SOCONEXGEN

(05/2022 – 12/2025)

LEAP-RE

Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

Pillar-1 project

The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

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Consortium

Project partners:

(1) FH Aachen University of Applied Sciences (coordinator, Germany)

(2) IBEU - Ingenieurbüro für Energie und Umwelttechnik (Germany)

(3) low-tec gGmbH (Germany)

(4) CDER - Centre de développement des énergies renouvelables (Algeria)

(5) Universidade de Évora (Portugal)

(6) Université Mohammed Premier Oujda (Morocco)

(7) Université de Tunis El Manar (Tunisia).

Aim of the project

SoCoNexGen aimed to develop secure, reliable, easy to use and environmentally friendly solar cooking technologies for domestic use.

Four different solar indoor cookers with energy storage, powered by solar thermal collectors and/or PV panels, were built and are being tested.

Relevance vs MARs

"Innovative solutions for priority domestic uses (clean cooking and cold chain)" by developing a modern and sustainable solar cooker.

Solar cooker (Photo © UdE)

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Scientific and/or technical objectives

- Focus on **design, construction, experimental testing** and **analysis** of **four** newly developed efficient, temperature-controlled **solar cookers with thermal energy sand storage (TES)** and/or **electrical battery storage (EBS)**
- Future target application: domestic (and commercial environments).

Barriers to be removed

- Acceptance by end users of solar cookers
- Funding options/financing for poorer population to buy solar cookers

Intended results

- Solar cookers tested and successful preparation of traditional dishes and food products, flexibility with storage units
- Potential study
- Standard testing procedure for solar cookers developed
- Have pathways for financing of solar cookers

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➢ *Results achieved: Université Mohammed Premier Oujda (Morocco)*

WP 2: Potential study

- **Location**: Rural areas of Tafoughalt (Douars Tghassrout, Tagma, Bini Bouala, Berkane province), located **80 km from Oujda and 20 km from Berkane**, altitude 500–900 m, exposed to fire risk. Survey conducted with about 20 families, each composed of **5–8 people**.
- **Households and current situation**: Majority of households rely on forest wood for cooking and heating, and use kerosene lamps for lighting. Strong energy dependence leads to deforestation and environmental degradation.
- **Identified problems**: Lack of access to reliable and clean energy; families require electricity for cooking and water heating 4–5 hours/day, day and night, throughout the year.
- **Energy consumption requirements:** Residents typically cook for **2 hours at night** and **3 hours during the day** with a **power of 500–600 W**, which corresponds to approximately **2.5–3 kWh/day**.
- **Activities carried out**: Surveys, design and field testing of solar cookers (photovoltaic, thermal, and hybrid). Awareness campaigns and training for residents and students.
- **Proposed cooker**: Solar cooker combining PV panels and batteries, requiring **3–4 kWh/day**, enabling cooking day and night, reducing wood use and CO_2 emissions (~38.6 kt/year).
- **Conclusion**: Photovoltaic and hybrid solar cookers provide a **realistic, efficient, and adapted solution** for the energy needs of rural households in Morocco, with significant environmental and socio-economic benefits.
- **Future outlook**: An estimated several million households in Morocco can benefit from a solar cooker combining PV panels and a battery storage in the future.

Photos © UMP

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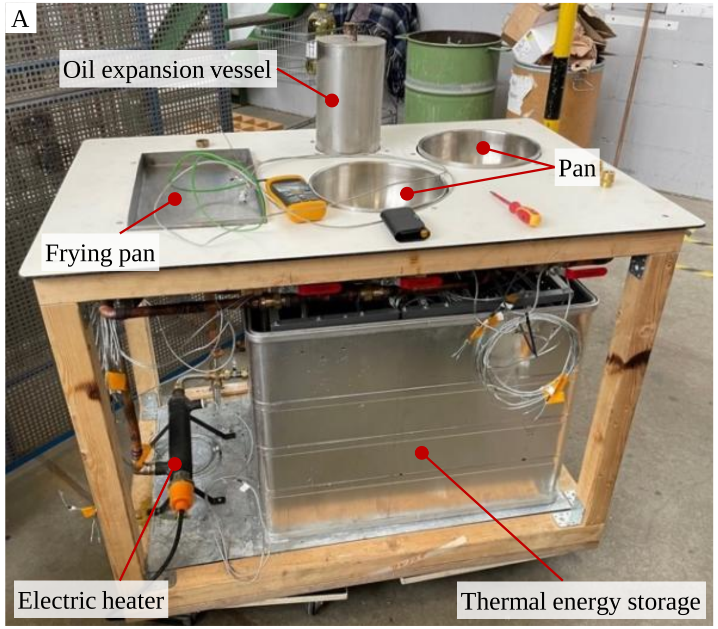
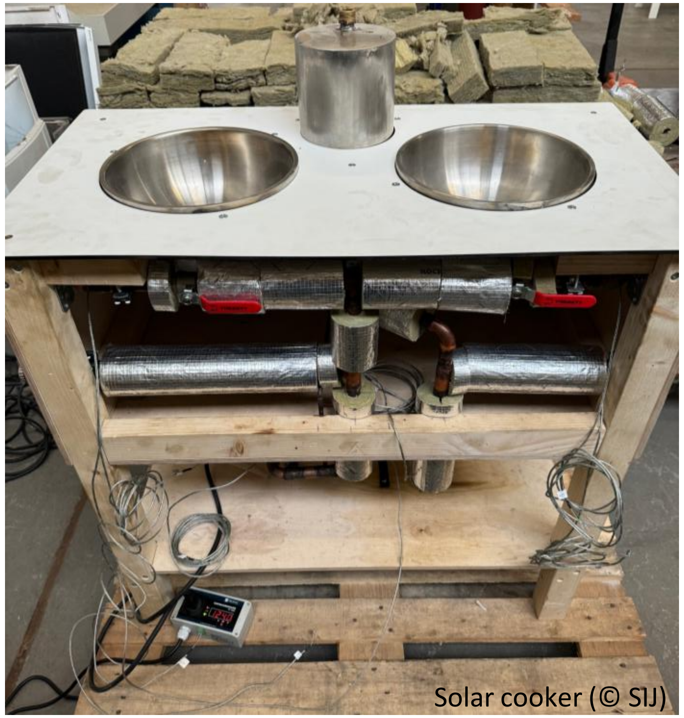
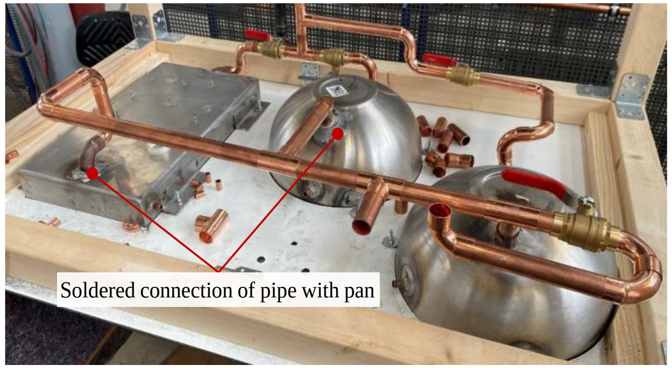
➢ *Results achieved: IBEU, SIJ, low-tec, UMP*

WP 3 – Technical design, construction and functional testing
Knowledge Transfer: The German company IBEU designed three oil-based thermal solar cookers (SIJ co-designed two cookers), which were then built by partner low-tec gGmbH and partially tested prior shipment to the partners in Algeria, Tunisia and Portugal. The Moroccan partner separately designed and built a PV electric solar cooker with battery storage.

