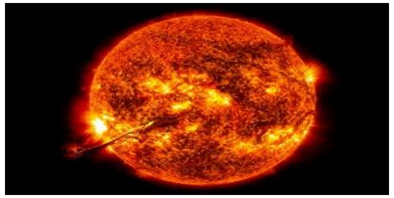  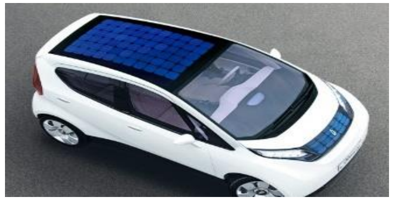  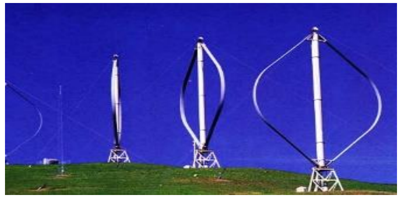 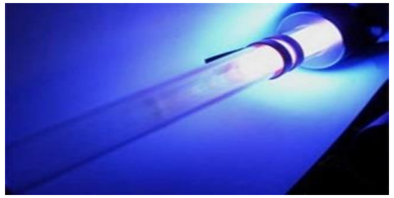

Comparative Analysis of Solar Tower and Parabolic Trough Systems for Solar Heat in a Steel Industry

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ERDEMİR

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3rd International Sustainable Energy Conference

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METU and ODTU-GUNAM

Middle East Technical University (METU/ODTU)

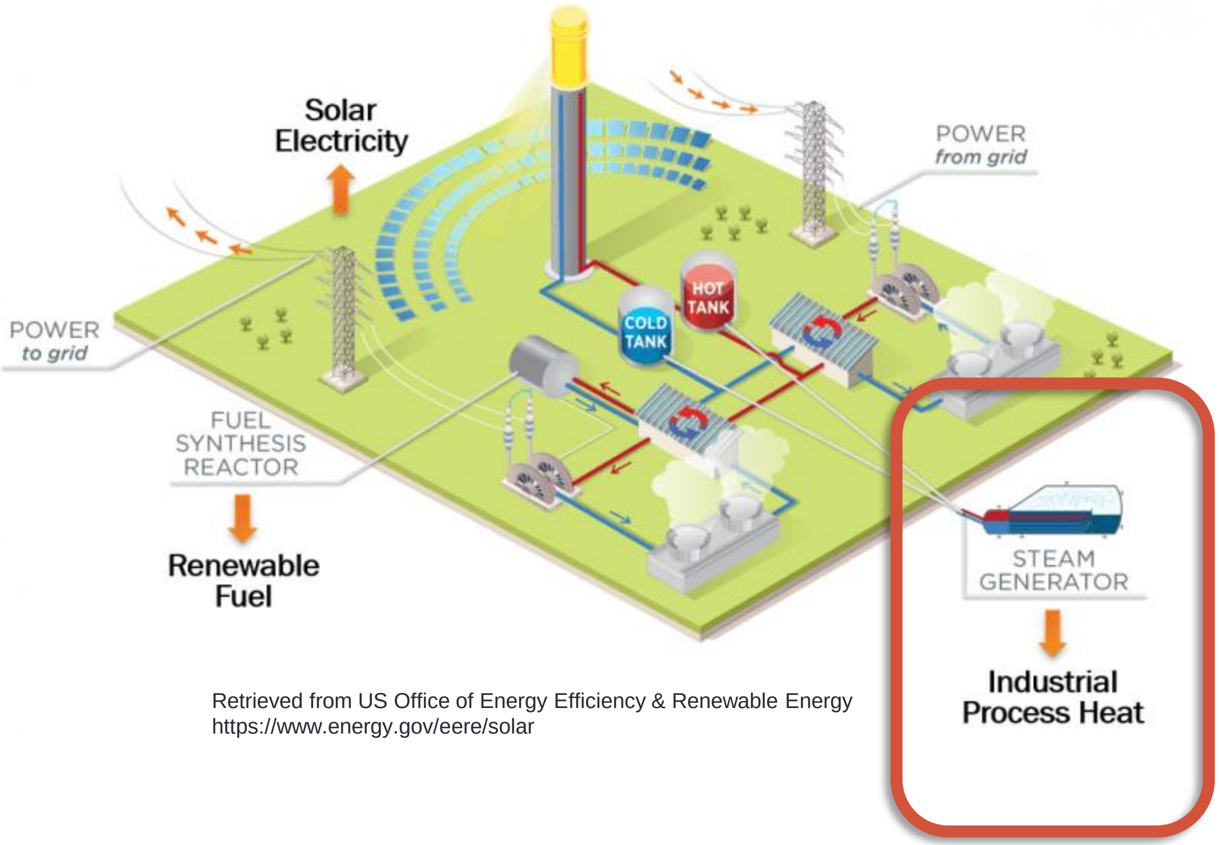
- Centered in Ankara, TR
- Established in 1956
- State research university with more than 28,000 students
- 451 international projects
- 224 EU framework programme projects

