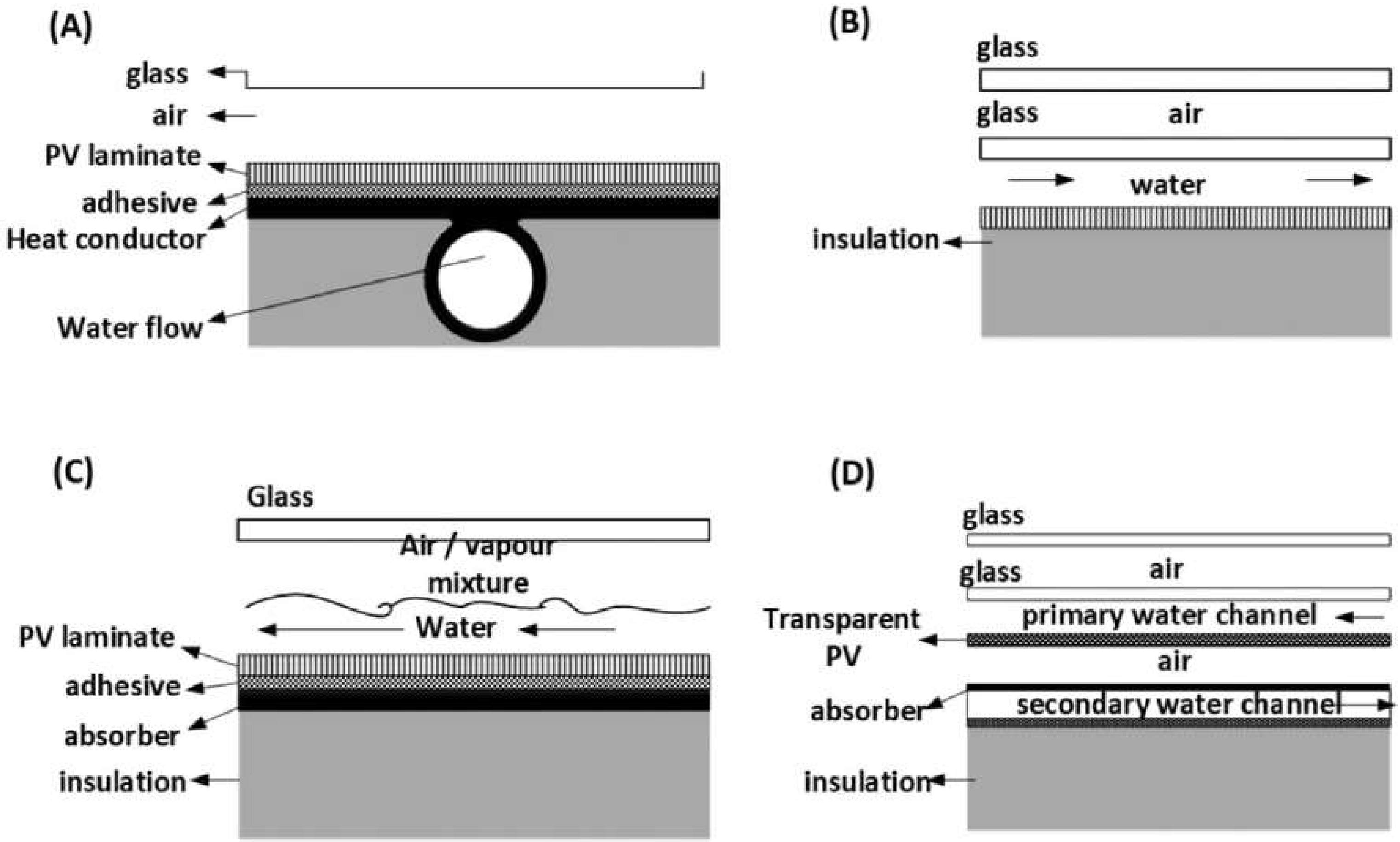
Source: Solarus product datasheet



CPVT with compound parabolic concentrators and triangular channel receiver

Source: Joshi et. al, 2018

Types of glazing systems on PV/T



Single-layer glazing

multi-layer glazing

Source: Abdelrazik et.al, 2017

Glazing systems

YES because

- Allows a cooling channel above the PV cells
- Allows a spectral filtering before solar radiation hits the PV cells
- Enhances the thermal performance
- Protects the PV cells from environmental influences

NO because

- Of optical absorption in the glazing glass layers
- Results in more expensive panels due to the glazing materials

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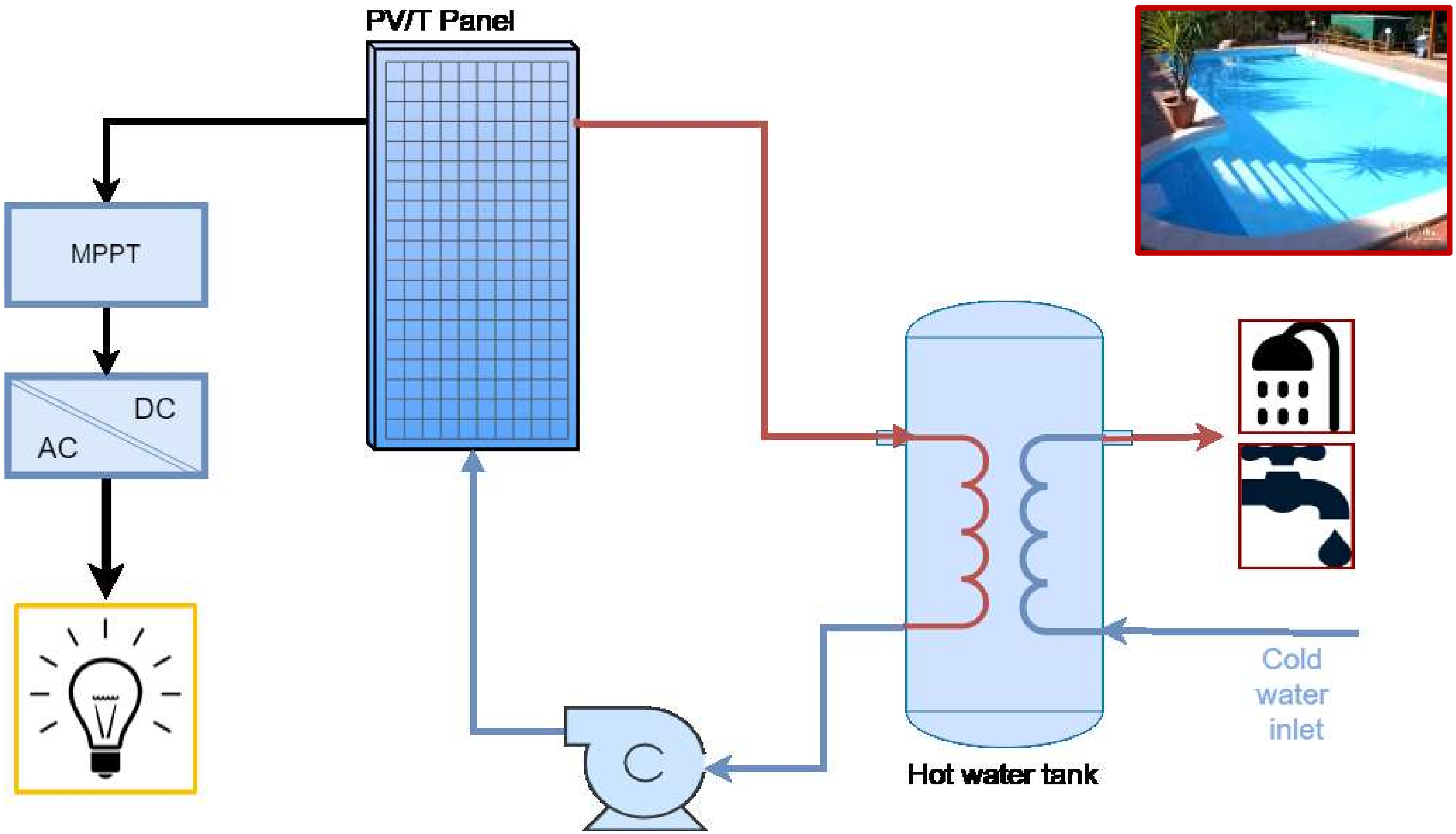
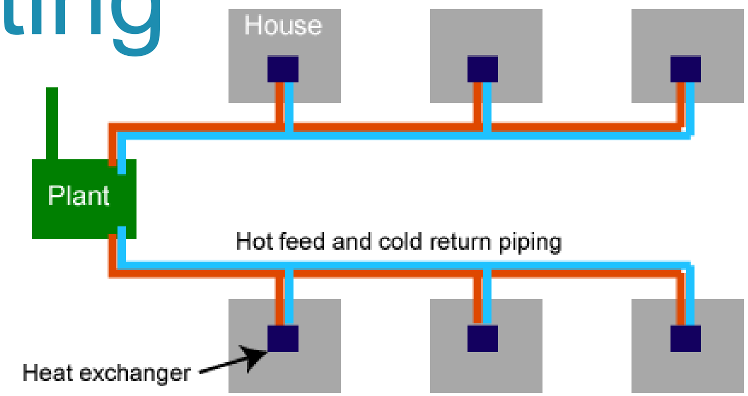
Water-based PV/T for domestic use