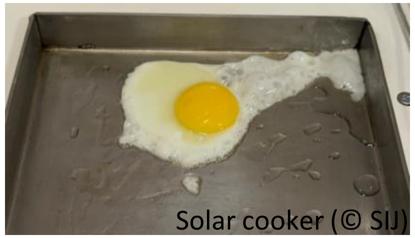


Solar cooker (Sattler et al. 2025)


Solar cooker (© SIJ)



System concept of cookers with oil circuit (Sattler et al. 2025)


Solar cooker (© SIJ)

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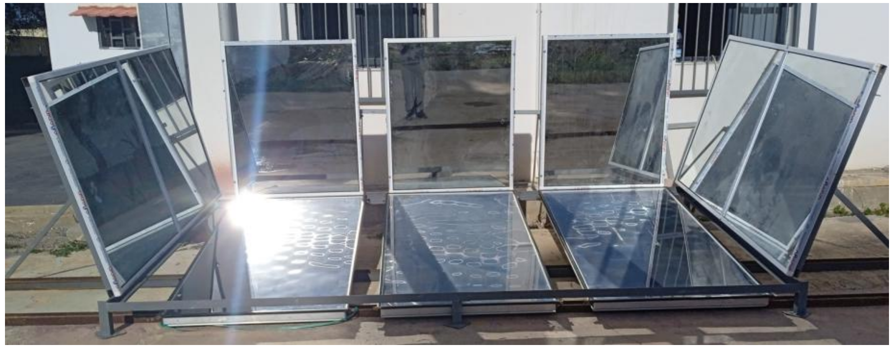
➢ *Results achieved: SIJ (Germany); CDER (Algeria)*

WP 3 – Technical design, construction and functional testing
The Solar-Institut Jülich (SIJ) built and tested a different design of an oil-based solar cooker which uses flat hobs for heating conventional pots and pans. Tests for cooking rice and eggs.

WP 4 – Shipment and installation
Knowledge Transfer: A small version was taken to Tunisia for a commissioning workshop where the cooker was built together with the SoCoNexGen project partners. The Algerian partner CDER built a modified flat-plate collector with guidance from the SIJ.



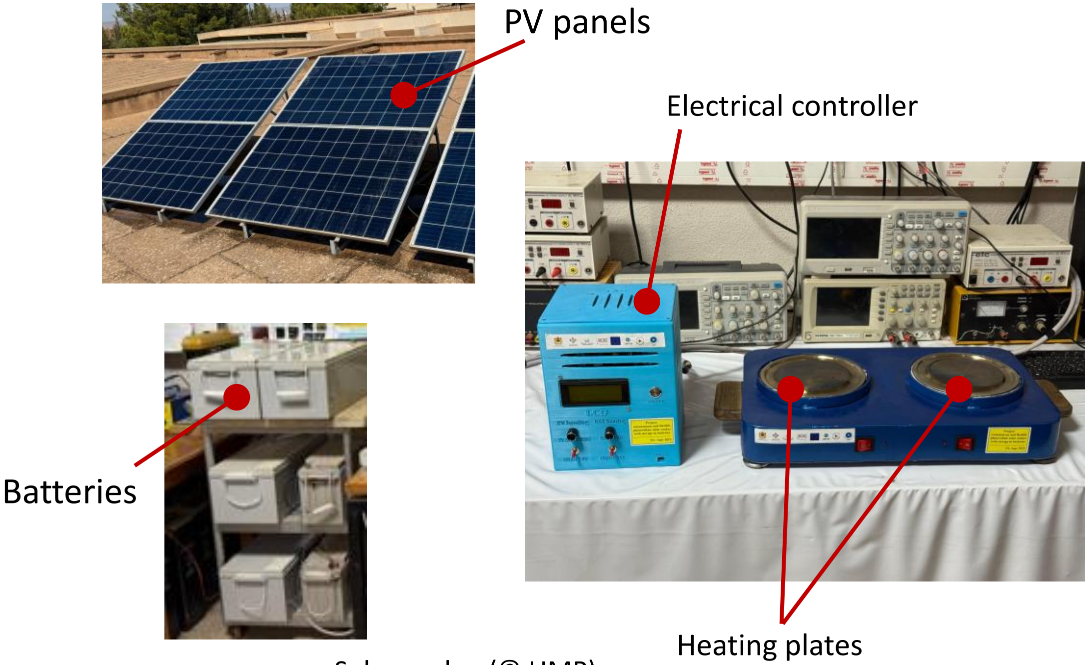
Modified flat-plate collector with mirrors © CDER (Sattler et al. 2025)

Solar cooker (© SIJ)

Results achieved: by Université Mohammed Premier Oujda – UMP (Morocco)

WP 3 – Technical design, construction and functional testing

Photovoltaic Solar Cooker with Battery Storage for Off-Grid Flexibility



Solar cooker (© UMP)

Technical Details

- **Power Supply System:**
  - ✓ **Photovoltaic field:** 1.2 kW total (4 × 300 W monocrystalline PV modules).
  - ✓ **Battery bank:** 48 V – 250 Ah (approximately 12 kWh storage capacity).

- **Control and Conversion Block:**
  - ✓**Block 1 – DC/DC converters:**
    - Converter 1: dedicated to power transfer from PV panels directly to the heating resistors.
    - Converter 2: dedicated to powering the heating resistors using the battery bank.
- **Block 2 – Regulation and Control:**
  - ✓ Supervises all operation scenarios (PV mode, battery mode, hybrid mode).
  - ✓ Manages the acquisition of electrical (*V*, *I*, *P*) and thermal (*T*) data.
  - ✓ Includes protection and **fault detection** systems (overvoltage, overcurrent, temperature).
- **Heating Plate:**
  - ✓ Two resistive heating elements (each 1000 W nominal).
  - ✓ Thermally insulated **using glass wool and bakelite layers to** minimize heat losses.

➢ *Results achieved: by Université Mohammed Premier Oujda – UMP (Morocco)*

WP 3 – Technical design, construction and functional testing & WP 5 – Field tests
Cooking tests using the “Photovoltaic Solar Cooker with Battery Storage” were conducted at the UMP laboratory. Both PV panels and battery operation were evaluated under controlled conditions. Key results are summarized below:

Photos © UMP

Test	Time for cooking plate’s resistor to reach temperature	Surface temp. of metal casing (°C)	Water/ food temp. (°C)	Cooking time (min)	Energy used (Wh)	Battery consump-tion (%)
Boiling 1 L of water	6 min to 200 °C; 17 min to 364°C	53	100	20	108	<1 %
Scrambled eggs (3)	7 min to 200 °C; 8 min to 286°C	54	~100	2	11	<1 %
Rice (200 g)	3.5 min to 200 °C; 11 min to 400°C	54	100	20	108	<1 %
Tagine (2 kg)	4 min to 200 °C; 14 min to 400°C	61	100	45	242	<2 %
Fries (400 g)	4 min to 200 °; 10 min to 363°C	66	115	5	27	<1 %
Bread	7 min to 200 °C; 11 min to 300°C	80	100	12	64	<1 %

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➢ *Results achieved: Université Mohammed Premier Oujda – UMP (Morocco)*

WP 5 – Field tests:

- ✓ **Tested with:** 4 families in a rural forested area
- ✓ **Installed units: 3 different versions of Photovoltaic Solar Cooker with Battery Storage** (600 W each)
- ✓ **Cooking uses:** Water heating, tagines, bread, daily meals
- ✓ **Positive feedback:**
  - Practical and effective for daily cooking
  - Appreciated the use of PV panels
- ✓ **Suggestions / Negative feedback:**
  - More flexibility using solar batteries
  - Preference for manual operation instead of touchscreen
- ✓ **Next step:**
  - Developed version P4 with battery operation and manual controls
  - Field testing with the same families planned for November 2025

