Network for Energy Sustainable Transition

Università, centri di ricerca ed imprese per la transizione Energetica Italiana.

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

NEST
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

Università degli Studi di Padova

Dipartimento di Ingegneria dell'Informazione

Consiglio Nazionale delle Ricerche

ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Spoke 1 aims to strengthen the photovoltaic (PV) and concentrated solar power (CSP)/concentrated solar thermal (CTS) sectors for the improvement of renewable energy production, at competitive costs, overcoming current limits and introducing low TRL innovation.

eurac research

Università degli Studi di Palermo

ISTITUTO ITALIANO DI TECNOLOGIA

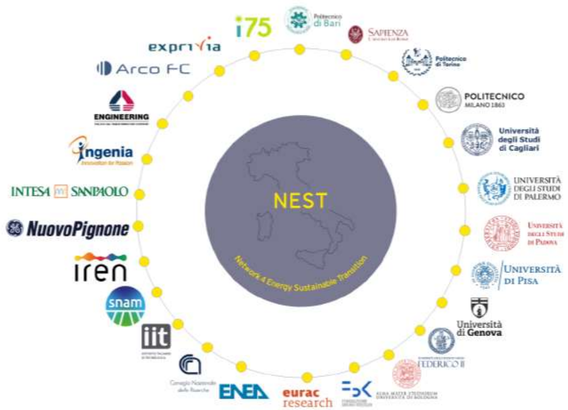
NEST Partners and Spokes

I 9 Spoke di Nest

1. SOLAR: CSP, CST, PV
2. ENERGY HARVESTING & OFF-SHORE RENEWABLE
3. BIOENERGY & NEW BIOFUELS FOR SUSTAINABLE FUTURE
4. CLEAN HYDROGEN AND FINAL USES
5. ENERGY CONVERSION
6. ENERGY STORAGE
7. SMART SECTOR INTEGRATION
8. FINAL USE OPTIMIZ., SUSTAINABILITY & RESILIENCE IN EN. SUPPLY CHAIN
9. ENERGY-SUSTAINABLE ADVANCED MATERIALS

NEST si compone di 25 soggetti:

- 16 soggetti pubblici di cui 4 centri di ricerca
- 9 soggetti privati



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SOLAR: CSP, CST, PV

LEADER

UNIPA

AFFILIATI ALLO SPOKE

ENEA
EURAC
UNICA
CNR
UNIPD
IIT

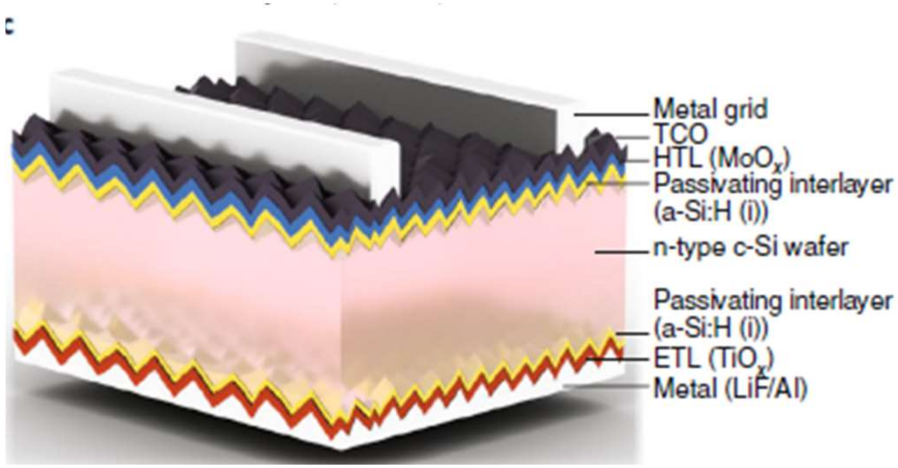
SPOKE 1: SOLAR: PV, CSP & CST

Spoke 1 *will focus on topics useful to boost the* ***PV and CSP/CTS sectors*** *toward higher amount of renewable energy production at competitive costs, overtaking the actual limits and introducing innovation at low Technology Readiness Level.*

The project promotes a considerable ***pipeline of new and advanced versions of existing technologies*** *unlocking the obstacles from lab to fab production, enabling robust continued* ***performance increase****, developing* ***new applications*** *and facilitating further* ***cost reduction****, improving the* ***ecoprofiles of materials****, technologies and systems within the PV, CSP and CST fields, by supporting local companies to develop and sell differentiated and high value products helpful to create* ***competitive development and local jobs****.*

The general framework of the activities is characterized by cross-cutting issues applying a sustainable horizontal integration between different topics and an eco-design approach for decarbonizing materials, systems and technologies.

HJT : Metal Oxide Transition instead of doped layer



The SHJ solar cell utilizes a set of dopant-free metal oxide and fluoride electron and hole transport layers to replace doped silicon layers.
Management of Wf and band alignment for HTL and ETL

NEST Spoke 1 Results:

- **Very good ohmic metal oxide contact**
- **very high passivation degree layers**

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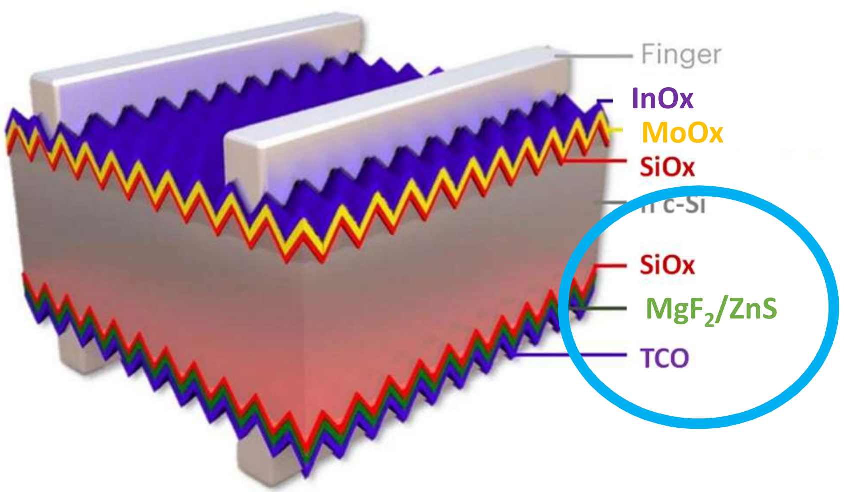
HJT : Metal Oxide Transition instead of doped layer