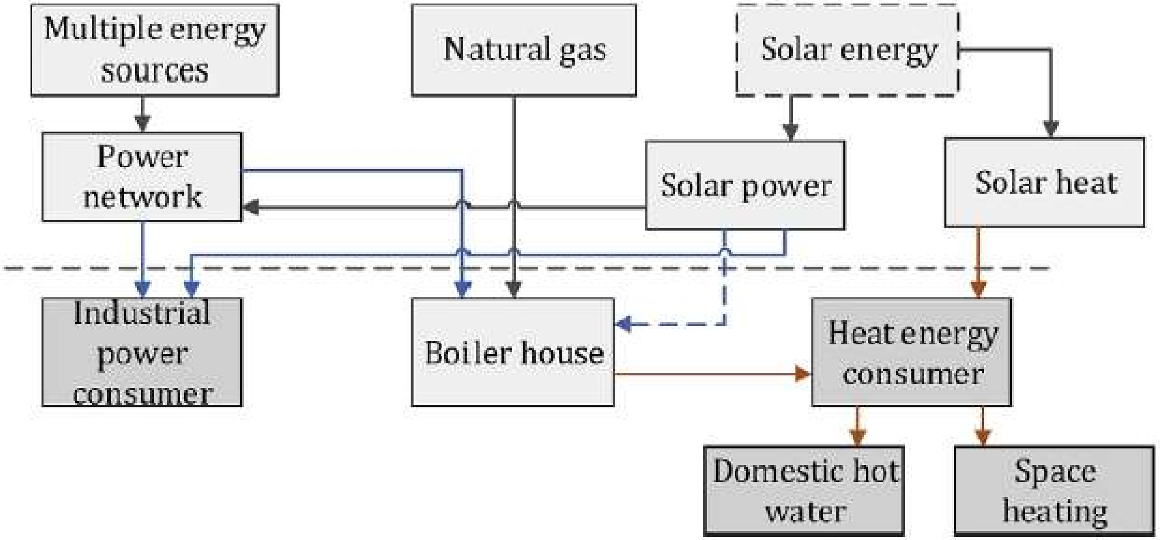
Target water temperature range: 40 to 65 °C



Water-based PV/T for district/industrial heating



Target water temperature range: 40 to 115 °C



Source: Pakere et.al. 2018

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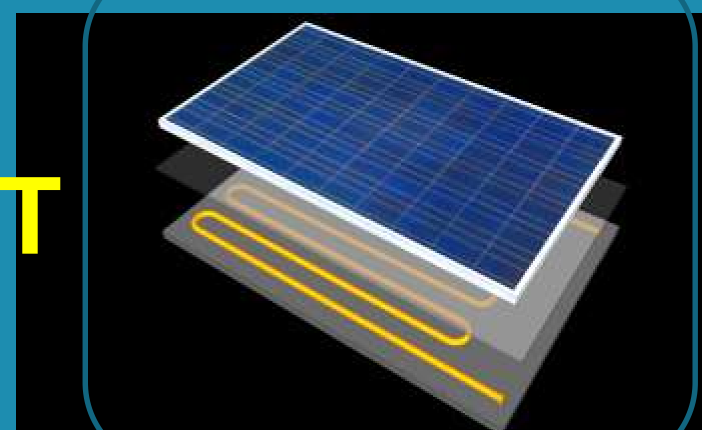
PV + T(hermal)

Evaluation vs

PV/T



Theoretical evaluation of performance: PV+T vs PV/T

From the values of datasheets

With

$$P = \frac{\text{Total power output of the collector}}{\text{Collector gross area}}$$

$$C = \frac{\text{Collector price}}{\text{Total power output of the collector}}$$

@ STC conditions
G = 1000 W/m²
T cells = 25 °C
AM1.5 spectrum

1 m² PV → P_{PV} = **190** Wp/m²
C_{PV} = **1.22** €/Wp

1 m² T → P_{T} = **856** W/m²
C_{T} = **0.47** €/W

1 m² PV/T → $P_{PV/T} = P_{therm} + P_{elec}$ = **591** W/m²
$C_{PV/T}$ = **0.93** €/W

PV/T: installed power and installation costs

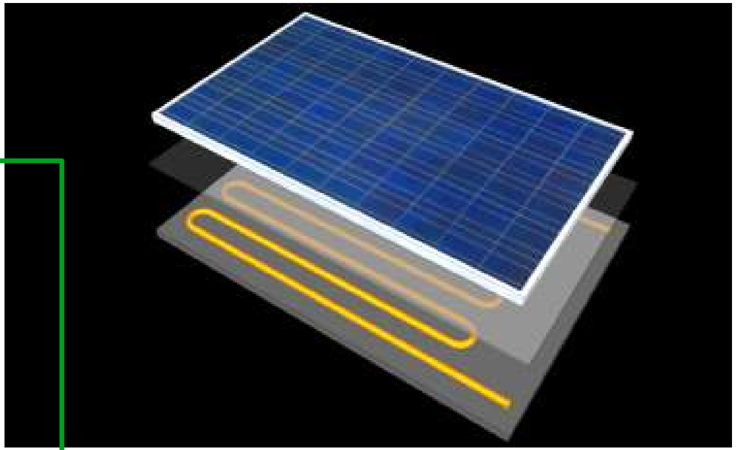
P_{PV} = **190** Wp/m²
C_{PV} = **1.22** €/Wp

