IEA-SHC Task 64
SolarPACES Task IV
Sub-Task C

Webinar
IEA SHC Solar Academy
29 November 2022
01 December 2022

Evaluation of uncertainty derived from SHIP plant simulations

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Objectives of Subtask C

Develop new information about ***simulation*** and ***monitoring*** tools for assessing the potential benefits SHIP plants, with ***known uncertainties*** sources.

- **C.1 Identification and Evaluation of available simulation tools for SHIP**
- **C.2 Simulation Tools for Solar Process Heat Systems**

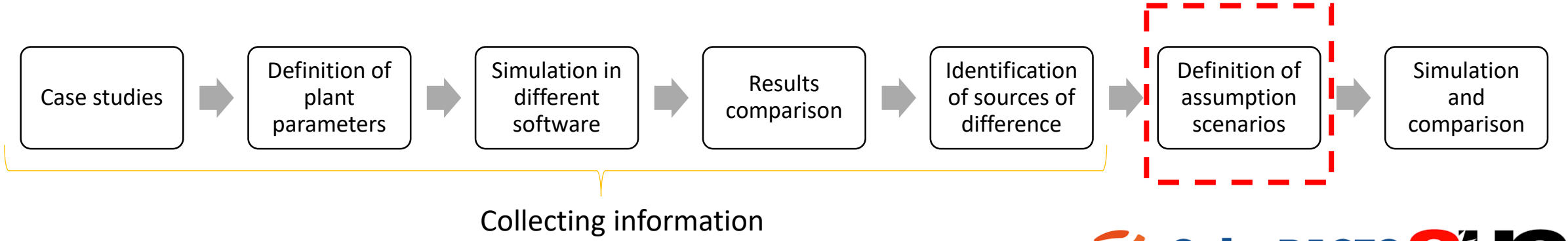
2020-2021

- **C.3 Yield assessment of Actual Solar Process Heat Systems (Monitoring)**

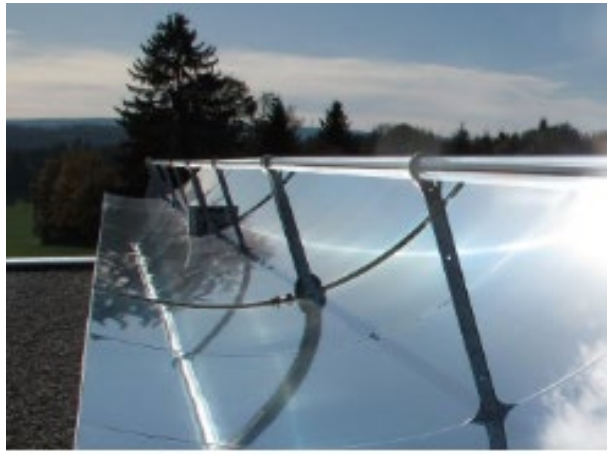
2022-2023

Methodology for simulation results comparison

- Definition of plants to be studied
- Creation and distribution of plant's design parameters
- Initial comparison and feedback to analysts
- Identification of sources of differences in results
- Definition of assumptions scenarios (to avoid "human" factor)
- Simulation and final assessment of deviations