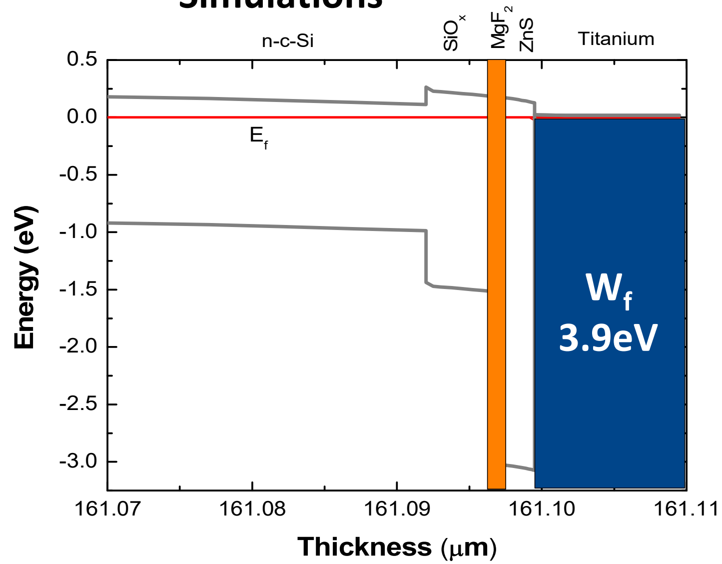
ETL: MgF_2/ZnS by evaporation process



ZnS choice

- Electron affinity (χ) 3.9 eV, very similar to that of SiOx
- Transparency Eg = 3.2 eV
- Deposition of ZnS damages SiOx passivation layer
- Insertion of MgF_2 thin layer recover SiOx passivation

Simulations



Band diagram distribution as deduced by numerical simulations

NEST Spoke 1 Results

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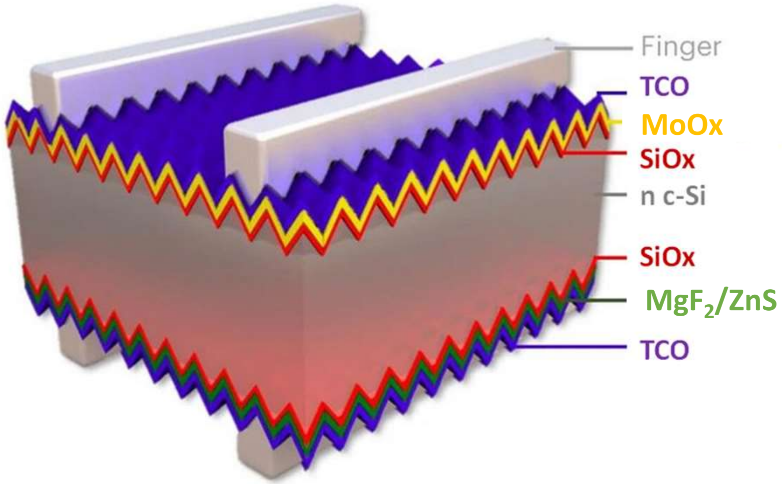
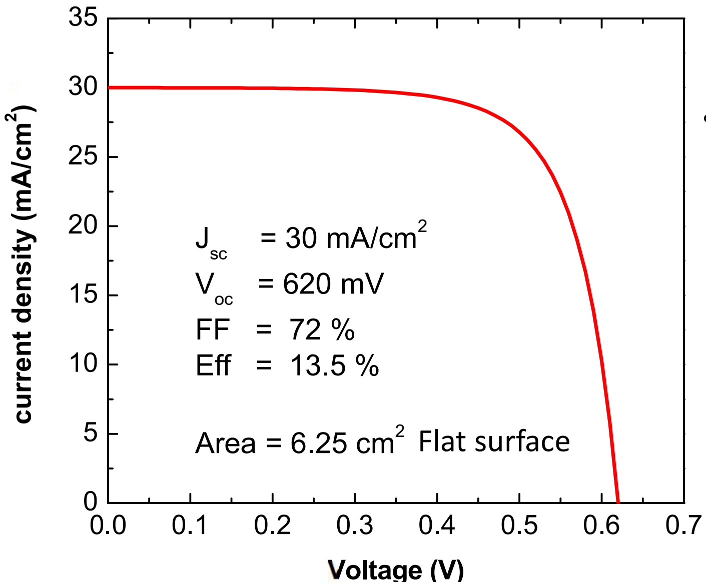
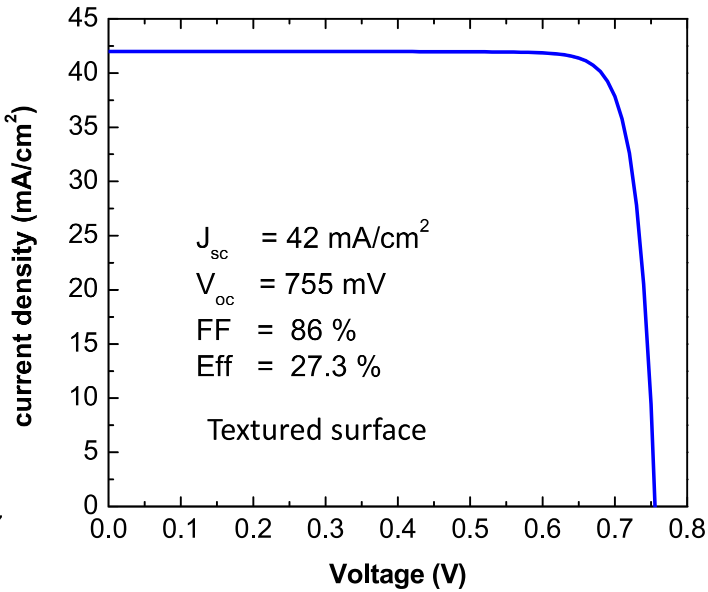
Bifacial Solar cell with evaporated selective HTL, ETL and TCO layers