$P_{PV/T}$ = **591** Wp/m²
$C_{PV/T}$ = **0.93** €/W

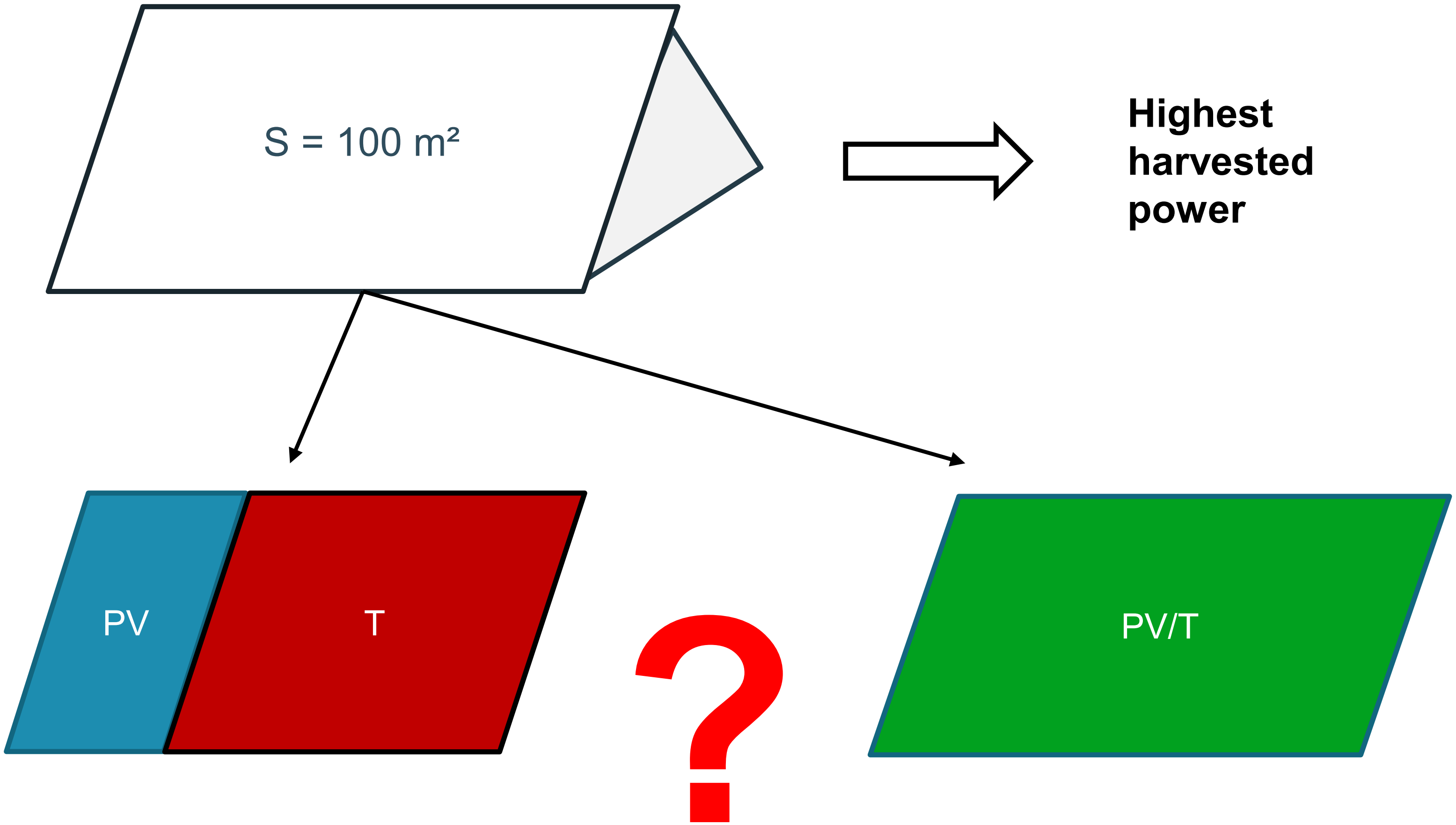
P_{T} = **856** W/m²
C_{T} = **0.47** €/W

PV and T collectors cannot be stacked on the same surface

- Roof surface optimization
- Simultaneous electrical and thermal power production



Can PV/T power production be higher than power production of a PV+T combination?



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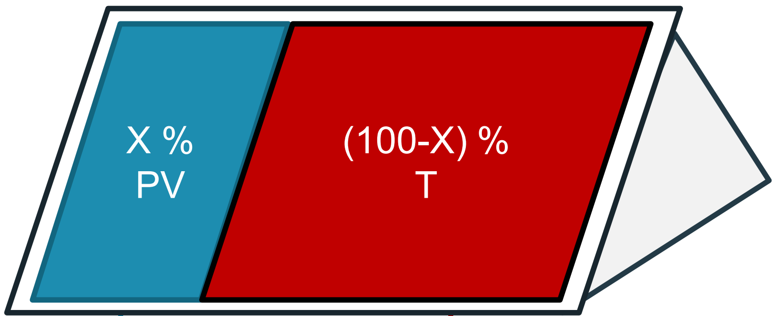
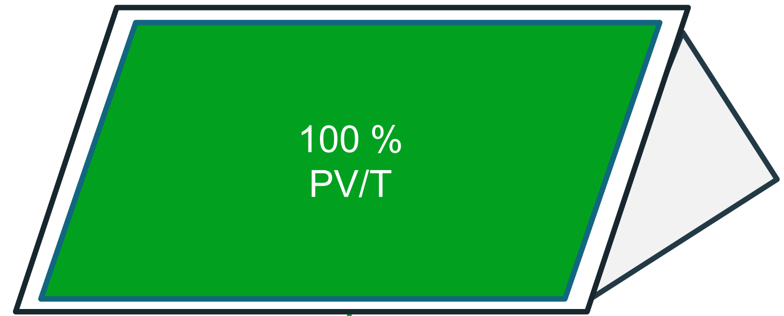