Comparative study

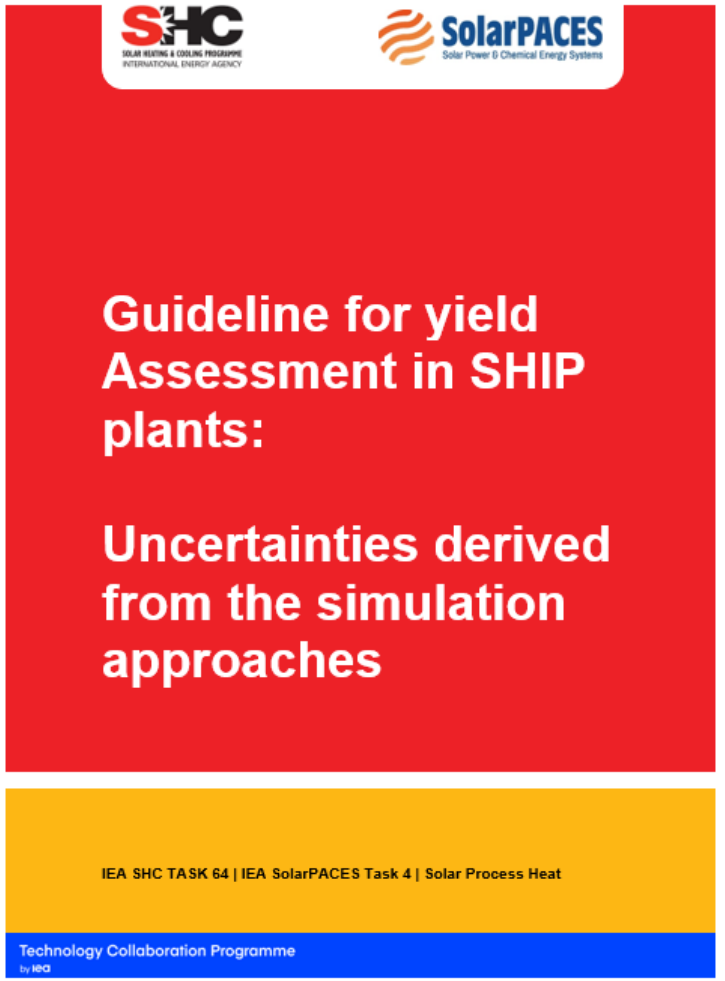


- **Case A:** Cooper mining in Chile (Flat-plate collectors)
- **Case B:** Paper mill in France (1-axis tracking flat-plate) - Newheat
- **Case C:** DSG Linear FRESNEL - SOLATOM
- **Case D:** Dairy Factory in Switzerland (parabolic trough)

Software analyzed	
A	CEA model, Greenius, SHIP2FAIR tool, SHIPcal, System Advisor Model (SAM), TRNSYS
B	NewHeat tool, Polysun, SHIP2FAIR tool, TRNSYS
C	Greenius, SAM, Scilab, SHIP2FAIR tool, SHIPcal, TRNSYS
D	Greenius, Polysun, TRNSYS

Deliverable C1: Guideline

- Methodology
- Case studies definition
- Deviation assessment results
- Impact of common assumptions in SHIP simulation
- Induced error assessment in SHIP simulation
- Recomendations



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Case studies – Input error comparison

- Parameters:
  - Time shifting
  - Thermal capacitance
  - Thermal insulation
  - HX effectiveness
  - TES nodes
  - Load
  - Piping losses

- Comparison metrics:
  - Depending on the time scale
    - Solar Fraction (Annual & monthly scale)
    - Energy delivered to the process (daily scale)
    - Dynamic time warping and residual values (hourly scale)
  - Comparison methodology
    - Developed for Case study A
    - Open access paper
    - Coded in python

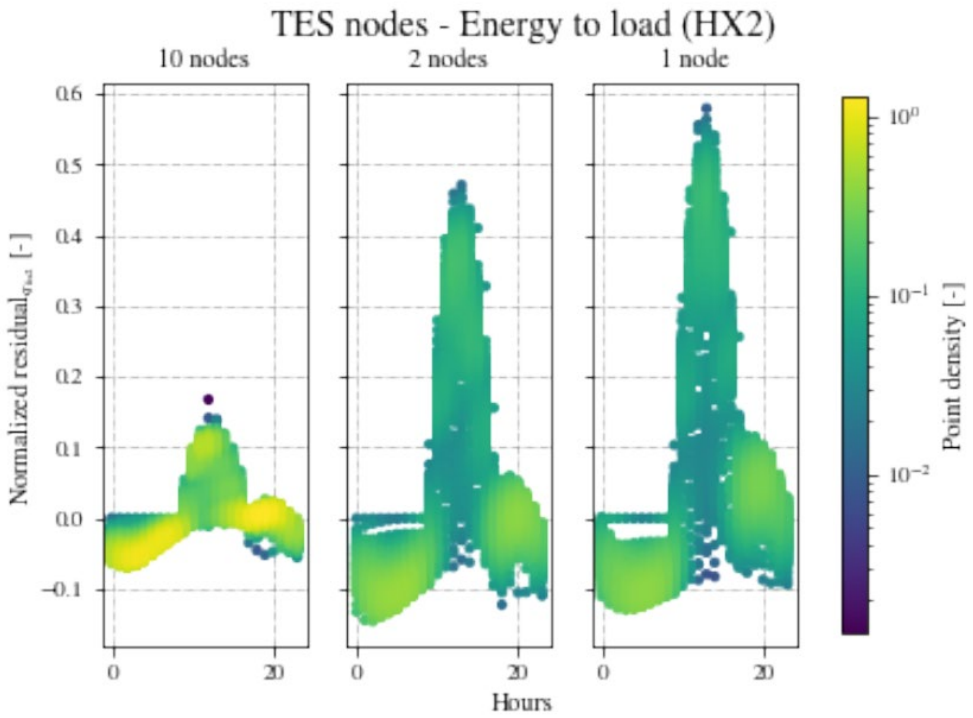
Example for “induced errors” simulations: Case A