ODTU Center for Solar Energy Research and Applications (ODTU-GUNAM)

- Located on METU campus in Ankara, TR
- Established in 2009 as a university research center at METU
- Become independent center of excellence in solar energy in 2021
- Has 6 divisions, mainly on PV

Introduction

- Industrial operations' increasing energy demand leading to increased fossil fuel usage
- Concentrated solar thermal (CST) to meet heat needs while reducing greenhouse gas emissions
- CST as an alternative to meet moderate temperature demand of industrial processes
- Also employed in renewable fuels (solar fuels) and grid electricity production
- Carbon Border Adjustment Mechanism from 2026



Retrieved from US Office of Energy Efficiency & Renewable Energy
https://www.energy.gov/eere/solar

Objectives

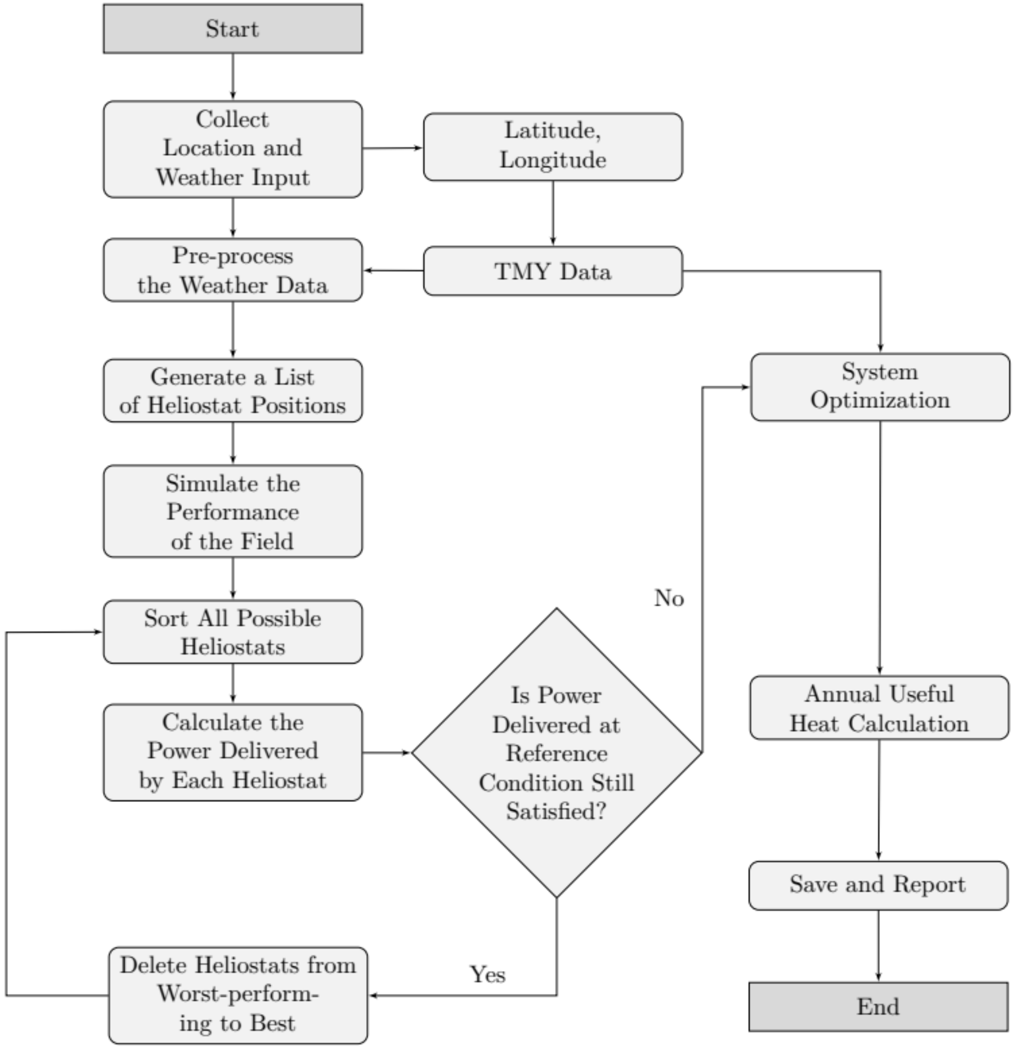
- To decarbonize steel production plant's blast furnace process
- To compare the performances of optimized Solar Tower (ST) and Parabolic Trough Collector (PTC) systems for provided location and available land area
- To report economical aspects of the optimized layout for ST and PTC systems
- To address the advantages and limitations of the systems and their integration to steel production process