Experiments



Simulations

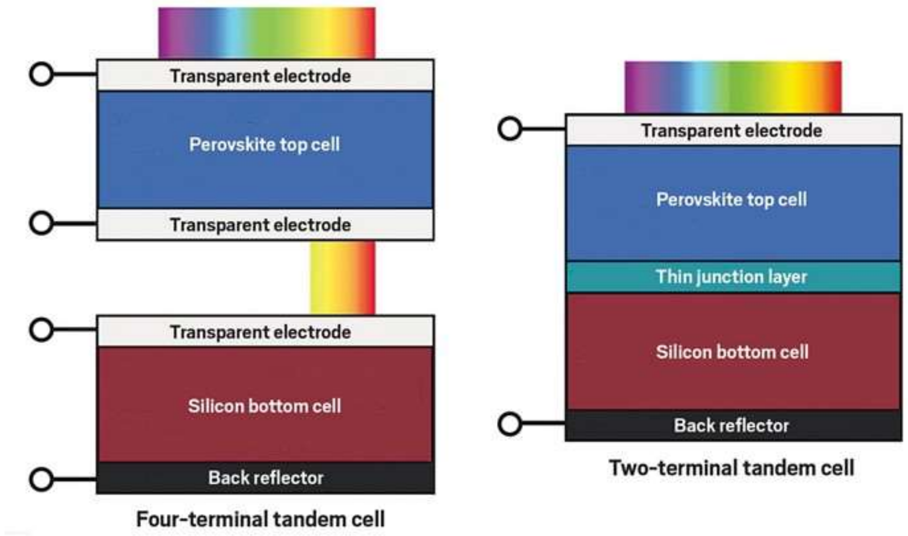


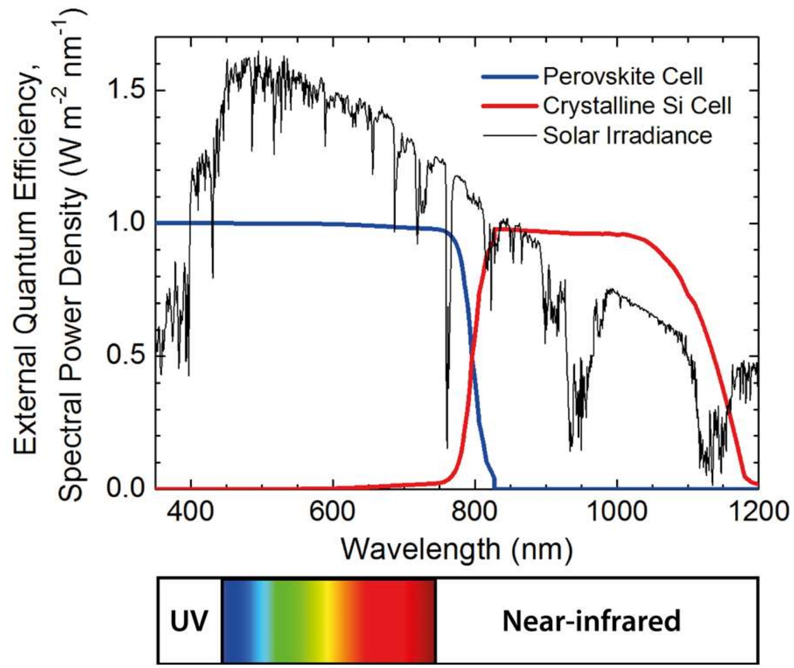
NEST Spoke 1 Results

This preliminary result demonstrated the evaporation process as a candidate for a new generation of silicon based solar cells

Emerging Technologies

Tandem Solar Cells: Combining **Perovskite** and **Silicon** for better performance; coupling different wavelengths absorber





Record Efficiency: 34,6% ; HJT/PVK - LONGi

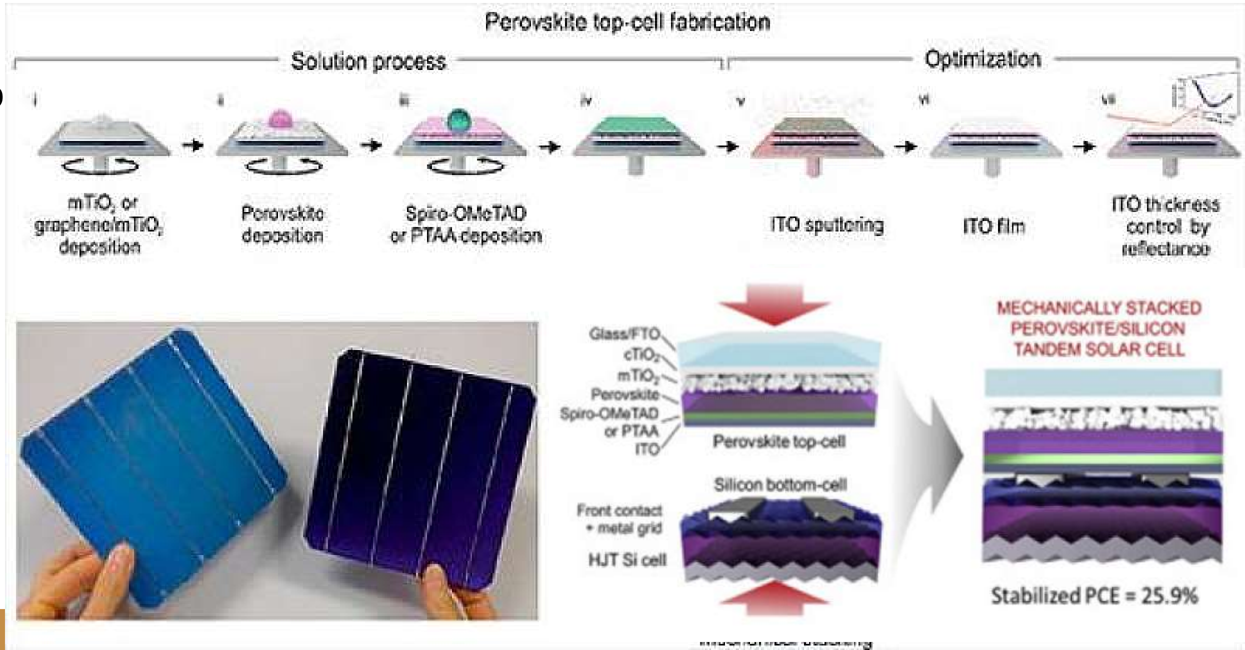
Emerging technology: ENEA/UniTorVergata/IIT: 4T Tandem cell PVK/HJT

(https://www.cell.com/joule/fulltext/S2542-4351(20)30045-3#articleInformation).