Photos © UMP

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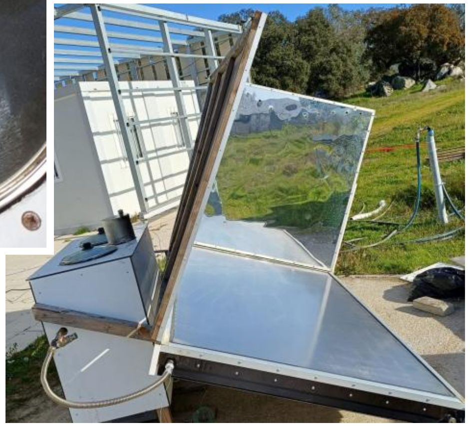
Results achieved: Universidade de Évora – UdE (Portugal)

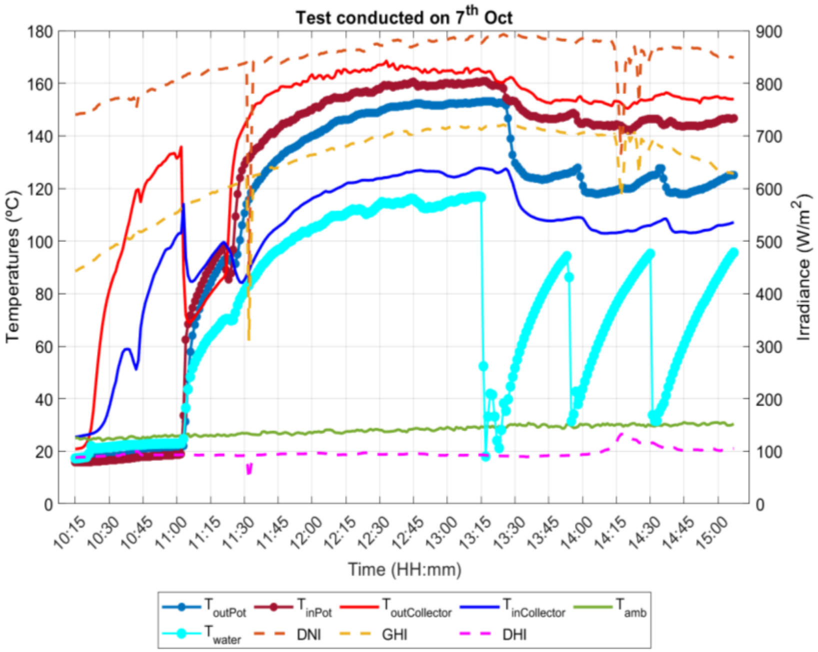
WP 5 – Field tests:
Collector cold start test: 3 litres of water were heated to between 30 °C and 95 °C. The process was repeated three times. The thermal efficiency of the system was calculated based on the time taken to reach 95 °C.
Collector hot start test: The procedure is the same as the collector cold start test, but it starts at noon. The collector heats the oil in the pipe circuit during the morning hours.

Pan (© UdE)



Solar cooker (© UdE)

Conclusion: Results show that the heat transfer from the hot oil circuit to the cooking pots in less efficient than anticipated. The solar cooker efficiency varied between 23 and 31 % (hot start operation).



Collector cold start test

1st: 3 litres heated
from **28 °C to 95 °C**
Time: **1h:47 min**

2nd: 3 litres heated
from **37 °C to 95ºC**
Time: **38 min**

3rd: 3 litres heated
from **32ºC to 95ºC**
Time: **34 min**

Collector hot start test

1st: 3 litres heated
from **21 °C to 95 °C**
Time: **30 min**

2nd: 3 litres heated
from **31 °C to 95 °C**
Time: **35 min**

3rd: 3 litres heated
from **31ºC to 95ºC**
Time: **34 min**

$$\eta_{specific} = \frac{m_{water} \cdot c_{p,water} \cdot \Delta T_{water,30-95°C}}{A_{collector} \cdot \int_{t\_start}^{t\_end} I_{Global}\, dt}$$

Efficiency of cooker with collector cold start test
η_1=8.4 %|η_2=16.3 % |η_3=18.8 %

Efficiency of cooker with collector hot start test
η_1=30.9 %|η_2=22.9 % |η_3=24.7 %

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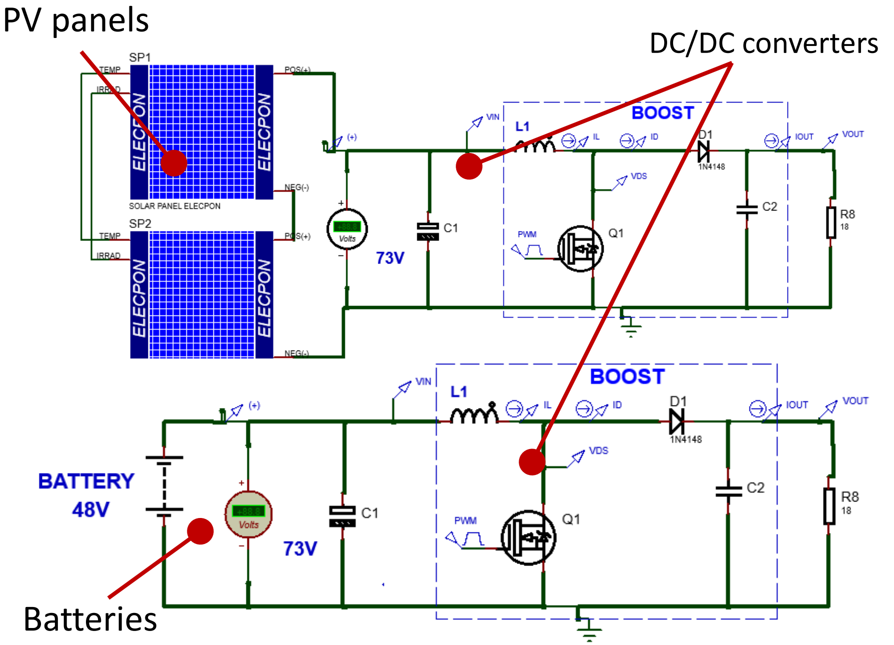
➢ Results achieved: UMP - WP 6 – Simulation, validation & evaluation

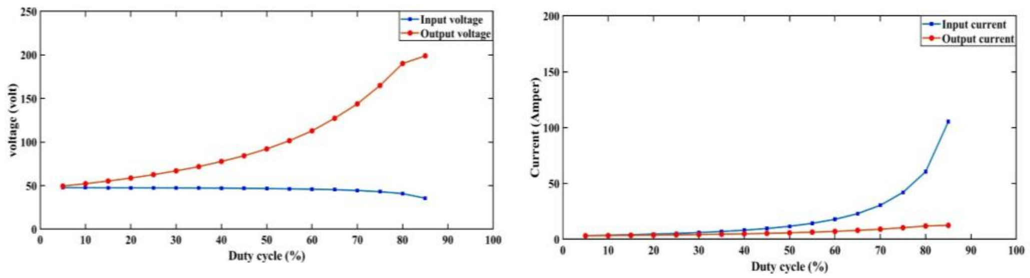
Photovoltaic Solar Cooker with Battery Storage.