$X * S * P_{PV}$ **+** $(1-X) * S * P_T$ $\;\;\;\;$ $S * P_{PV/T}$

↓ $\;\;\;\;$ ↓

$$\mathbf{P_{PV+T;tot}} \;\; \mathbf{<} \;\; \mathbf{P_{PV/T;tot}}$$

↓

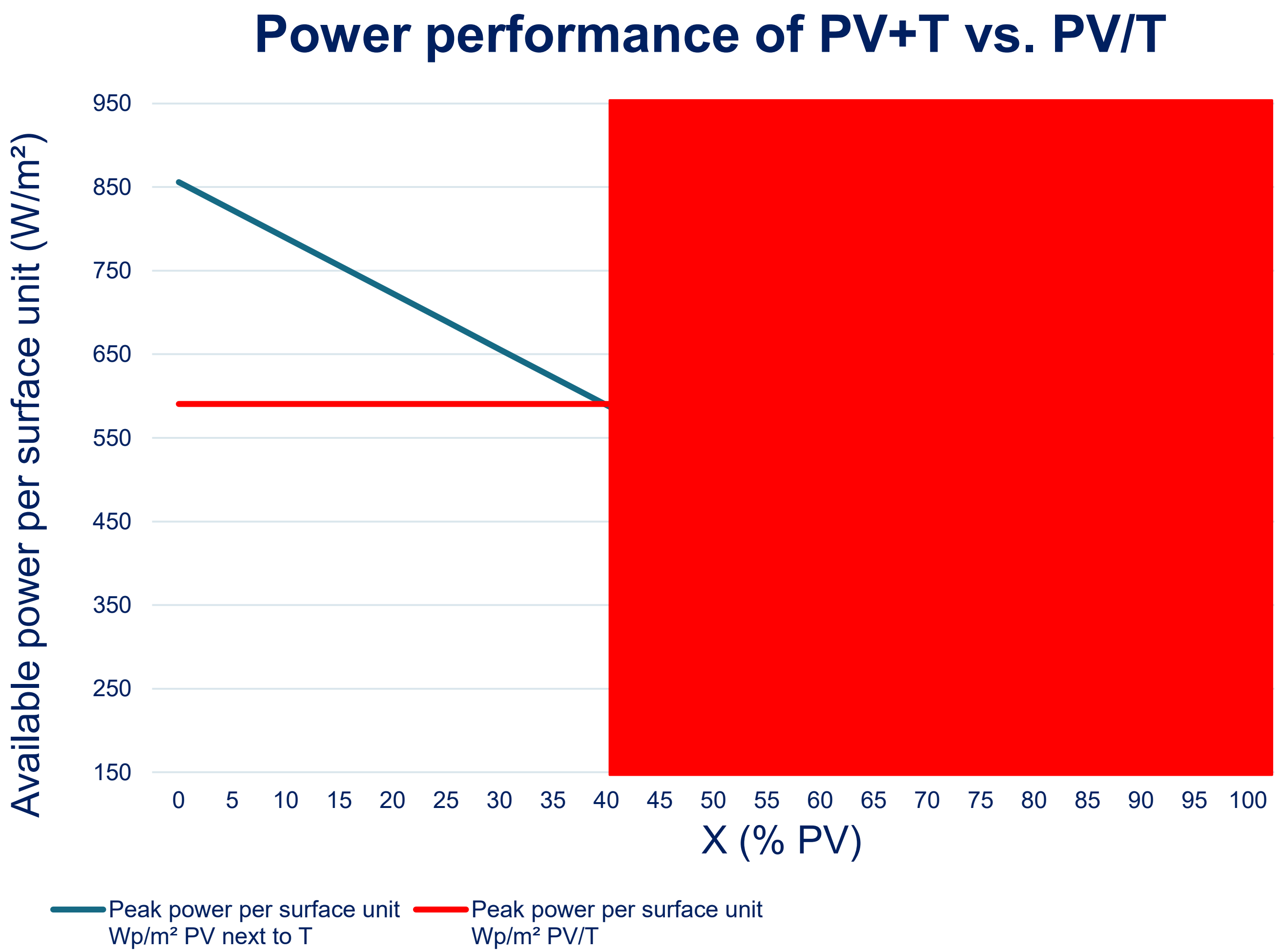
P_{PV} = **190** Wp/m²

P_T = **856** W/m²

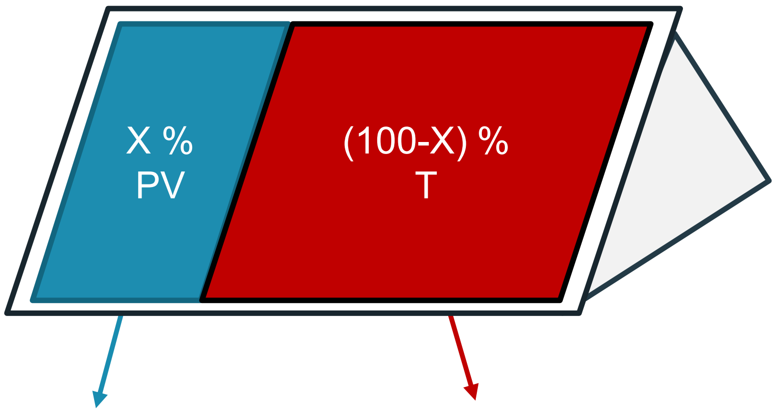
$P_{PV/T}$ = **591** Wp/m²

YES, if X > 40 %

Power yield: PV+T vs PV/T



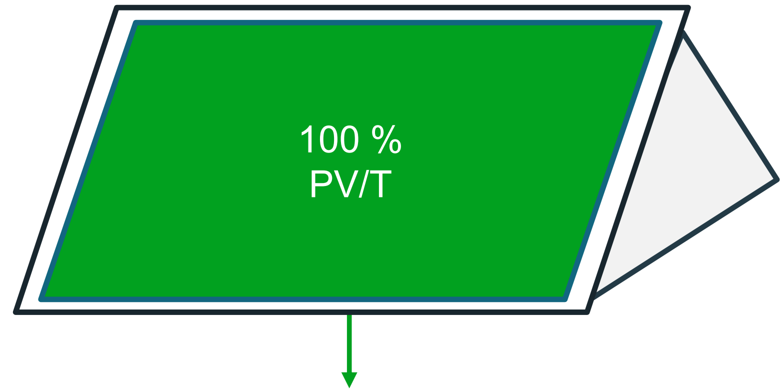
Costs PV/T lower than PV+T ?