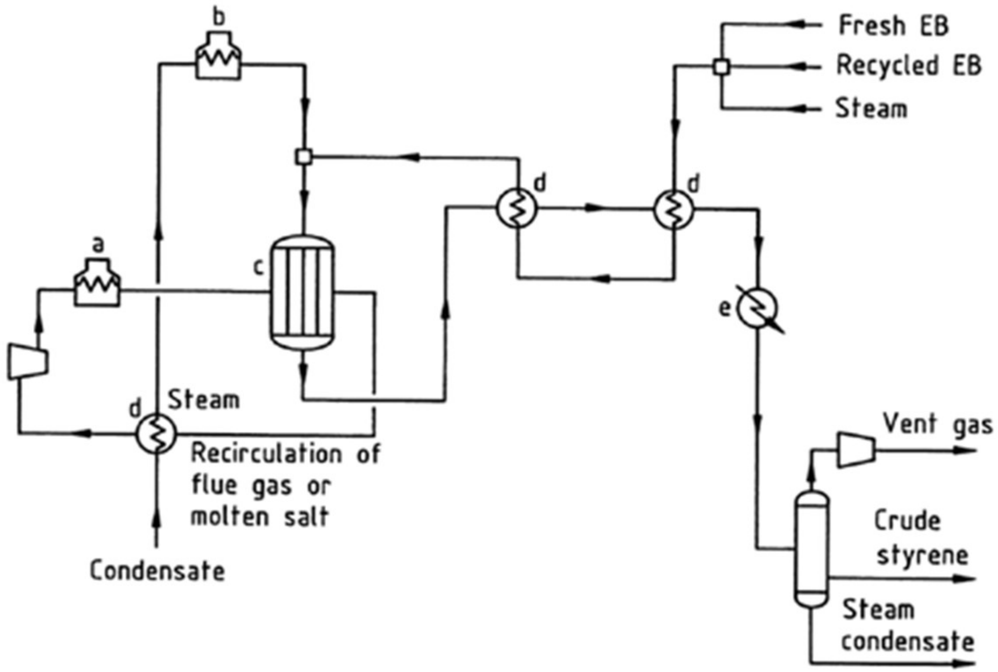
Eff. 26%

e and contacts (to be

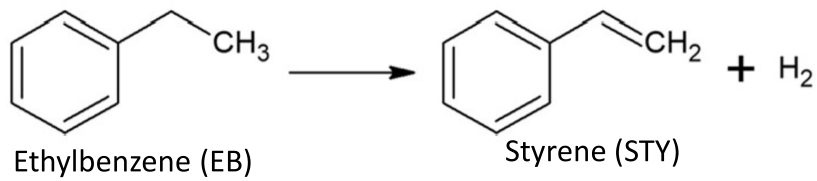
pub



The thermocatalytic dehydrogenation of ethylbenzene to styrene



Process diagram of the BASF plant for isothermal dehydrogenation of ethylbenzene adapted from [2] a) heater; b) steam superheater; c) fixed bed shell and tube reactor; d) heat exchanger; e) condenser



$\Delta H_r(600°C)=124.9$ kJ/mol

Highly energy demanding reaction very important for synthetic rubber production.

Chemical commodity: production volume 31 Mt in 2018 and expected to grow up to 36 Mt in 2024 [1]

[1] HDIN Research, https://www.hdinresearch.com/news/28
[2] James DH, Castor WM. Styrene. Ullmann's Encyclopedia of Ind. Chem. A25. Wenham: Wiley-VCH; 1994.

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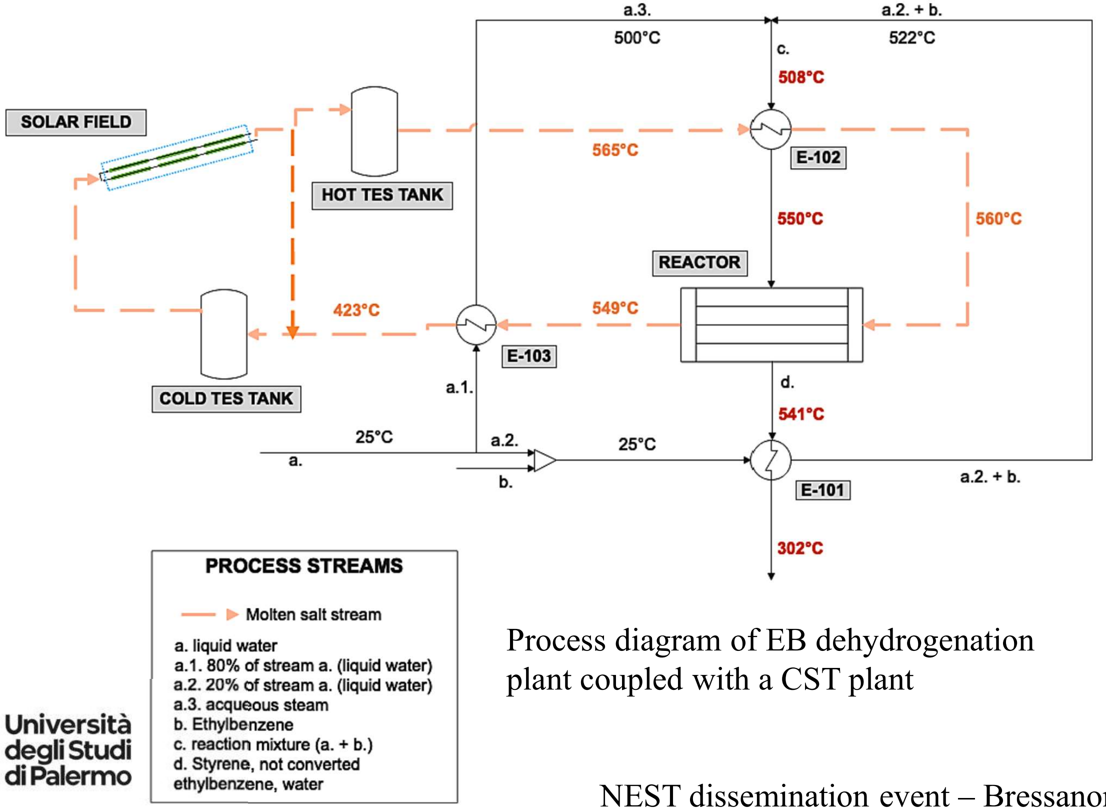
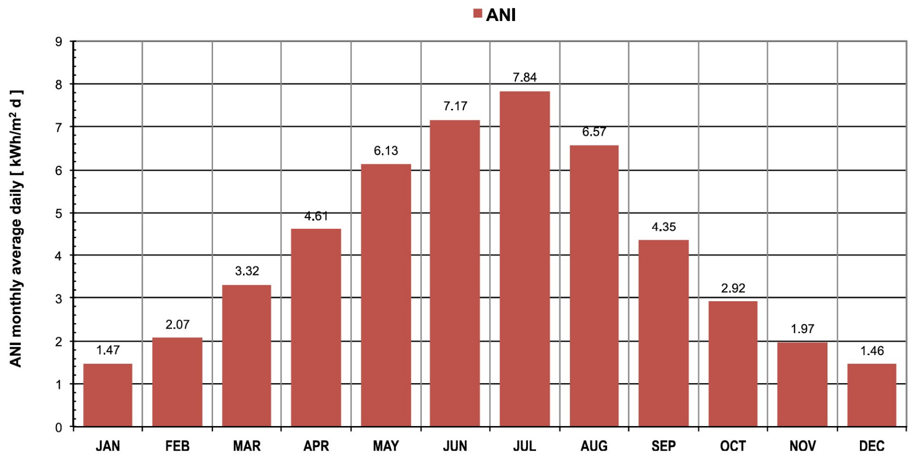
Integration strategy

Substitution of the furnace with the CSP plant so that to use the heat transfer fluids (e.g. molten salts) as vector of the solar heat to decarbonize the energy intensive ethyl benzene (EB) dehydrogenation



Process diagram of EB dehydrogenation plant coupled with a CST plant

Monthly distribution of the daily mean value of ANI for Priolo (Sicily)