- UMP implemented the proposed circuits in the **control box** and conducted simulations to monitor their behavior.
- The simulation models were created using **OrCAD PSpice and ISI Proteus**, and included: **PV panels and battery circuits**, **DC/DC converters**, **resistive heating elements**



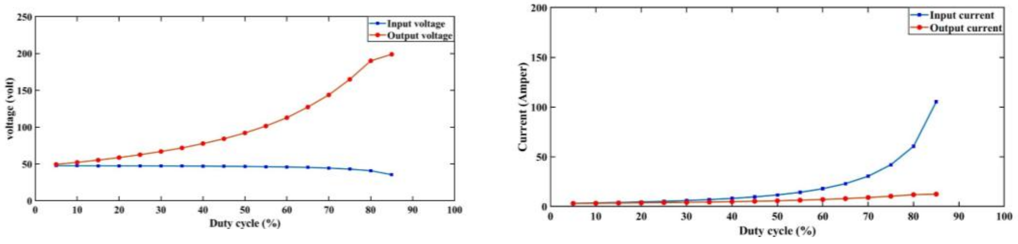
- **Proper Operation of PV Panels and Converter 1 (see detailed report)**

Input and Output Voltage and Current of Converter 1



- **Proper Operation of Batteries and DC/DC Converter 2 (see detailed report)2**

Input and Output Voltage and Current of Converter 2



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➢ *Progress in comparison with the state of the art*

Photovoltaic Solar Cooker with Battery Storage for Off-Grid Flexibility

- Contribution to the solar cooker field: improved autonomy, integration of electrical energy, and experimental validation of new hybrid solar cooking strategies.
- Autonomous operation thanks to PV panels (1.2 kW) and batteries (250 Ah, 48 V). In low sunshine periods, autonomy for at least 6 days → Crucial for avoiding that people use wood as backup fuel with traditional cooker.
- Rapid heating: the resistor reaches 500 °C in a few minutes.
- Continuous cooking even without sunlight, meeting the needs of users in both rural and urban areas.
- Field trials: high user acceptance due to ease of use and increased efficiency.
- Smart control block for energy management and temperature regulation.
- Efficient and uniform heating thanks to the electric resistors.
- Modular and portable design for household and community use.
- Performance monitoring and data acquisition for system optimization.
- Involvement of local authorities and industry to expand adoption and prepare the commercialization of the system.
- Alternative solution to other PV and battery solar cooker products.

Oil-circuit cookers

- Prototype with simpler cooker design tested (with flexible piping, easy pipe connections, flat hob).
- Experience gained with sand-gravel storage and cooking with flat hob.
- Cookers with electric heater and pump were tested.
- Publication about problems and solutions (Open Access).
- More results pending.

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Increase in TRL (if relevant for the project)

- Aim: TRL 6 – technology demonstrated in relevant environment

Possible evolutions of the objectives in progress of the project (explain), problems encountered during the project

- Development phase of the oil-operated solar cooker prototypes took several months longer than anticipated
- Construction times of the oil-operated solar cooker prototypes was longer than anticipated
- Design problems for oil-operated solar cooker prototypes lead to lower efficiency than anticipated
- Problems encountered with oil pump
- Bulky and heavy design of oil-operated solar cookers can be difficult for installation, e.g., if doors are too narrow
- Oil-gravel thermal energy storage is simpler to design than sand-gravel thermal energy storage
- High costs for the oil-operated solar cookers. The Photovoltaic Solar Cooker with Battery Storage is cheapest (between 1,200 and 2,500 €, depending on the quality of the components)

Specify whether the project has resulted in new products or developments (instruments, methods, software, etc.)

- An online interface for (remote) monitoring relevant measurement data during experiments was developed
- Simulation models of solar cookers were or are being developed

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- ***Specific role and achievement of the private sector member of the consortium***
  - The private sector member of the consortium made essential contributions in the development of the oil-based thermal cookers in the project

- ***Specify how the project contributes to a gender equal societal development?***
  - Solar cookers, in general, contribute to gender equal societal development by reducing the disproportionate burden of time, health risks, and economic constraints placed on women and girls in traditional cooking systems.
    - Solar cookers enable freeing up more time as fuel does not need to be collected anymore.
    - Time freedom is a major step toward shifting roles and empowering women economically and socially (e.g., women can start micro-enterprises (selling solar-cooked food or teaching solar cooking methods).
    - No smoky indoor air → Less respiratory disease, eye irritation, and burns → Health improvement.
    - School attendance rates for girls tend to rise where fuel burdens are lifted → Education is important for reaching gender equality in the future.

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- ***Planned follow-up work, new pathway to explore…***
  - At Innovation Fair – Pitch focused on Photovoltaic Solar Cooker with Battery Storage for Off-Grid Flexibility – search for investor → Funding needed to launch industrial production, secure financing or partnerships, and establish an efficient distribution network to reach rural and urban households
- ***Become of the consortium set up on this project***
  - Depends on funding opportunities
- ***New collaborations initiated thanks to the results of the project (following publications, conference presentations, etc.)***
  - Morocco: Municipality of the province of Berkane is interested in purchasing ~100 PV electric cookers, but this requires funding for finalizing the cooker (including further improvements to insulation, and developing a safe battery enclosure box).
- ***New collaborations planned for the future (to answer what problem? Industrial or other perspectives?…)***
  - Collaboration for industrial production for PV electric cooker needed
- ***New funded projects and/or funding applications (what type(s) of funding?)***
  - Follow-up project LEAP-SE project proposal not successful

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Expected outcomes in case of success of the project (2030)

If one of the four tested solar cookers, such as the **Photovoltaic Solar Cooker with Battery Storage**, can be launched and distributed:

1. Long-term savings in fossil fuel costs and reduction of GHG
2. Relief for the population in remote dry regions of North Africa
3. Education and relief of daily life
4. Creation of an infrastructure for the construction and sale of solar cooking technology
5. Relief to rural communities regarding reduction in pollution from traditional woodstoves
6. Relief to nature (less deforestation, expansion of deserts and air pollution)
7. Reduction in time and effort primarily for women and children for collecting firewood

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Contribution of the project to AU – EU R&D partnership

1. In the long term, creation of jobs through local manufacturing and distribution (e.g., of the Photovoltaic Solar Cooker with Battery Storage for Off-Grid Flexibility).
2. Education of people, knowledge transfer and capacity building.
3. Multiple publications: 5 in international journals, 3 book chapters, 1 book edition (in progress), 11 conference publications with peer-reviewer committee, 1 patent.
4. Dissemination workshops can lead to further collaborations (two are in planning).
5. Expansion of knowledge about the use of solar cookers in Africa and Europe.

Interest of Consortium members in participating in LEAP-RE clustering activities

The SoCoNexGen consortium is interested to hear about the topics of the other LEAP-RE projects.

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ACKNOWLEDGEMENT

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Ministère de l'Enseignement supérieur et de la Recherche scientifique (Algérie)

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Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de l'Innovation

THANK YOU

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Backup slides for Q & A Session