$X * C_{PV}$ **+** $(1-X) * C_T$

↓

$\mathbf{C_{PV+T\ tot}}$



$C_{PV/T}$

↓

$\mathbf{C_{PV/T\ tot}}$

$\mathbf{C_{PV+T\ tot}} < \mathbf{C_{PV/T\ tot}}$

↓

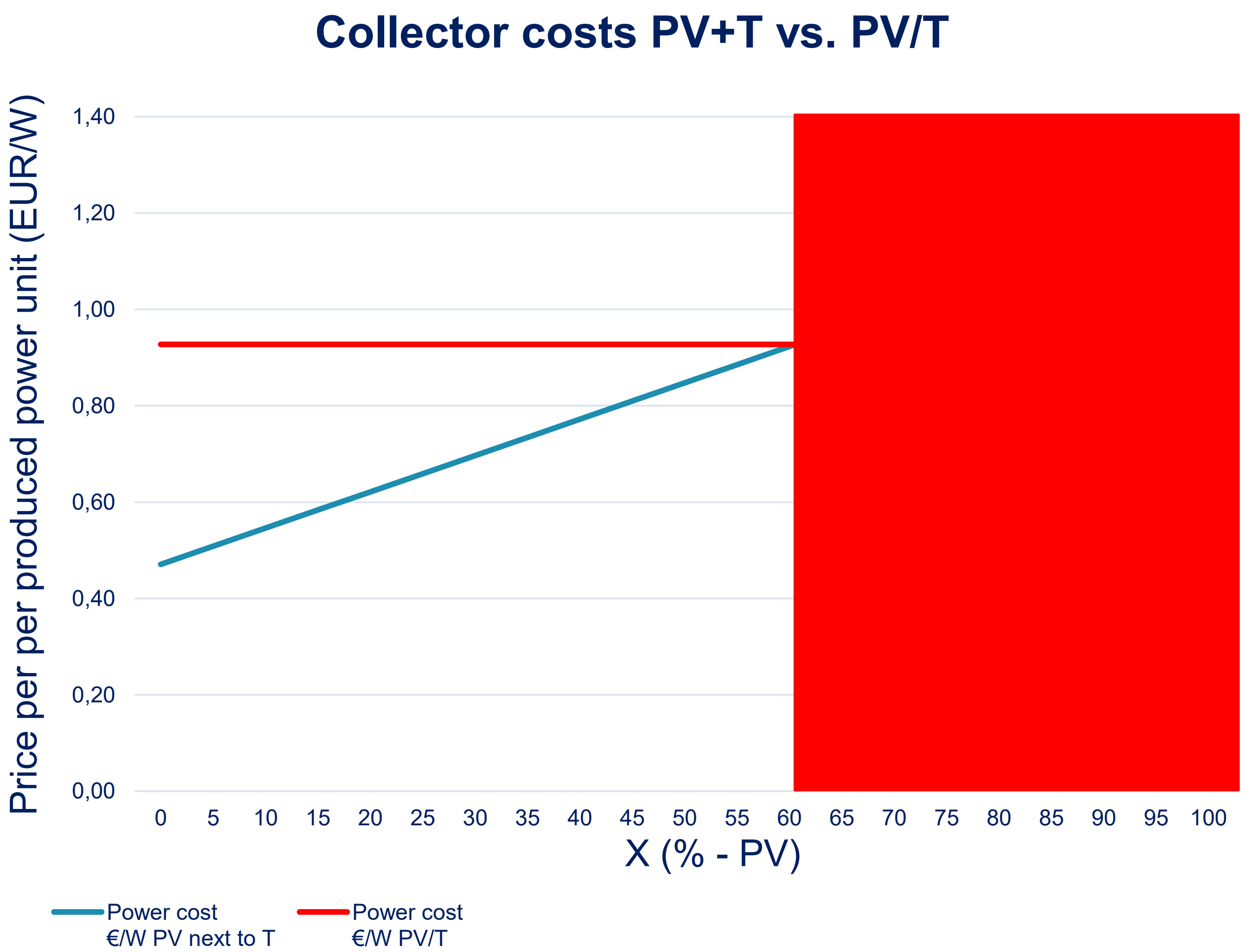
YES, if X > 60 %

C_{PV} = **1.22** €/Wp

C_T = **0.47** €/W

$C_{PV/T}$ = **0.93** €/W

Costs PV/T lower than PV+T ?



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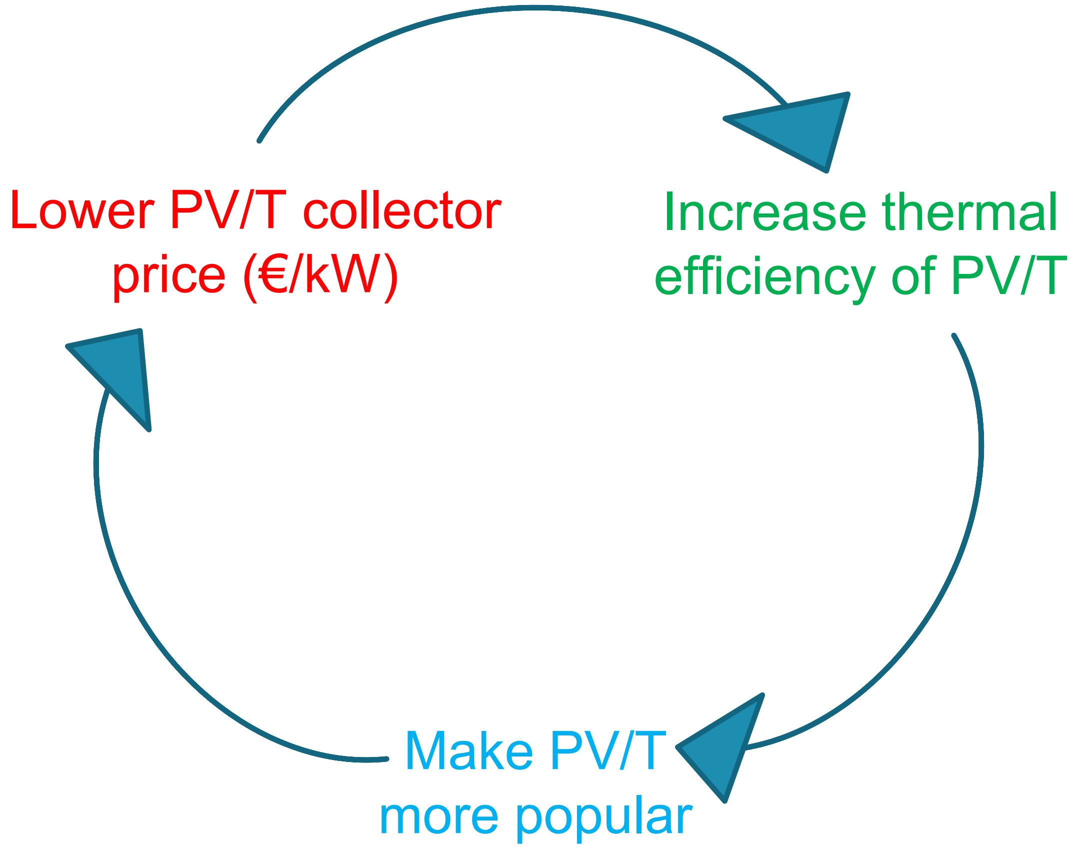
PV/T uptake: challenges



Are these actually **opportunities** not challenges?

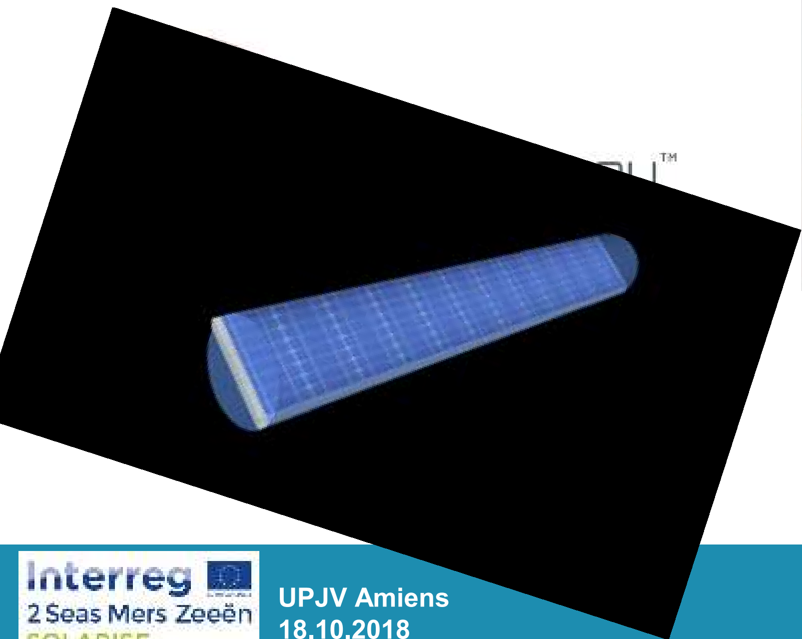
Challenge 1: how to make PV/T cheaper (affordable)?