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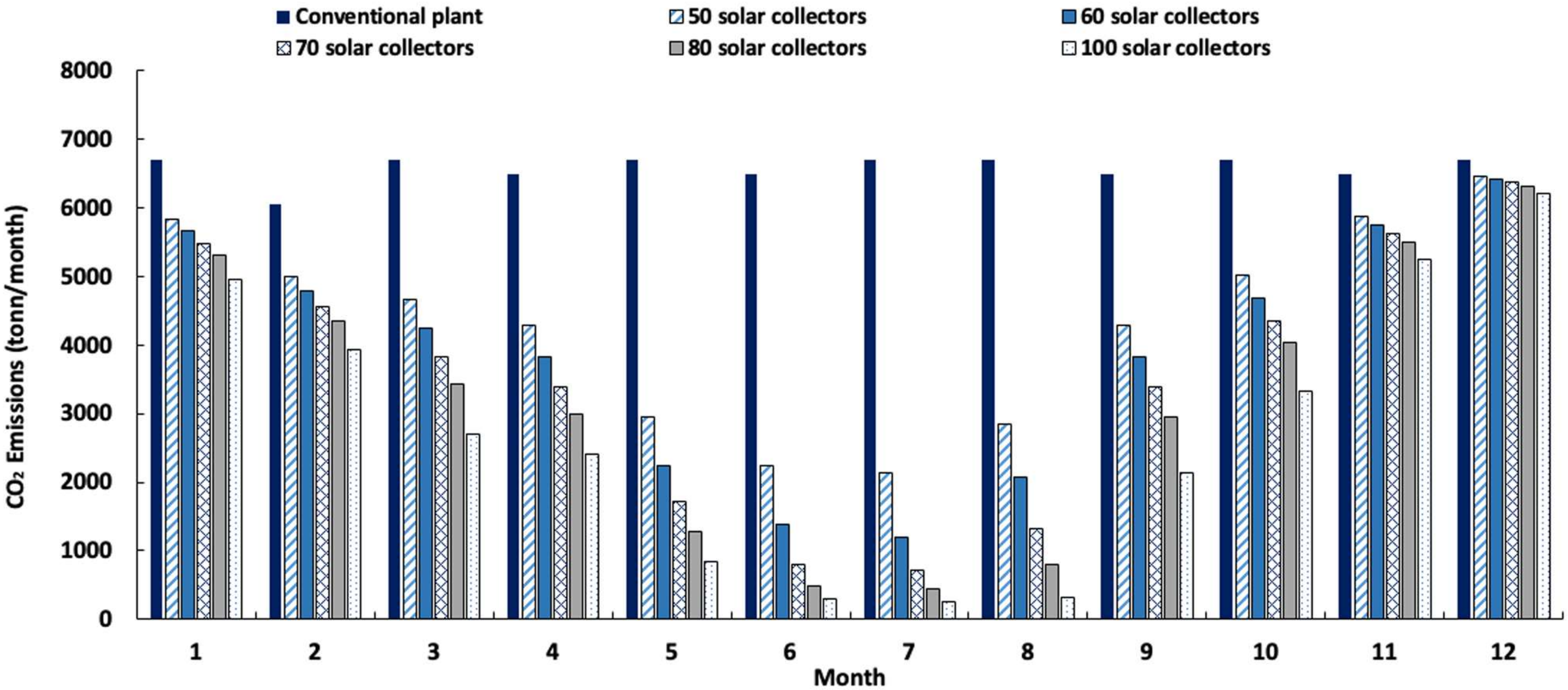
CO_2 emissions of a production plant of STY totally driven by methane combustion (conventional plant) and of plants hybridized with CST changing the size of solar field (number of solar collectors)



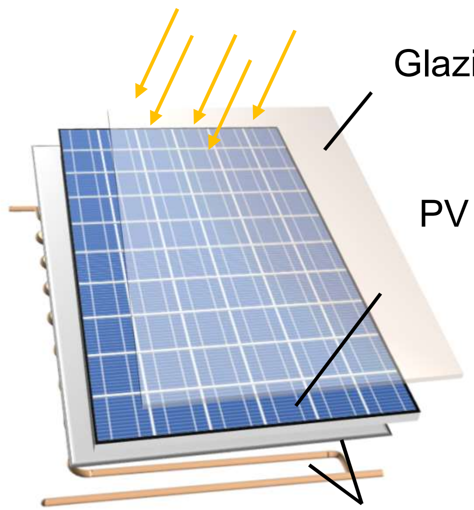
WHAT IF USING SOLAR RADIATION AS THERMAL SOURCE?

Solar Assisted Heat Pump with PV-T evaporators

- Heat pump using solar energy as the low temperature thermal source (evaporator)
- Photovoltaic-thermal (PV-T) collector working as the evaporator
- Use of CO_2 as the working fluid

Main advantages

- Possibility to achieve higher COP compared to air source heat pumps
- Combined production of electrical power and heat
- The refrigerant evaporating in the PV-T cools down the PV cells



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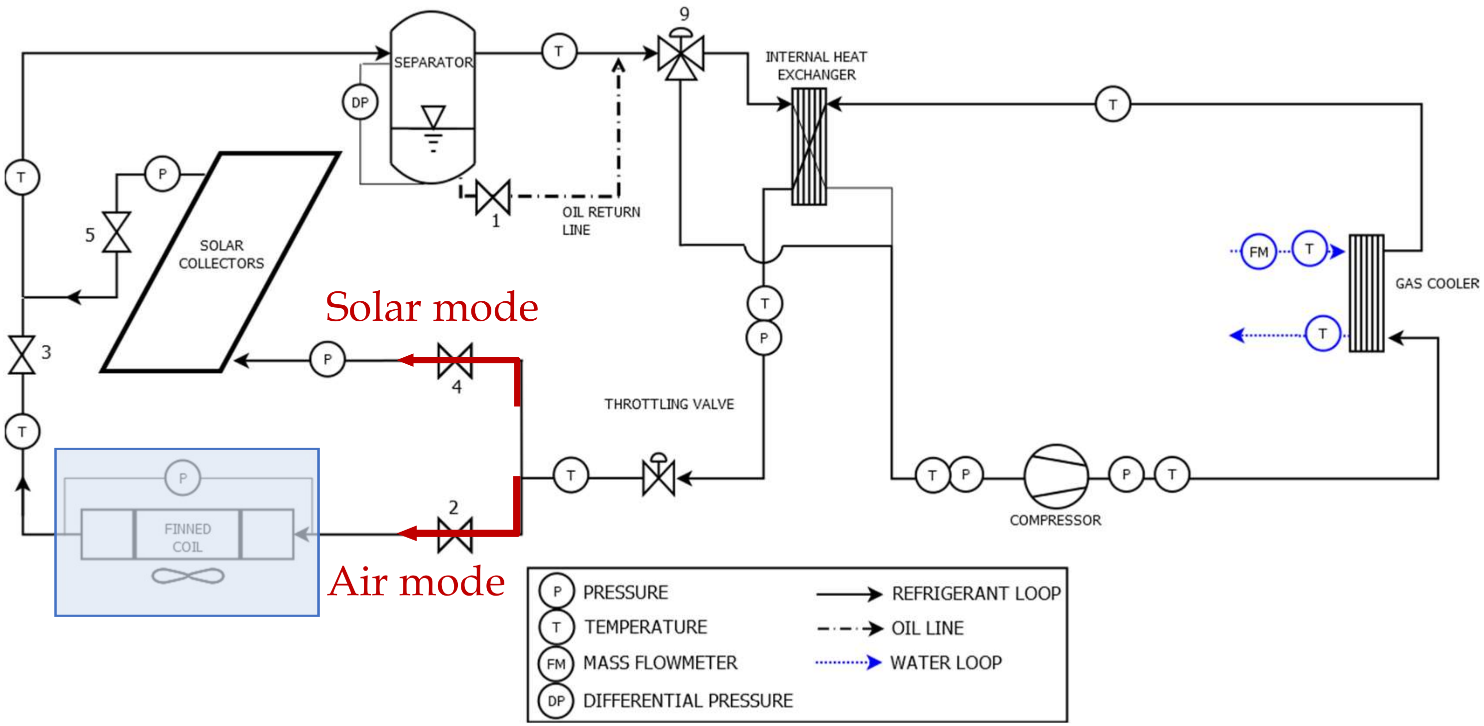
SOLAR-ASSISTED HEAT PUMP