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➢ *Results achieved*

- Solar cookers 1a and 1b

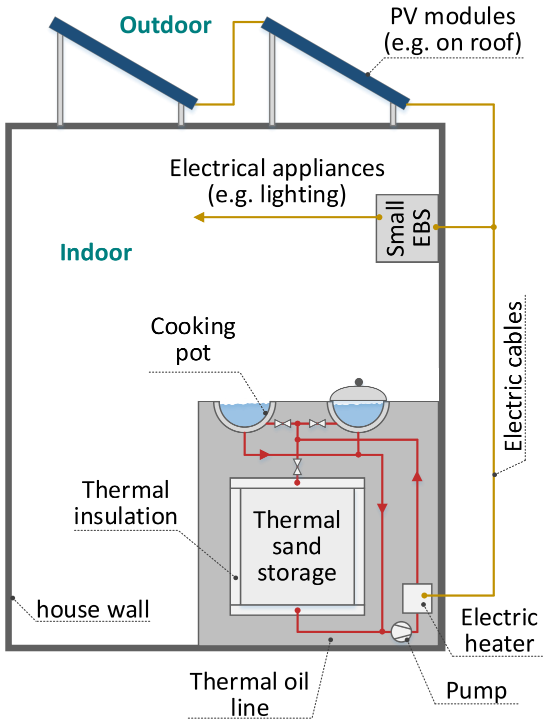

Figure: Solar cooker 1a © SIJ

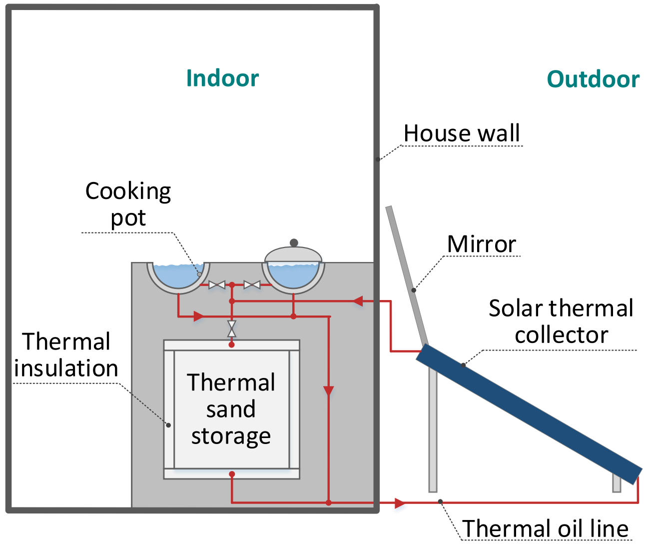

Figure: Solar cooker 1b © SIJ

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➢ Results achieved

- Solar cookers 2 and 3

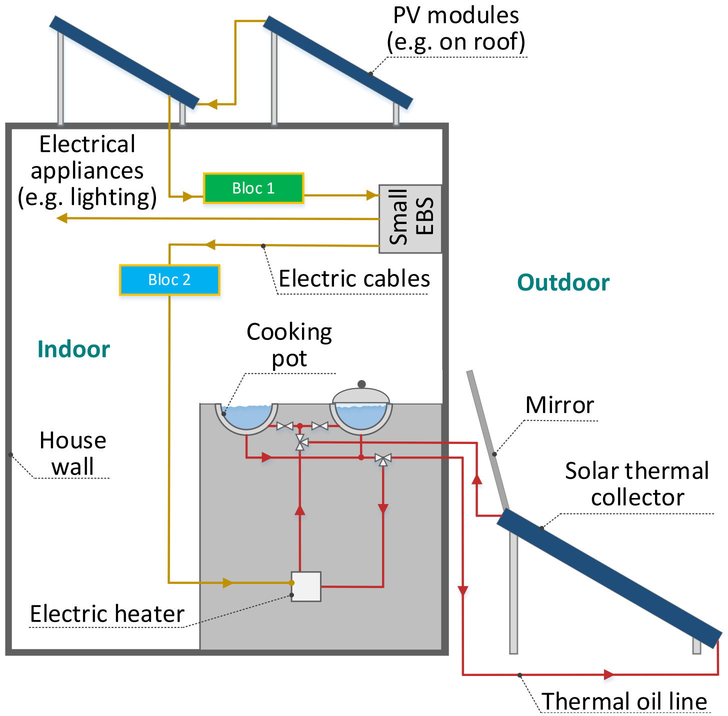

Figure: Solar cooker 2 © SIJ, IBEU

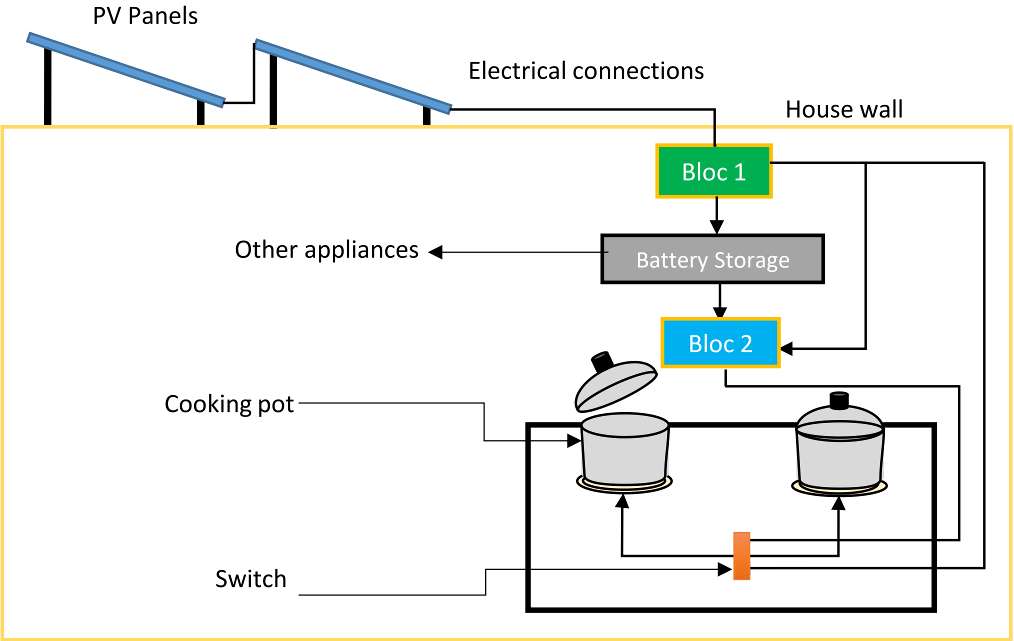

Figure: Solar cooker 3 © UMP

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➢ Results achieved: All - Publications

Innovation Patent

Patent – Moroccan Office of Industrial and Commercial Property (OMPIC), No. MA62943,
Filed on 7 November 2023, positive report on 17 April 2024, published on 30 May 2025.
Inventors: Hajar Chadli, Mohammed Hmich, Khalid Salmi, Sara Chadli, El Hassan Chadli, Olivier Deblecker, Khalil Kassmi, Rachid Malek
Title: Autonomous Solar Cooker Powered by Photovoltaic Panels and Solar Batteries
Available on OMPIC Publication Server (PDF generation required): https://patent.ompic.ma/publication-server/result-list

Book Edition (In progress)

Solar Cookers and Sustainable Cooking Solutions for the Post-Energy Crisis
Khalil KASSMI (khkassmi@yahoo.fr), Olivier Deblecker (olivier.deblecker@umons.ac.be)
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250 Broadway, Suite 620, New York, NY 10007, USA
Proposition of Chapter :
Ch. N/A: Innovation and Digitization of Solar Cookers Towards Sustainable Energy Management (170725-023414)

International Journals

1. M. Hmich, B. Zoukarh, R. Malek, S. Chadli, O. Deblecker, K. Kassmi, N. Bachiri, *Design and experimentation of an innovative photovoltaic solar cooker with battery storage: A sustainable solution for Africa's future*, Scientific African 29 (2025) e02791. https://doi.org/10.1016/j.sciaf.2025.e02791
2. M. Hmich, H. Chadli, S. Chadli, K. Salmi, R. Malek, O. Deblecker, K. Kassmi, N. Bachiri, *Innovative electric heating system for a hybrid solar cooker (photovoltaic/thermal) using photovoltaic energy with battery storage*, Springer Nature, Interactions, Volume 245, article number 329 (2024). https://doi.org/10.1007/s10751-024-02173-9
3. Noureddine El Moussaoui , Ali Lamkaddem , Mohammed Rhiat, Khalil Kassmi, Rachid Malek, Olivier Deblecker, Najib Bachiri, Power system of DC/DC applications: Case of cooking, Materials Today: Proceedings Volume 72, ISSN: 2214-7853, part 7, 2023, Pages 3392–3397, Elsevier, Science Direct, 2023. https://doi.org/10.1016/j.matpr.2022.07.442 https://www.sciencedirect.com/science/article/pii/S2214785322051410
4. A. LAMKADDEM, N. EL MOUSSAOUI, M. RHIAT, R. MALEK, K. KASSMI, O. DEBLECKER, N. BACHIRI, System for powering autonomous solar cookers by batteries, Scientific African 17 (2022) e01349, ISSN 2468-2276. https://doi.org/10.1016/j.sciaf.2022.e01349 https://www.sciencedirect.com/science/article/pii/S2468227622002563?via%3Dihub
5. N. El Moussaoui, A. Lamkaddem, M. Rhiat, K. Kassmi, R. Malek, O. Deblecker, N. Bachiri, Autonomous power system powered by solar batteries: A case of box oven heating, August 2022, International Journal of Renewable Energy Research (IJRER), Vol.12, No.3, pages 1269-1278, September 2022, ISSN: 1309-0127. DOI : https://doi.org/10.20508/ijrer.v12i3.13139.g8512 https://www.ijrer.org/ijrer/index.php/ijrer/article/view/13139/pdf