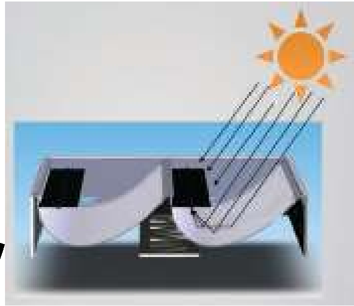
More companies on the market?

DUALSUN

SOLARUS
SUNPOWER FOR THE PEOPLE

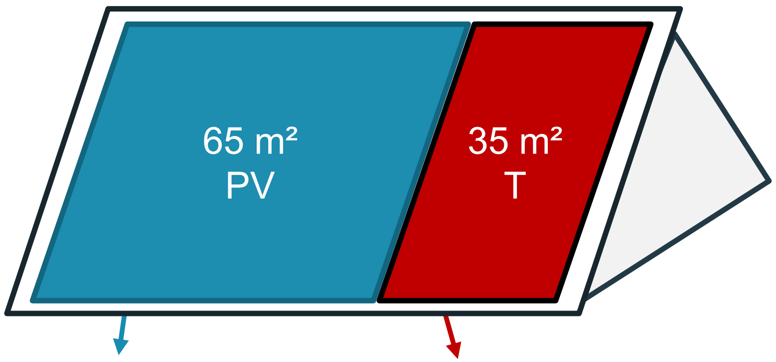
SOLIMPEKS
Solar Energy Corp.





Challenge 2: how to increase thermal (and overal) efficiency of PV/T?

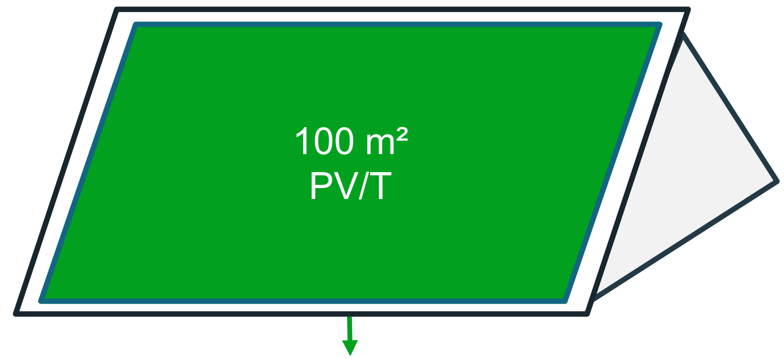
P_{ther} / P_{elec} ratio if X=65% PV



P_{elec} = 12.3 kW

P_{ther} = 30.0 kW

P_{ther} / P_{elec} = **2.43**



P_{elec} = 19 kW

P_{ther} = 85.6 kW

P_{ther} / P_{elec} = **4.5**.

This ratio is not adaptable, and may not suit the power needs.

Challenge 3: how to make PV/T more popular?

- Demonstration projects (SOLARISE, …)
- Instruct (hands-on trainings) the local installers
- Show PV/T state-of-the-art and state-of-the-practice solutions to general public, students, etc.

Other challenges for the PV/T uptake

How to enhance the reliability of PV/T-systems?

- Early detection of possible PV/T failures
- Increasing PV/T-panels lifetime by better materials/design

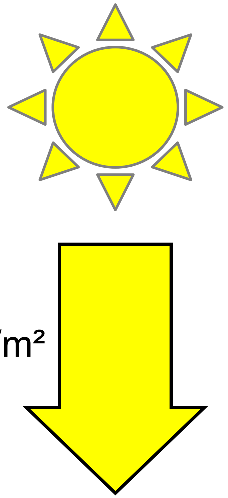
PV panels	25-year performance warranty
T panels	10-year product warranty
PV/T panels	25-year PV performance warranty 10-year product warranty

← **Limit** (T panels: 10-year product warranty)

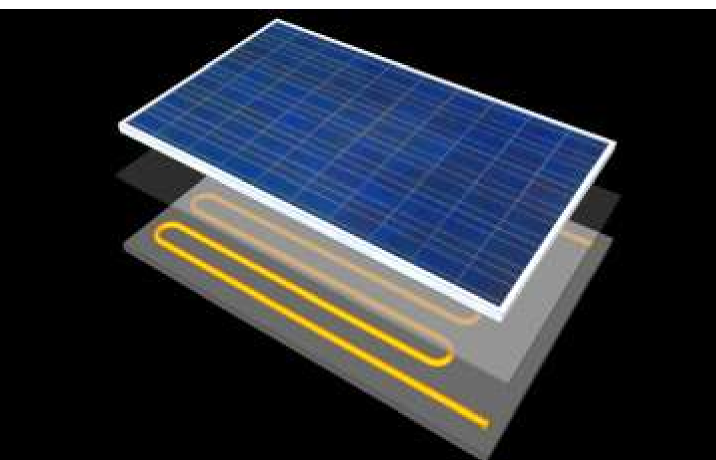
Best warranty durations on the market

Content

Definition of the yield of PV/T panels



1000 W/m²



Electrical Power Output

IEC 61215

$$\text{Elec. Eff.} = \frac{\text{Electrical Power}}{\text{Solar radiation Power}}$$

20 %

?