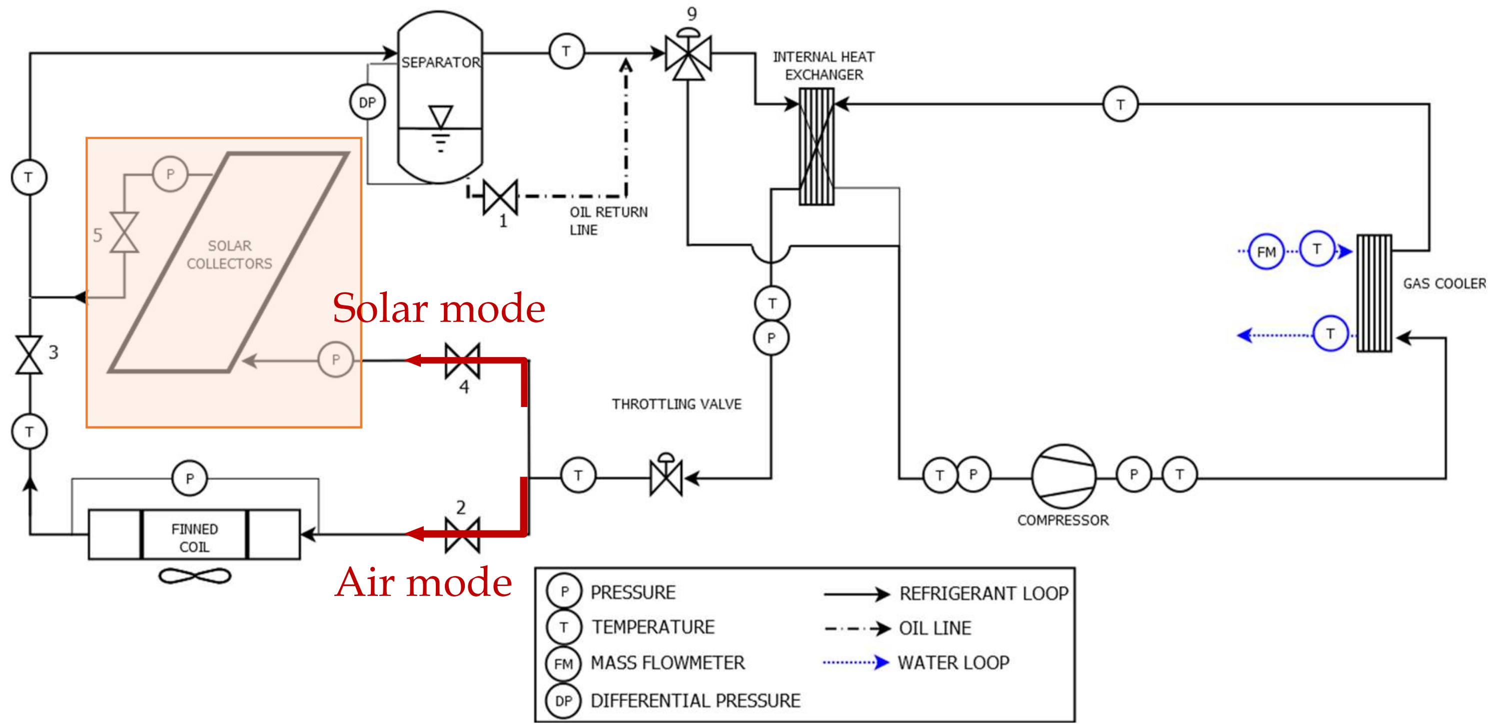
Dual source heat pump: possibility to operate with a finned coil evaporator (4 circuits with 88 tubes, 9.5 mm internal diameter)



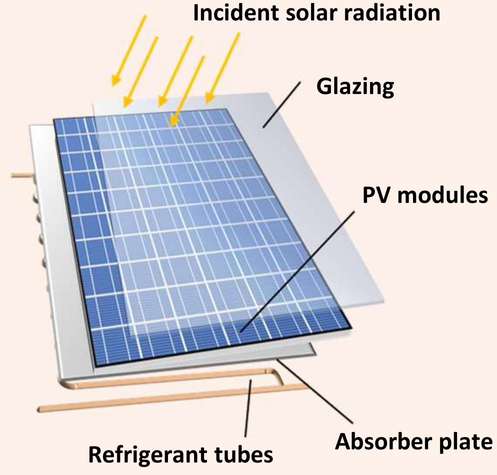
Finned coil evaporator

SOLAR-ASSISTED HEAT PUMP

PV-T evaporators: 3 multicrystalline silicon 270 W_p PV modules connected in series with 45° tilt angle; sheet-and-tube heat exchangers with aluminum absorber