LEAP-RE

Chapters in books

1. B. Zoukarh, M. Hmich, R. Malek, S. Chadli, O. Deblecker, K. Kassmi, and N. Bachiri, "Digitization of an Innovative Solar Cooker Using Photovoltaic Solar Energy with Battery Storage," in Advances in Energy Research, vol. 43, M. J. Acosta, Ed. New York, NY, USA: Nova Science Publishers, 2025, Book Chapter, pp. 191–216. ISBN: 979-8-89530-753-3.
   DOI: https://doi.org/10.52305/QBQK0231
   https://novapublishers.com/shop/advances-in-energy-research-volume-43

1. Hajar Chadli, Khalid Salmi, Sara Chadli, Mohammed Hmich, Rachid Malek, Olivier Deblecker, Khalil Kassmi & Najib Bachiri, Feasibility of a Power and Control System for an Autonomous Photovoltaic Hot Plate Type Cooker (600 Wp), Advances in Control Power Systems and Emerging Technologies. ICESA 2023. Advances in Science, Technology & Innovation. Springer, Cham. Pages 19-31, 01 June 2024
   Print ISBN978-3-031-51795-2
   Online ISBN978-3-031-51796-9
   https://doi.org/10.1007/978-3-031-51796-9_3
   https://link.springer.com/book/10.1007/978-3-031-51796-9

[3] M. Hmich, B. Zoukarh, S. Chadli, R. Malek, O. Deblecker, K. Kassmi, and N. Bachiri, "Exploring the Potential of a Battery-Assisted Solar Cooking System," in Solar Capacitors and Batteries, N. D. Sankir and M. Sankir, Eds. Hoboken, NJ, USA: Wiley–Scrivener Publishing LLC, 2025, Book Chapter 9, pp. 267–287.
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Conference with Peer-Reviewed Committee

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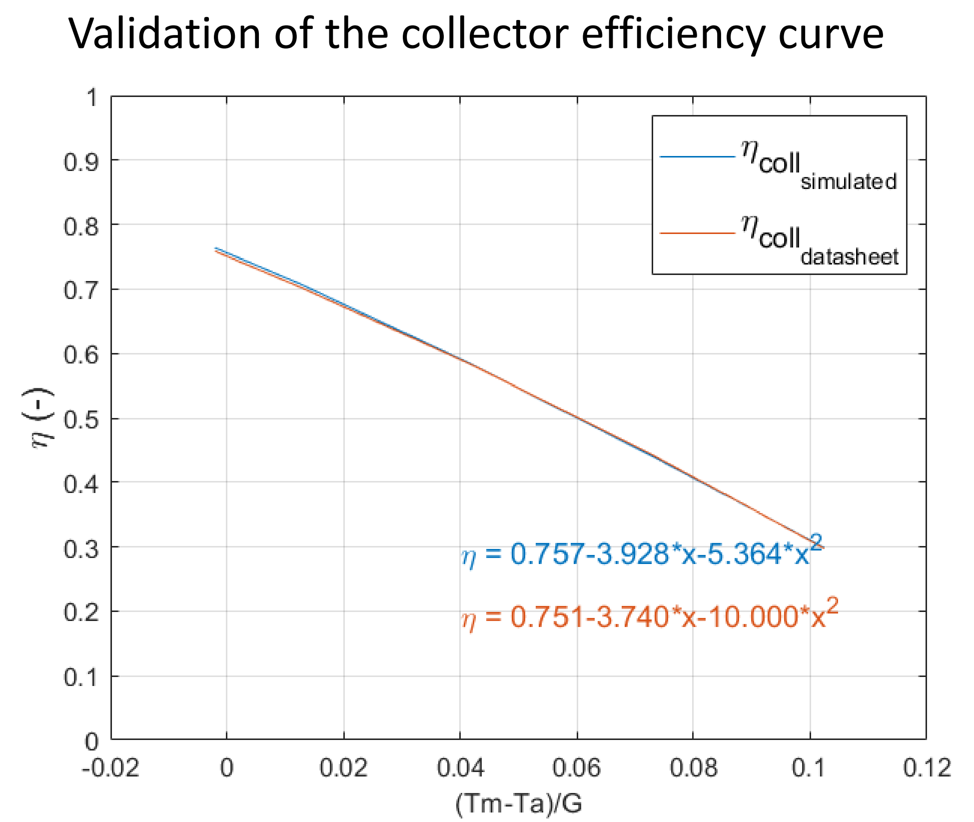
Results achieved: UdE - WP 6 – Simulation, validation & evaluation

```
clear
clc
close all
%% Collector, piping and pot properties
collector_properties=setCollectorProperties();
piping_properties=setPipingProperties();
pot_properties=setPotProperties();

Aa=collector_properties.Aa; % Aperture area
Lc=collector_properties.Lc; % length of the colector
m_plate=1.7035; %  [kg] mass of the plate is considered to be volume*density of insulation
Cp_plate=896; % [J/kgK]thermal heat capacity of Almeco-Tinox Highly Selective Aluminum

%% HTF and the content inside the pot
% Choose the heat transfer fluid (HTF) 'water','air','sunflower_oil',
% 'palm_oil','sunflower_oil','canola_oil'
fluid='sunflower_oil';
% Set the content inside the pot, can be water, oil or

%% Incident and absorbed solar radiation, and transmissivity absortivity product average

% Gt and S are the Incident and absorbed solar radiation, respectively
% transmissivity absortivity product average (tau_alpha_avg)
[Gt_vector,S_vector,~,tau_alpha_n_product_vector,~,~,AST_vector]=incident_solar_radiation(N_day,N_reflector,colle

%% Initial conditions
Tfin_coll=20+273; % fluid temperature at collector inlet [K]
Tfout_coll=25+273; % fluid temperature at collector outlet [K]
Tpmean_coll=23+273; % mean temperature of the collector's absorber plate [K]
UL=0; % overall collector heat loss coefficient [W/m^2K]
mf_coll=0.01;% mass flow [kg/s]
% FR=0.01; % heat removal factor [-]
m_potcontent=1; % mass of the content inside the pot [kg]
Twall_pot=Tamb; % pot wall temperature [K]
Tpot_content=Tamb(1)+1; % water temperature inside the pot [K]
Tfmean_coll=(Tfin_coll+Tfout_coll)/2; % mean fluid temperature [K]

tol=1e-1; % tolerance of the iterative method

% data storage struct
data_array = initialisingVectors(length(S_vector));
```