+

100 %

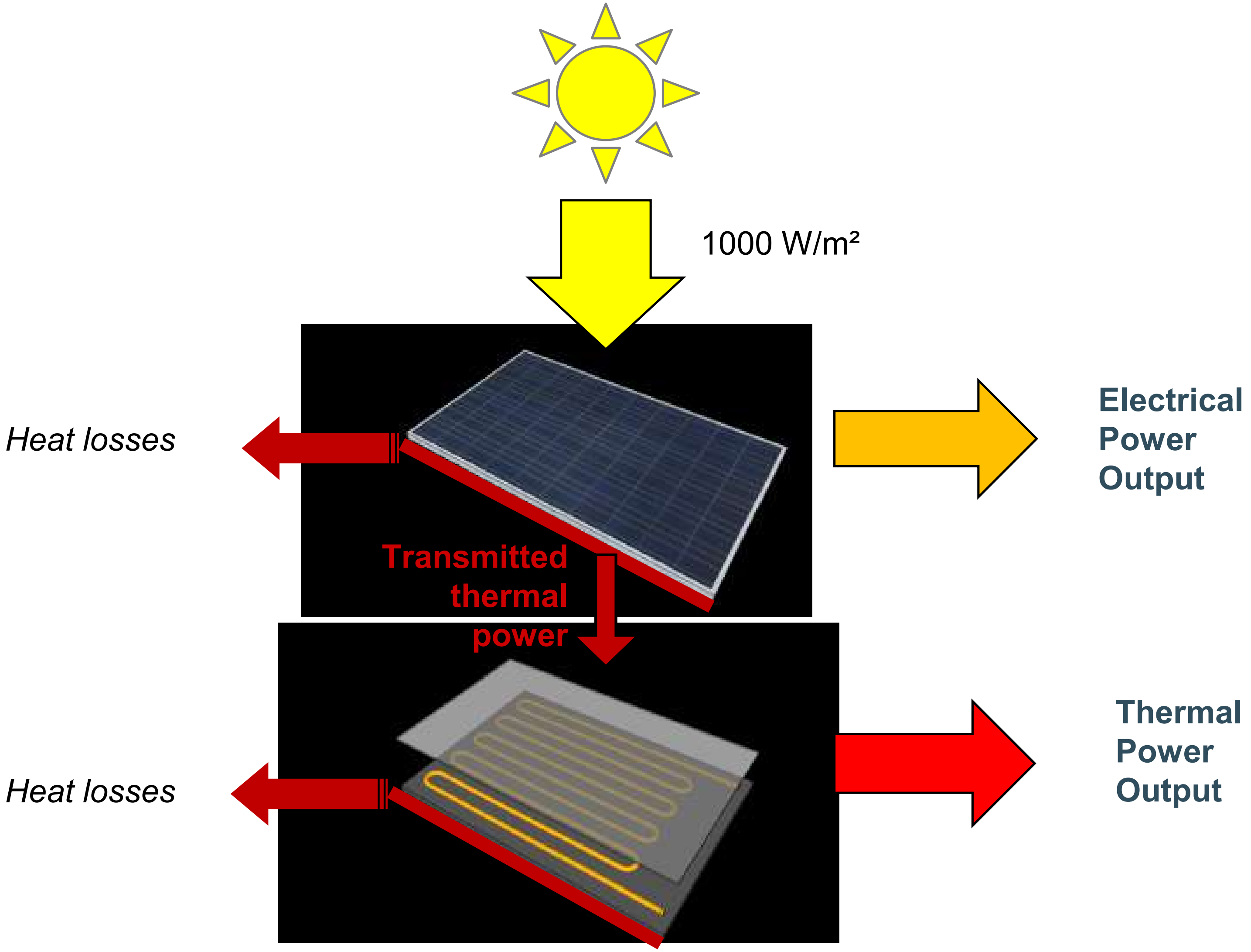
Thermal Power Output

EN 12975

$$\text{Therm. Eff.} = \frac{\text{Thermal Power}}{\text{Solar radiation Power}}$$

80 %

Energy flow in a water-based PV/T panel



Future research on PV/T: yield

Research questions related to the yield of PV/T panels :

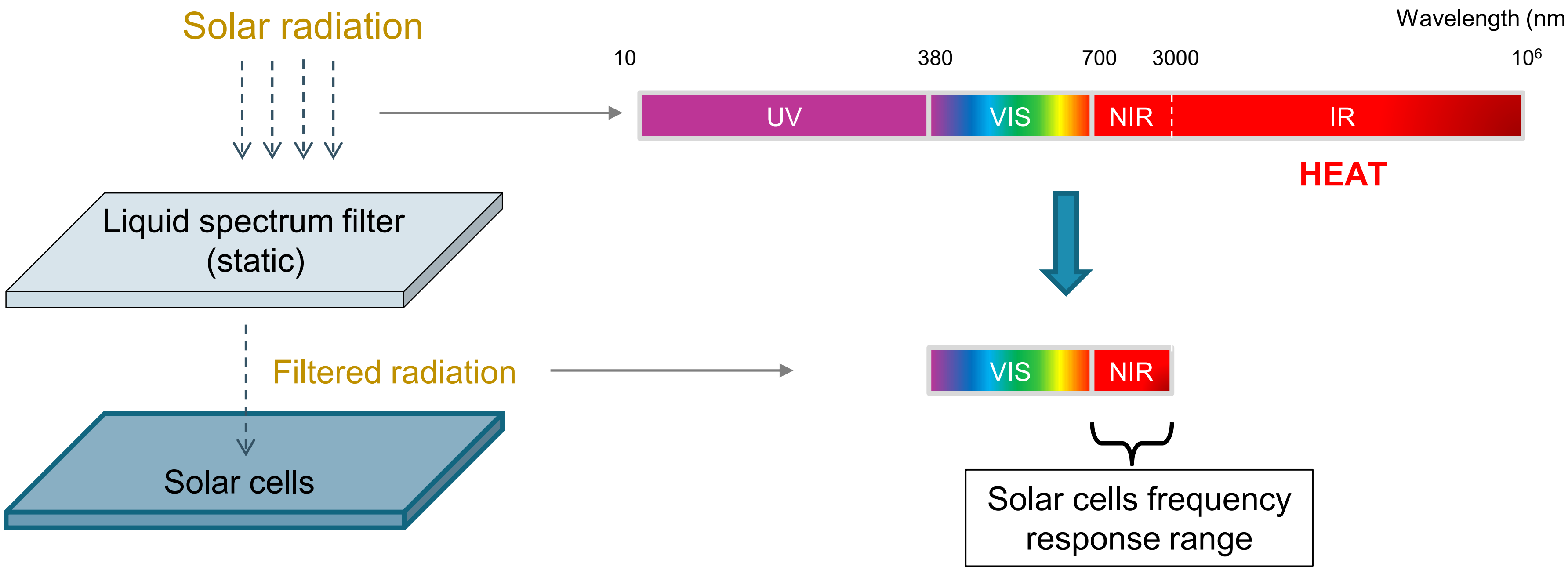
- How to define the overall efficiency of a PV/T panel?
- A standard unified norm for PV/T performance assessment is needed: currently the PV and T parts are tested separately in accordance to two norms (PV and T-collectors)

Future research on PV/T: metrology enhanced modeling

Measure and model state-of-the-art PV/T technology:

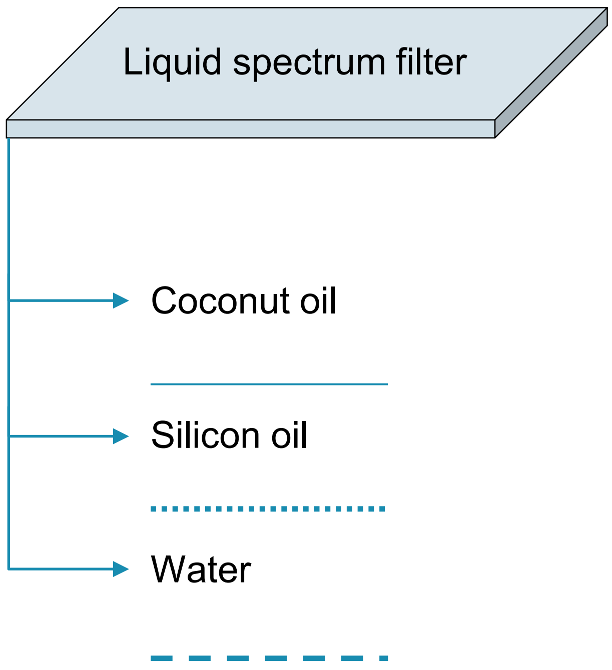
- Beam-splitting PV/T
- Evacuated tubes PV/T
- Use of Fully-Graded Materials heat absorbers