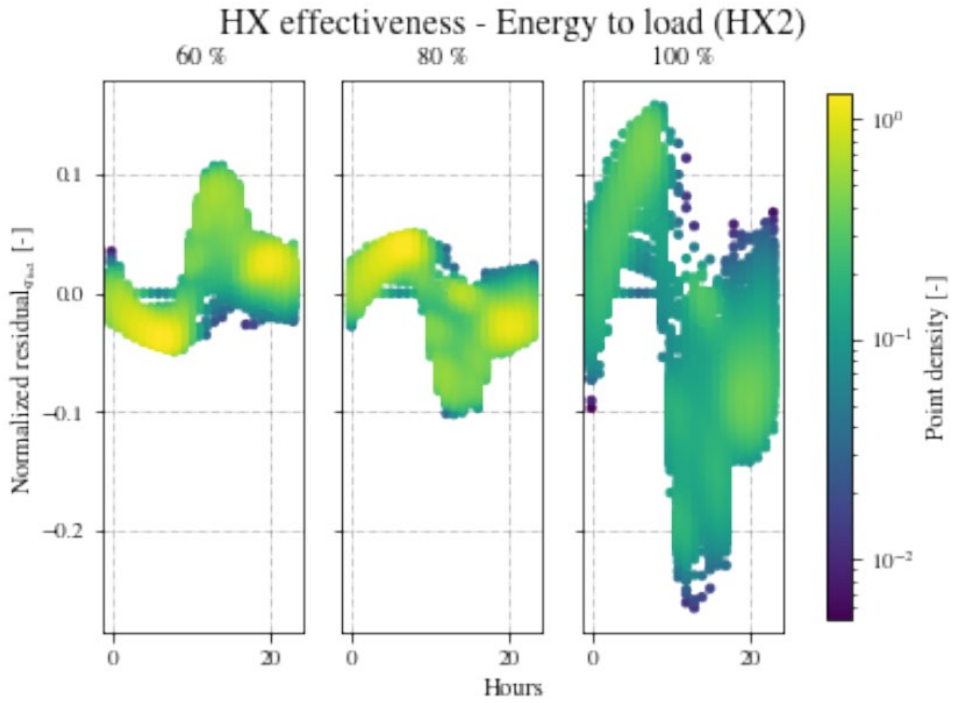
Reference

Scenarios	Time Shifting [h]	Thermal Capacitance [\%]	Thermal Insulation (cm)	HX Effectiveness [\%]	TES nodes [-]	Load
Scenario 0	**0**	**5**	**5**	**70**	**20**	**Std**
Scenario 1	1	5	5	70	20	Std
Scenario 2	0,5	5	5	70	20	Std
Scenario 3	-1	5	5	70	20	Std
Scenario 4	-0,5	5	5	70	20	Std
Scenario 5	0	0,0001	5	70	20	Std
Scenario 6	0	150	5	70	20	Std
Scenario 7	0	200	5	70	20	Std
Scenario 8	0	250	5	70	20	Std
Scenario 9	0	300	5	70	20	Std
Scenario 10	0	5	Underground	70	20	Std
Scenario 11	0	5	10	70	20	Std
Scenario 12	0	5	5000	70	20	Std
Scenario 13	0	5	5	60	20	Std
Scenario 14	0	5	5	80	20	Std
Scenario 15	0	5	5	100	20	Std
Scenario 16	0	5	5	70	10	Std
Scenario 17	0	5	5	70	2	Std
Scenario 18	0	5	5	70	1	Std
Scenario 19	0	5	5	70	20	0--0
Scenario 20	0	5	5	70	20	2--2