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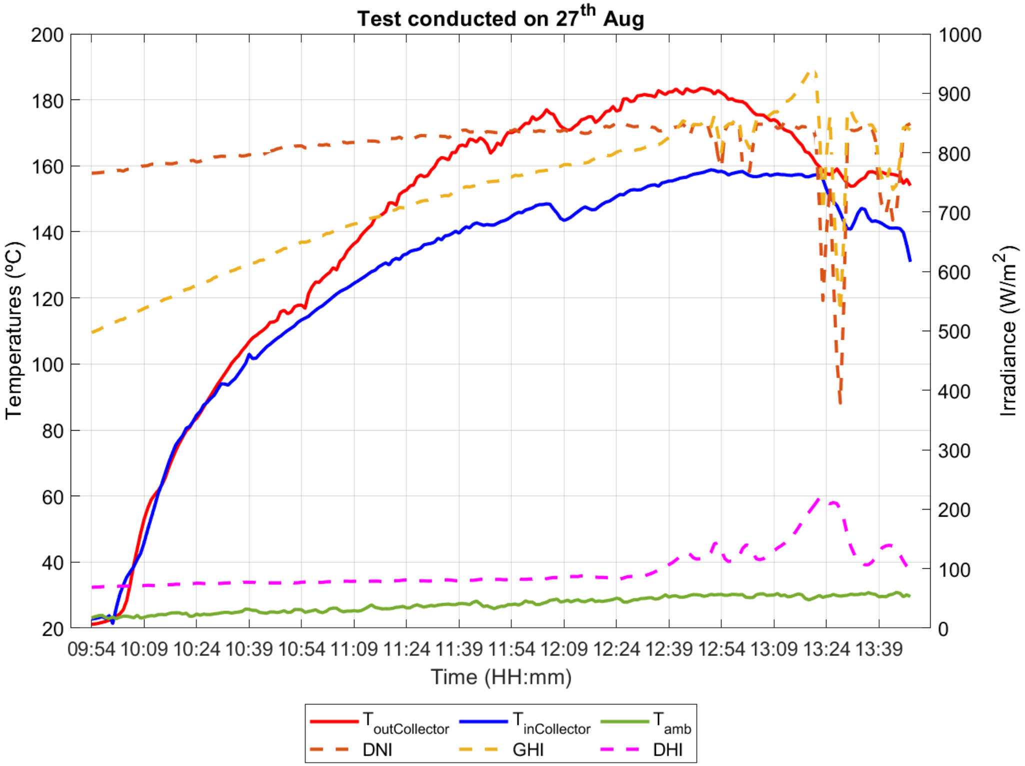
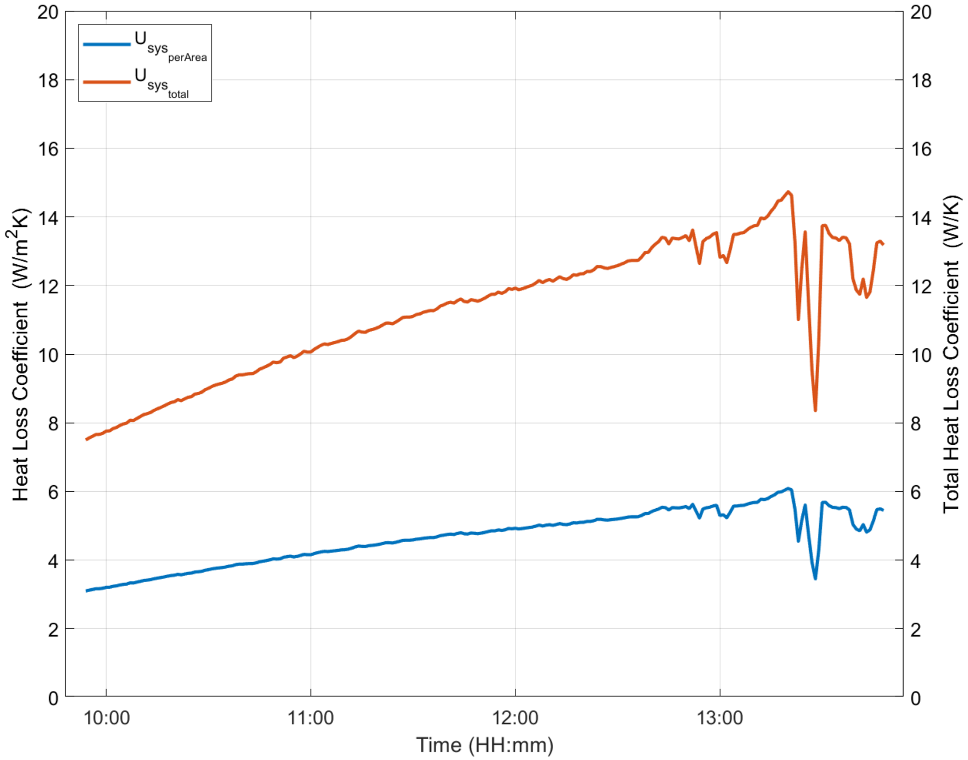
Results achieved: Universidade de Évora – UdE (Portugal)

WP 5 – Field tests: Tests conducted at the University of Évora using the project-developed standard procedure.
Stagnation test with flat-plate collector: The fluid in the collector reached a maximum temperature of 183 °C, with a maximum heat loss coefficient of 6 $W/(m^2K)$ and a maximum total heat loss coefficient of 14.7 W/K.





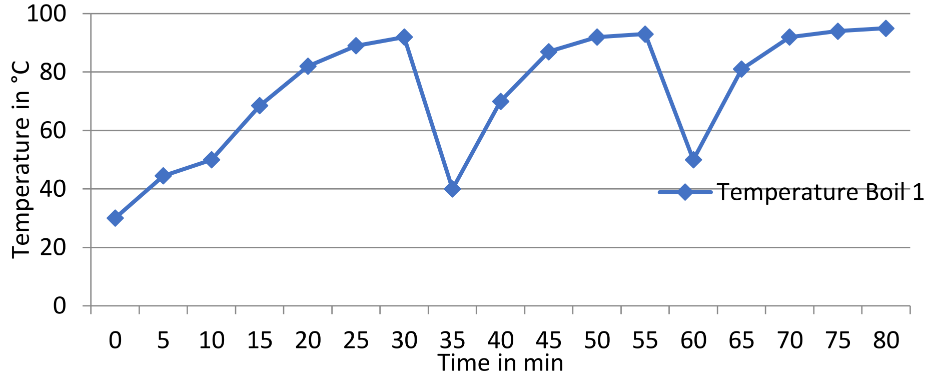
➢ Results achieved: UTM - WP 6 – Simulation, validation & evaluation