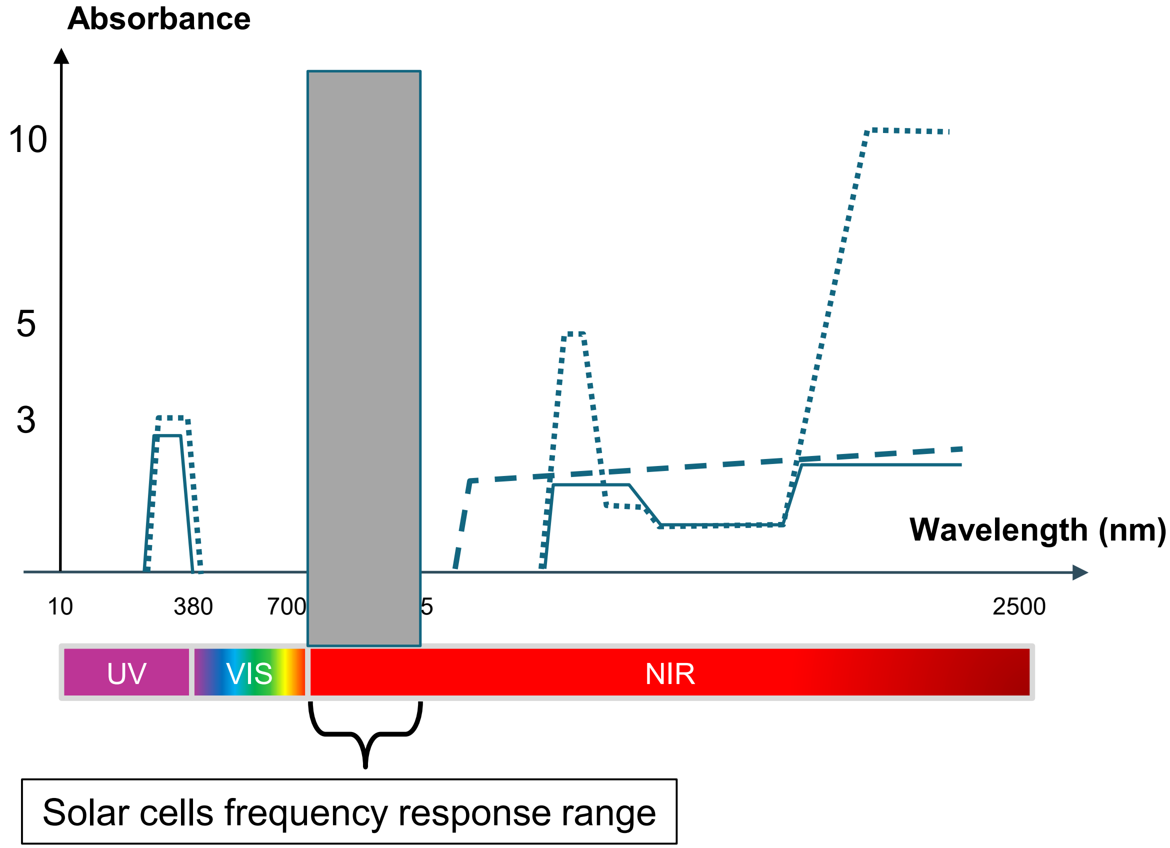
Beam-splitting PV/T (BSPVT)



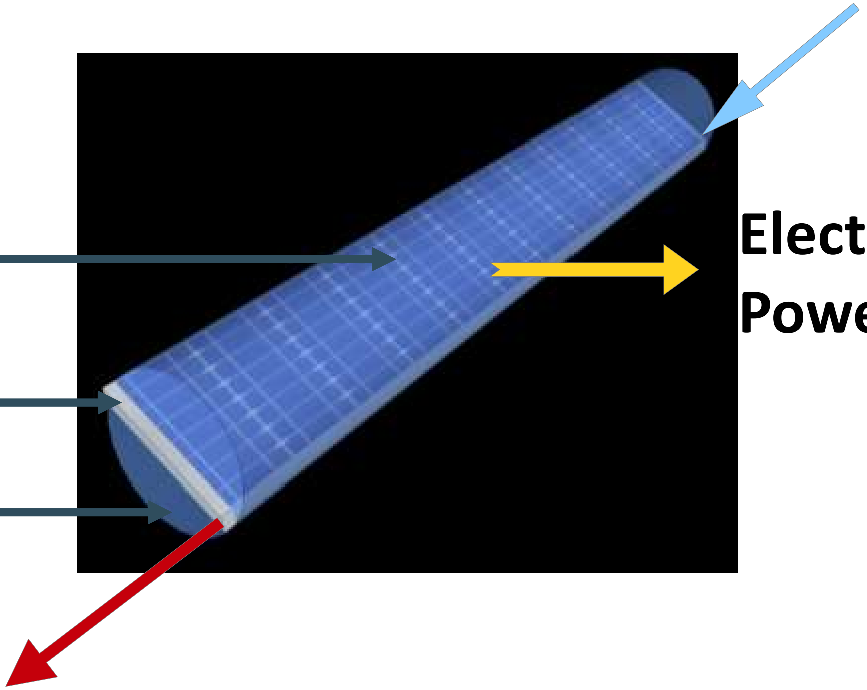
Possible liquids: silicon oil, therminol, nanofluids, …

Beam-splitting PV/T (BSPVT)

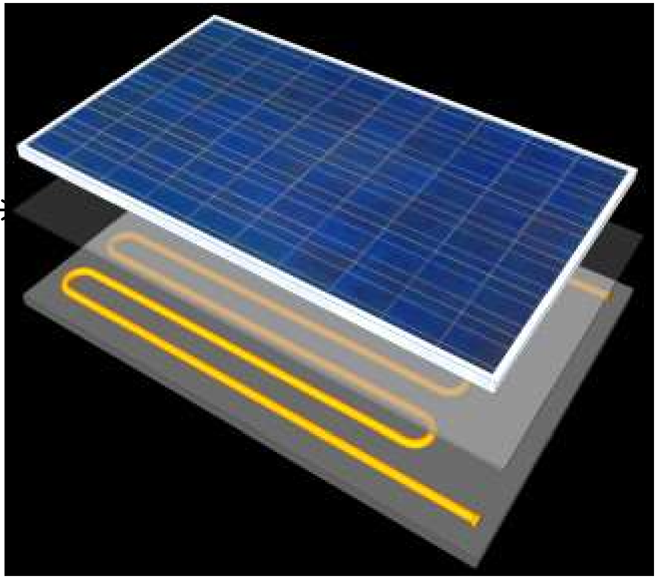




Evacuated tubes PV/T collectors

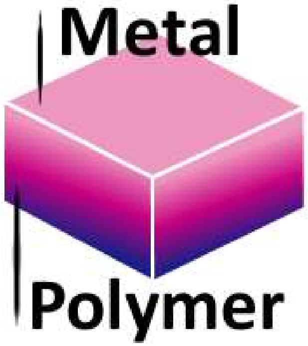


Fully-Graded Materials (FGM) for absorbers



- Higher thermal conductivity
- Light-weight

- But longer production process



Conclusion:



Why PV/T?

Strengths
• Simultaneous, direct thermal and electrical power • Better PV performance due to fluid cooling • Suitable for users with increased thermal needs
Opportunities
• New state-of-the-art technologies • EU 1 m2 solar thermal per capita to be reached • Consumers are more interested to directly use thermal energy (easy to store as warm water)

Thank you for your attention

Questions?

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State-of-the-art technology, challenges and opport

For more information

Prof.dr.ir. Emilia Motoasca Emilia.Motoasca@kuleuven.be

PhD res. Clément de la Fontaine Clement.delafontaine@kuleuven.be

PhD res. Baptist Vermeulen Baptist.Vermeulen@kuleuven.be