Control Volume	Energy to load	
Parametric analysis	nRMSE	%DIF
Scenario 1	0,17	-6,46
Scenario 2	0,09	-1,34
Scenario 3	0,16	-5,33
Scenario 4	0,09	-0,95
Scenario 5	0,03	0,78
Scenario 6	0,02	-0,72
Scenario 7	0,04	-1,53
Scenario 8	0,05	-2,37
Scenario 9	0,07	-3,26
Scenario 10	0,00	-0,02
Scenario 11	0,00	0,16
Scenario 12	0,01	0,42
Scenario 13	0,09	-2,95
Scenario 14	0,08	2,19
Scenario 15	0,22	4,96
Scenario 16	0,10	-0,40
Scenario 17	0,34	-6,28
Scenario 18	0,42	-13,67
Scenario 19	0,07	-0,55
Scenario 20	0,23	-5,33

Hourly data: residual values analysis





Calculation of the residual values for each simulation and normalized with the hourly demand of heat:

$$r = (q_{ref} - \hat{q}_{sim})/q_{h,dem}$$

For each day, the PDF is calculated with the hourly values (24 bins) and showed in a common color scale

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Appendix: Simulation Tools for ST Systems

- Up-to-date table listing the available software able to model solar thermal systems (continuing work done in Task 49)

Software Name	State	Scope	Design Flexibility	Economical Prefeasibility Analysis	Licensing	Developing institution	Homepage
CEA (SHIP2FAIR)	Operational	Research/ Professional Design	User Defined Schemes	Yes	Under Development	CEA, in the context of the SHIP2FAIR European Project	http://ship2fair-h2020.eu/
GREENIUS	Operational	Simple Design	Predefined Schemes	Yes	Freeware	DLR, German Aerospace Center	http://desire.htwberlin.de/greenius.php
NEWHeat - OWN	Operational	Research/ Professional Design	User Defined Schemes	Yes		NEWHeat. It was developed to perform their own simulations and verifications	
POLYSUN	Operational	Research/ Professional Design	User Defined Schemes	Yes	Commercial	Vela Solaris	http://www.velasolaris.ch
System Advisor Model (SAM)	Operational	Research	Predefined Schemes	Yes	Open Source	NREL, National Renewable Energy Laboratory, USA	Home - System Advisor Model (SAM) (nrel.gov)
Transient System Simulation Tool (TRNSYS)	Operational	Research	User Defined Schemes	Yes	Commercial	Univ. Wisconsin, Solar Energy, Lab. Madison, USA	http://sel.me.wisc.edu/trnsys/
COLSIM	Operational	Research		Yes	Free online	Fraunhofer ISE	https://www.colsim.org/
COLSIM CSP	Operational	Research	User Defined Schemes	Yes	Internal Use	Fraunhofer ISE	
Prosol simulation tool	No Operational	-				Politecnico Milano	-
SOLTERM	Operational	Simple Design	Predefined Schemes	Yes	Commercial	LNEG, IP (Portugal)	solterm5 | LNEG Laboratório Nacional de Energia e Geologia