PV-T evaporators



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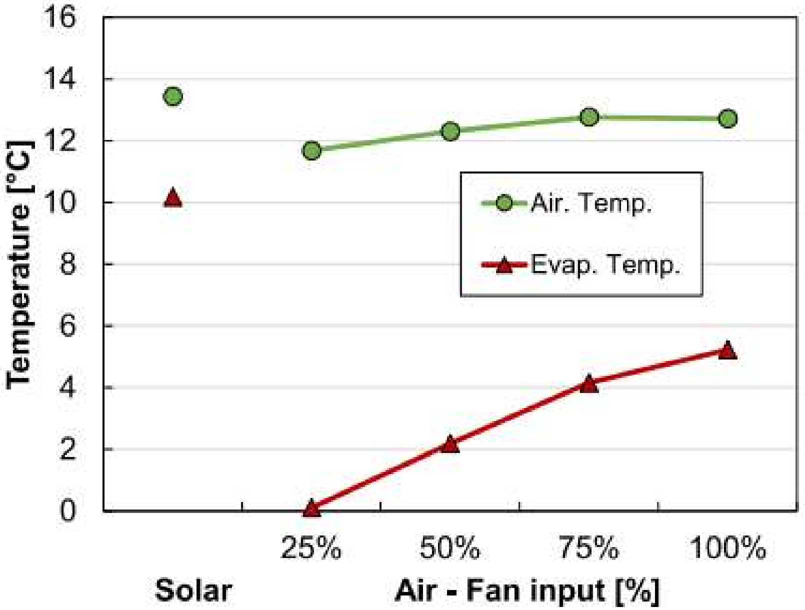
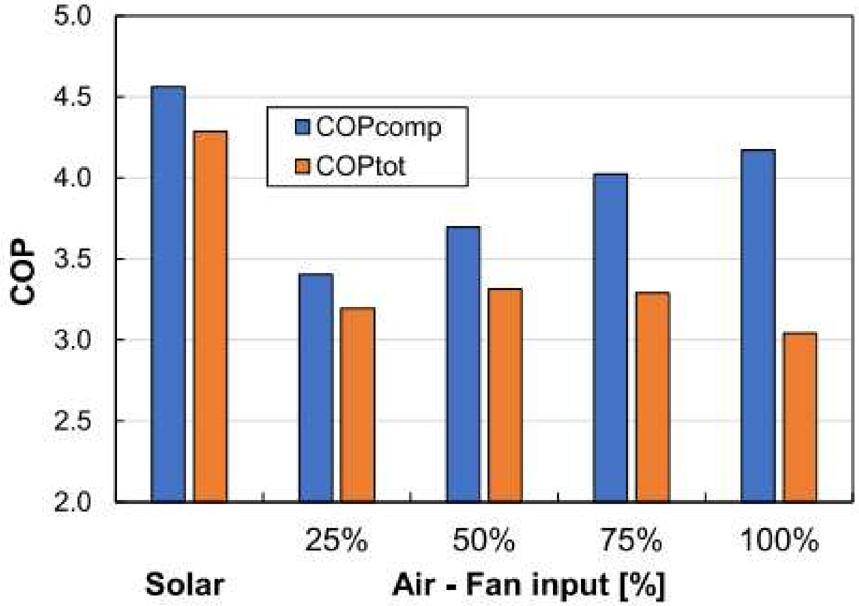
PERFORMANCE OF THE SOLAR-ASSISTED HEAT PUMP

WORKING CONDITIONS

- Compressor speed: 40% of its maximum speed
- High pressure: 80 bar
- Irradiance (in solar mode): 1100 W/m²





$$COP_{comp} = \frac{Q_{gc}}{P_{comp}}$$

$$COP_{tot} = \frac{Q_{gc}}{P_{tot}}$$

Application of Eco-design and LCA in NEST

Life cycle assessment (ISO 14040, ISO 14044)
Life cycle costing, levelized cost of electricity
with reference to:

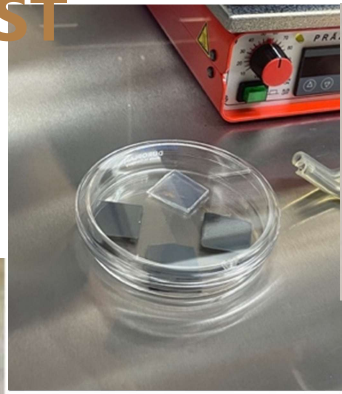
- Product Environmental Footprint guidelines

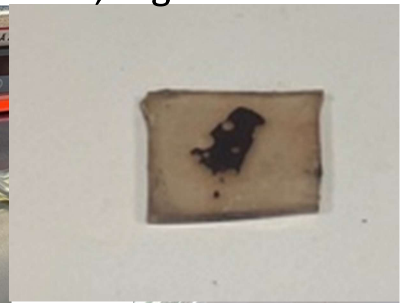
for energy products, and

- IEA guidelines on LCA of solar PV technologies.

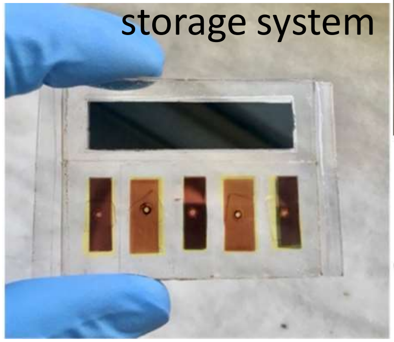
Eco-design guidelines for solar energy technologies

Perovskite solar cells, organic solar cells





Solar energy havesting and storage system



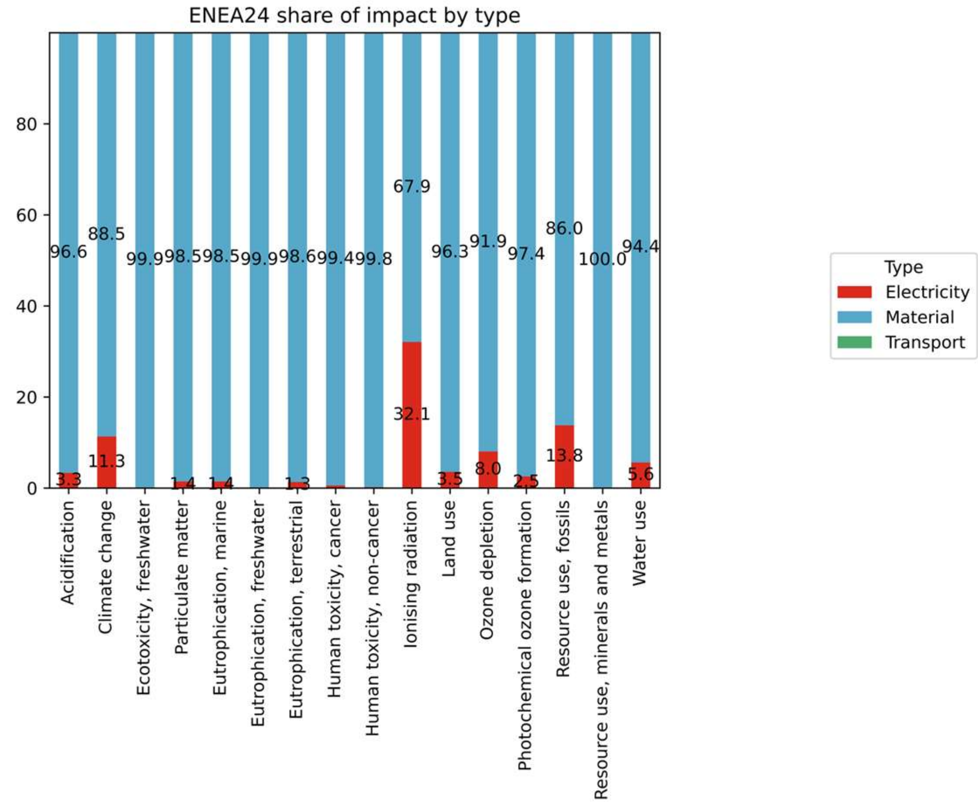
A junction box
in fault diagnosis and monitoring system