Mathematical matrix state model: T' = A . T + B . U

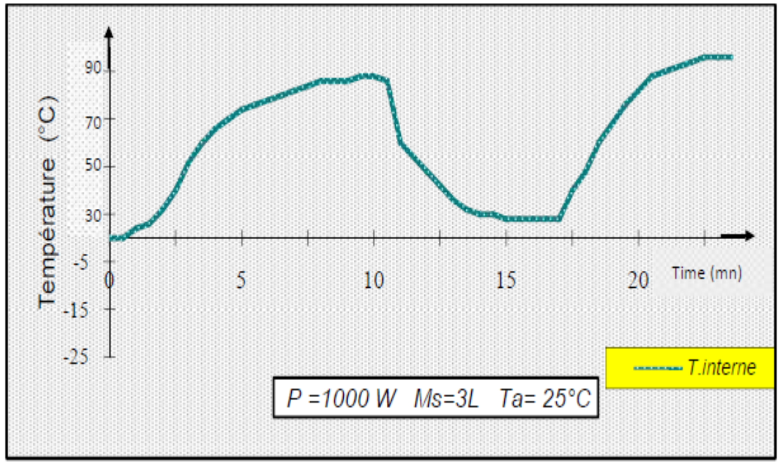
$$\begin{bmatrix} \dot{T}_C \\ \dot{T}_S \\ \dot{T}_i \\ \dot{T}_P \end{bmatrix} = \begin{bmatrix} -\frac{\lambda_c . S_c}{X_c . M_c . C_c} & \frac{\lambda_c . S_c}{X_c . M_c . C_c} & 0 & 0 \\ \frac{\lambda_c . S_c}{X_s . M_s . C_s} & -\frac{\left(K_{sa} . S_s + \frac{\lambda_{is}}{X_{is}} . S_{is} + \frac{\lambda_c}{X_c} . S_c\right)}{M_s . C_s} & \frac{\lambda_{is} . S_{is}}{X_{is} . M_s . C_s} & 0 \\ 0 & \frac{\lambda_{is} . S_{is}}{X_{is} . M_i . C_i} & -\frac{K_{ia} . S_{ia} + \frac{\lambda_{is}}{X_{is}} . S_{is} + \frac{\lambda_p}{X_p} . S_p + \varepsilon . k_\varepsilon . S_\varepsilon}{M_i . C_i} & \frac{\lambda_p . S_p}{X_p . M_i . C_i} \\ 0 & 0 & \frac{\lambda_p . S_p}{X_p . M_i . C_i} & -\frac{\lambda_p . S_p}{X_p . M_i . C_i} \end{bmatrix} . \begin{bmatrix} T_c \\ T_s \\ T_i \\ T_p \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ \frac{-1}{M_s . C_s} & \frac{K_{sa} . S_{sa}}{M_s . C_s} \\ 0 & \frac{K_{ia} . S_{ia} + \varepsilon . k_\varepsilon . S_\varepsilon}{M_i . C_i} \\ 0 & 0 \end{bmatrix} . \begin{bmatrix} Q_e \\ T_a \end{bmatrix}$$

Time response of simulation model: 12 min.
Experimental response: 20 min.
Difference can be explained by high thermal losses.

Experiment: Boiling 3L of water



Simulation

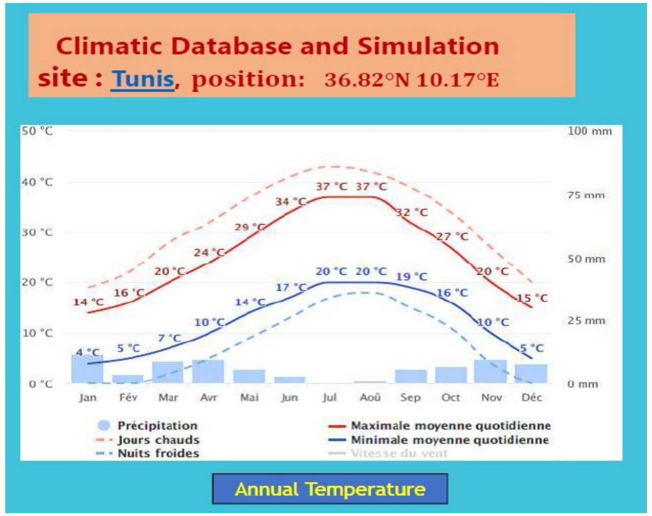


Results achieved: UTM (Tunisia)

WP 2: Potential study

Tunisia is a highly favorable environment for solar thermal cookers due to its abundant sunshine, and incentive-based government policies such as subsidies for water heating. The adoption of these devices, which can reduce energy bills and improve air quality, is supported by initiatives aimed at increasing the share of renewable energy in the country, as:

- High Sunshine: average sunshine (5.5 kWh/m² per day), making the use of solar heat highly efficient in cost and environment
- Government Support: National energy strategies encourage the use of renewable energy and financial assistance, such as subsidies for solar water heating (PROSOL program)
- The use of thermal cooker in Tunisia is limited (<1% of rural population)
- Most population (6%) uses solar passive panels for water heating in bathrooms
- Few domestic uses of solar cookers are limited to hybrid electric/PV models with limited power between 0.5 and 2 kW.



Experimental solar cooker in Sfax

➢ Results achieved: Université de Tunis El Manar – UTM (Tunisia)

WP 5 – Field tests

Dashboard of the remote supervision system

➢ *Results achieved: Université de Tunis El Manar – UTM (Tunisia)*

WP 5 – Field tests

Positive points: stable values of temperature , no greenhouse emissions

Negative points: cooker very heavy and cannot be transportable, the response time is long one compared with electric cooker, requests a high power (3KW); high thermal losses; An input power of 1kW is not sufficient to cook some lunches.

Meeting of November 2024 in Tunis

New Control & remote supervision system

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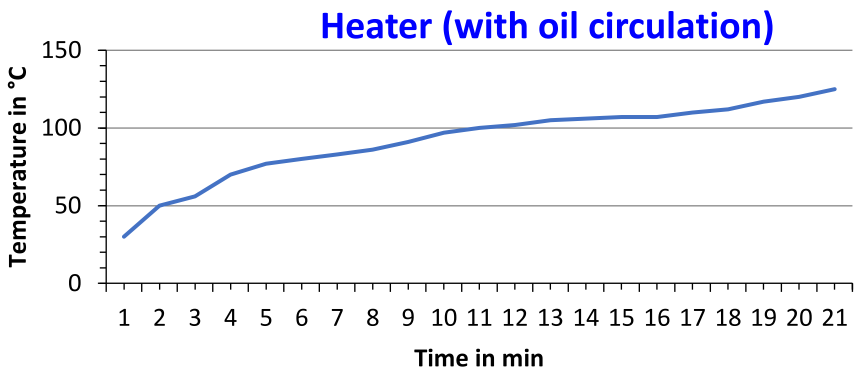
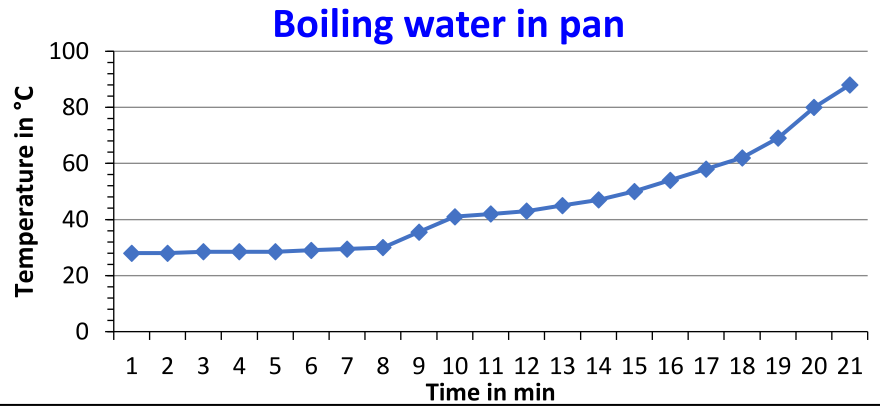
Results achieved: Université de Tunis El Manar – UTM (Tunisia)

WP 5 – Field tests





Power: 1 kW
Pan (bowl) 1: 3L
Pan (bowl) 2: 3L
Ambient temp.: 28 °C
Humidity: 60 %
Time to reach 90 °C in each pot (bowl): 20 min

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➢ *Results achieved: WP 7 – Dissemination and communication*

WP 7: Dissemination Workshop in Morocco

After discussions with the **President of the University** and the **Vice Dean**, it was agreed to propose the following schedule to the project partners:

- Dates**:** Arrival on 18 November 2025
- Workshop: **19–20 November 2025**
- Departure: 21 November 2025

Venue: Mohammed First University – UMP, Oujda, Morocco
Participants: Project partners
Planned activities:

- Presentations and discussions on project results
- Visit to the LETSER Laboratory at UMP to see the **Photovoltaic Solar Cooker with Battery Storage** and to give a demonstration

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➢ *Results achieved*