Software Name	State	Scope	Design Flexibility	Economical Prefeasibility Analysis	Licensing	Developing institution	Homepage
T*SOL Pro	Operational	Professional design	User Defined Schemes	Yes	Commercial	Dr. Valentin Energie Software GmbH	T*SOL – Valentin Software GmbH (valentin-software.com)
SOPRO	No Operational	Simple Design	Predefined Schemes	No	Internal Use	Fraunhofer ISE	Offline
Appsol-Therm	Operational		Predefined Schemes	Yes	Free online	Appsol	Appsol – Energía solar para industria
Engineering Equation Solver (EES)	Operational	Simple Design/ Research	-	No	Commercial	F- Chart Software	EES: Engineering Equation Solver | F-Chart Software - Engineering Software
Environmental Life-cycle Impacts of Solar Airconditioning systems (ELISA)	Operational	Research	Predefined Schemes	No	Freeware	Universidad de Palermo	IEA SHC || Task 53 || Software/Tools (iea-shc.org)
F-Chart	Operational	Simple Design	Predefined Schemes	Yes	Commercial	SA Klein & WA Beckman - F-Chart Software	F-CHART: Solar Systems Analysis | F-Chart Software - Engineering Software
HOMER	Operational	Professional Design	Predefined Schemes	Yes	Commercial	UL - NREL	HOMER - Hybrid Renewable and Distributed Generation System Design Software (homerenergy.com)
IKI Solar Payback Calculator	Operational	Simple Design	Predefined Schemes	Yes	Freeware	Fraunhofer ISE	Solar Heat for Industry | Economic Potential (solar-payback.com)
Insel	Operational	Research/ Professional Design	User Defined Schemes	Yes	Commercial	INSEL.eu	INSEL - Homepage - INSEL en

Software Name	State	Scope	Design Flexibility	Economical Prefeasibility Analysis	Licensing	Developing institution	Homepage
optiCAD	No Operational	Optical simulation		No	Commercial	OptiCAD Corporation	(OFFLINE) www.opticad.com
Resspi	Operational	Research/ Professional Design	Predefined Schemes	Yes	Free online	SOLATOM	Resspi ©, the solar simulator for industrial processes
RETScreen Expert	Operational	Simple Design	Predefined Schemes	Yes	Commercial	CanmetENERGY	RETScreen (nrcan.gc.ca)
SHIPCal-CIMAV	Operational	Simple Design/ Research	Predefined Schemes	Yes	Free online	Centro de Investigación en Materiales Avanzados.	http://shipcal.cimav.edu.mx/accounts/login/
SHIP CALCULATOR	Operational	Research	Predefined Schemes	Yes	Freeware	Fraunhofer Institute for Solar Energy Systems.	File:20190301 SHIP Feasibility Calculator.xlsx — energypedia.info
SHIP Desing Tool	No Operational	Research		No	Free online	Hochschule fur Technik Stuttgart	(OFFLINE) https://www.fp7-insun.eu/
Solar Plant Sizing and Layout	Operational	Professional Design	User Defined Schemes	Yes	Free online	SOLARE PROZESSWARME	Solar Plant Sizing and Layout — Solare Prozesswärme (xn--solare-prozesswrme-ztb.info)
Transol	No Operational	Professional Design	Predefined Schemes	Yes	Commercial	AIGUASOL & Centre Scientifique et Technique du Bâtiment	Software para el diseño, optimización y gestión energética de sistemas solares térmicos. TRANSOL – Aiguasol
T53E4	Operational	Simple Design	Predefined Schemes	Yes	Free online	Universität Innsbruck & Daniel Neyer[Brainworks.	IEA SHC || Task 53 || Software/Tools (iea-shc.org)
Thermal Engineering Systems in Python (TESpy)	Operational	Simple Design/ Research	User Defined Schemes	No	Open Source		Libraries (oemof.org)

Final remarks

- **Invitation to participate** in the second stage: monitoring ST systems
- Next Subtask C meeting Friday 02/12 – 14:00 CET
- All the information is available at the Task 64 website: https://task64.iea-shc.org/
- Open-access paper detailing methodology: Cardemil, J. M., Calderón-vásquez, I., Pino, A., Starke, A., Wolde, I., Felbol, C., L Lemos, L. F., Bonini, V., Arias, I., Iñigo-labairu, J., Dersch, J., & Escobar, R. (2022). Assessing the Uncertainties of Simulation Approaches for Solar Thermal Systems Coupled to Industrial Processes. *Energies*, *15*(9), 3333. https://doi.org/10.3390/EN15093333
- Presentations at SWC2021, CIES2022, Eurosun 2022.

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