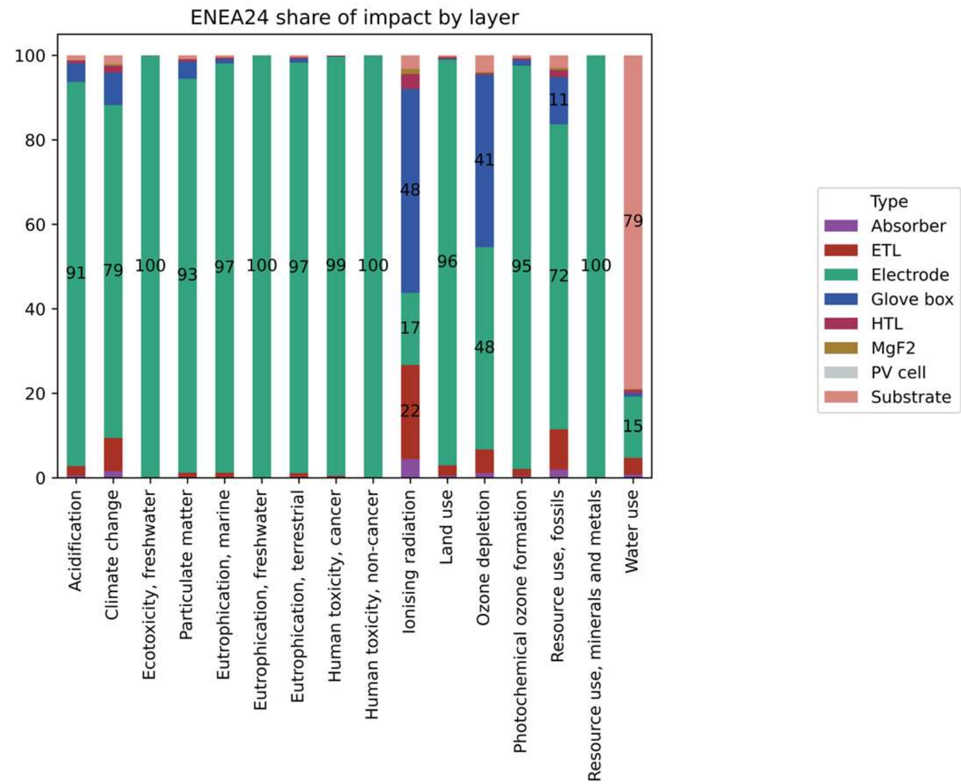
Perovskite layer in a tandem solar cells

Applying LCA to compare environmental profiles of solar cells

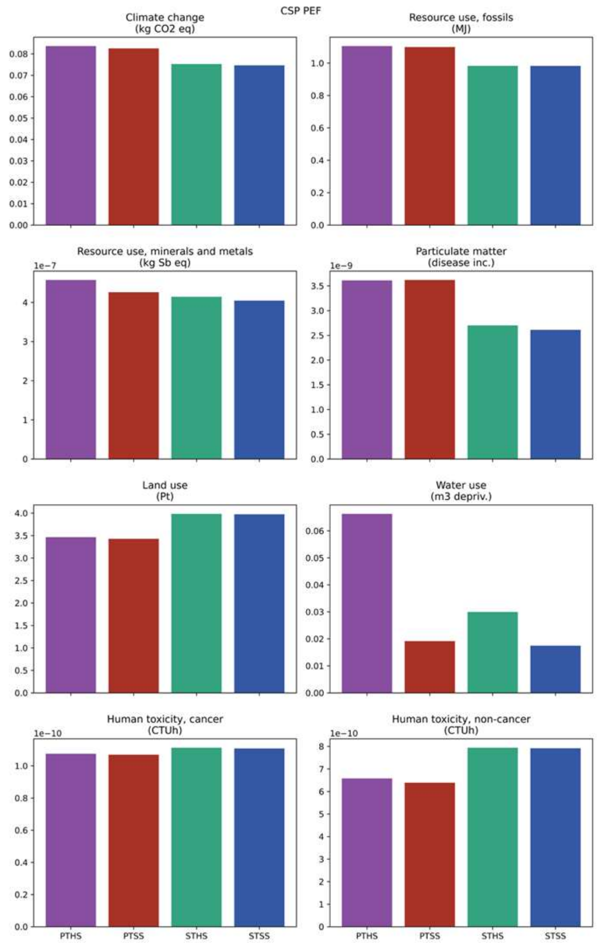
Environmental impacts	Unit	ENEA24	ENEA25	ENEA26	UNIPA27	UNIPA28
Acidification	mol H+ eq	4,57E+01	4,57E+01	4,63E+01	4,59E+01	4,12E+00
Climate change	kg CO2 eq	3,15E+03	3,15E+03	3,31E+03	3,20E+03	7,32E+02
Ecotoxicity, freshwater	CTUe	1,10E+06	1,10E+06	1,10E+06	1,11E+06	3,91E+03
Particulate matter	disease inc.	5,27E-04	5,27E-04	5,28E-04	5,48E-04	5,42E-05
Eutrophication, marine	kg N eq	1,61E+01	1,61E+01	1,62E+01	1,64E+01	7,34E-01
Eutrophication, freshwater	kg P eq	6,28E+01	6,28E+01	6,28E+01	6,28E+01	7,25E-02
Eutrophication, terrestrial	mol N eq	1,99E+02	1,99E+02	2,00E+02	2,02E+02	7,94E+00
Human toxicity, cancer	CTUh	2,70E-05	2,70E-05	2,71E-05	2,71E-05	3,06E-07
Human toxicity, non-cancer	CTUh	2,98E-03	2,98E-03	2,98E-03	2,98E-03	7,25E-06
Ionising radiation	kBq U-235 eq	1,41E+02	1,41E+02	1,62E+02	1,21E+02	1,01E+02
Land use	Pt	4,91E+04	4,91E+04	4,99E+04	5,19E+04	4,75E+03
Ozone depletion	kg CFC11 eq	1,05E-04	1,05E-04	1,09E-04	1,10E-04	1,85E-04
Photochemical ozone formation	kg NMVOC eq	4,38E+01	4,38E+01	4,43E+01	4,48E+01	2,94E+00
Resource use, fossils	MJ	4,00E+04	4,00E+04	4,25E+04	4,11E+04	1,23E+04
Resource use, minerals and metals	kg Sb eq	8,60E+00	8,60E+00	8,61E+00	8,61E+00	4,13E-03
Water use	m3 depriv.	4,02E+03	4,02E+03	4,12E+03	4,78E+03	2,07E+03
LCoE	Eur per kWh	11,047	11,053	11,042	41,587	30,450

Applying LCA to identify the largest contributor





In case of CSP…



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https://fondazionenest.it/spoke/solar/

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