Retrieved from the University of Birmingham and Scanrail

Methodology: Solar Tower

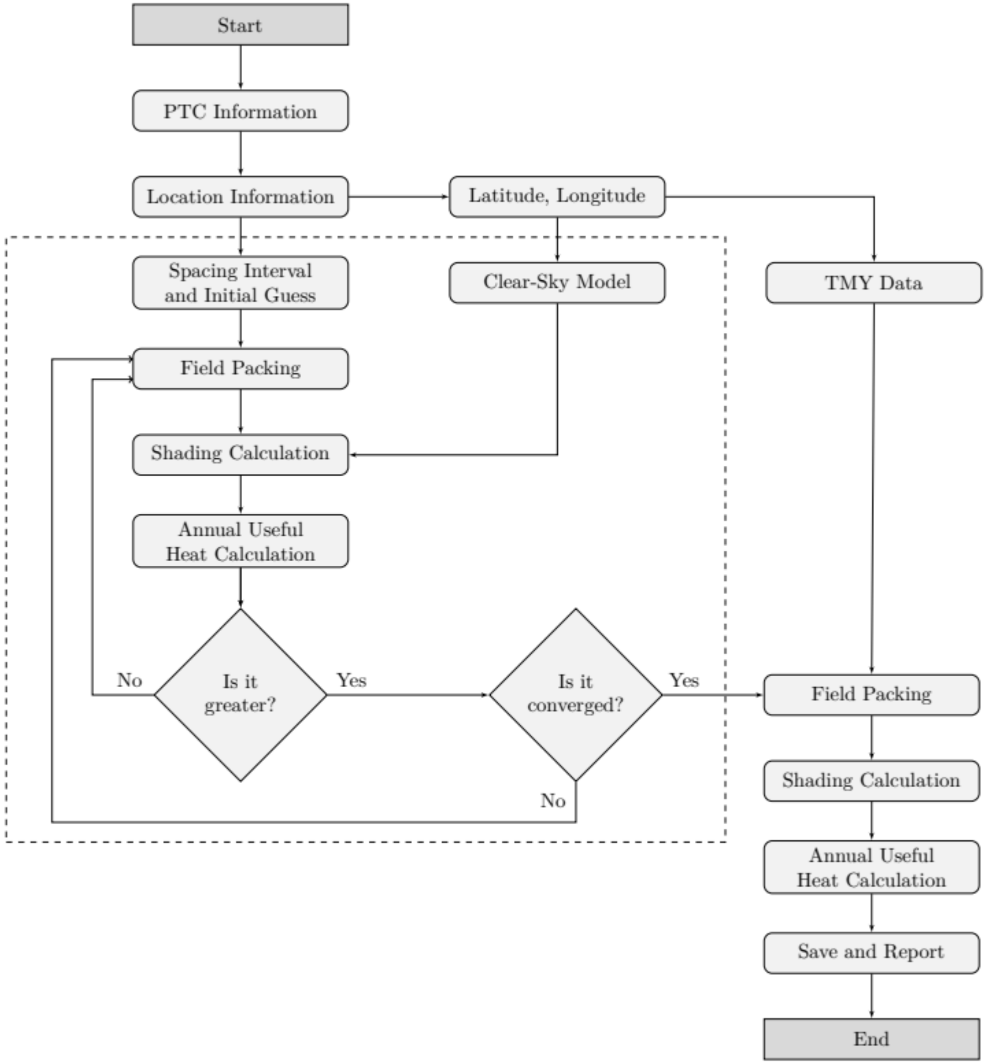
- ST system layout and modelling by commercially available software, SolarPILOT by NREL
- Rank heliostats by thermal power output, removing the least efficient until meeting the power production threshold, ensuring optimal field layout
- Focus on minimizing total cost against yearly energy output, incorporating a penalty for systems underperforming compared to desired thermal output

$$Z(\bar{x}) = \frac{C_{tot}(\bar{x})}{E_{ann}(\bar{x})}\left(1 + \left(1 - \min\left[\frac{\dot{q}_{sf}(\bar{x})}{\dot{q}_{sf,des}(\bar{x})}, 1\right] P\right)\right)$$

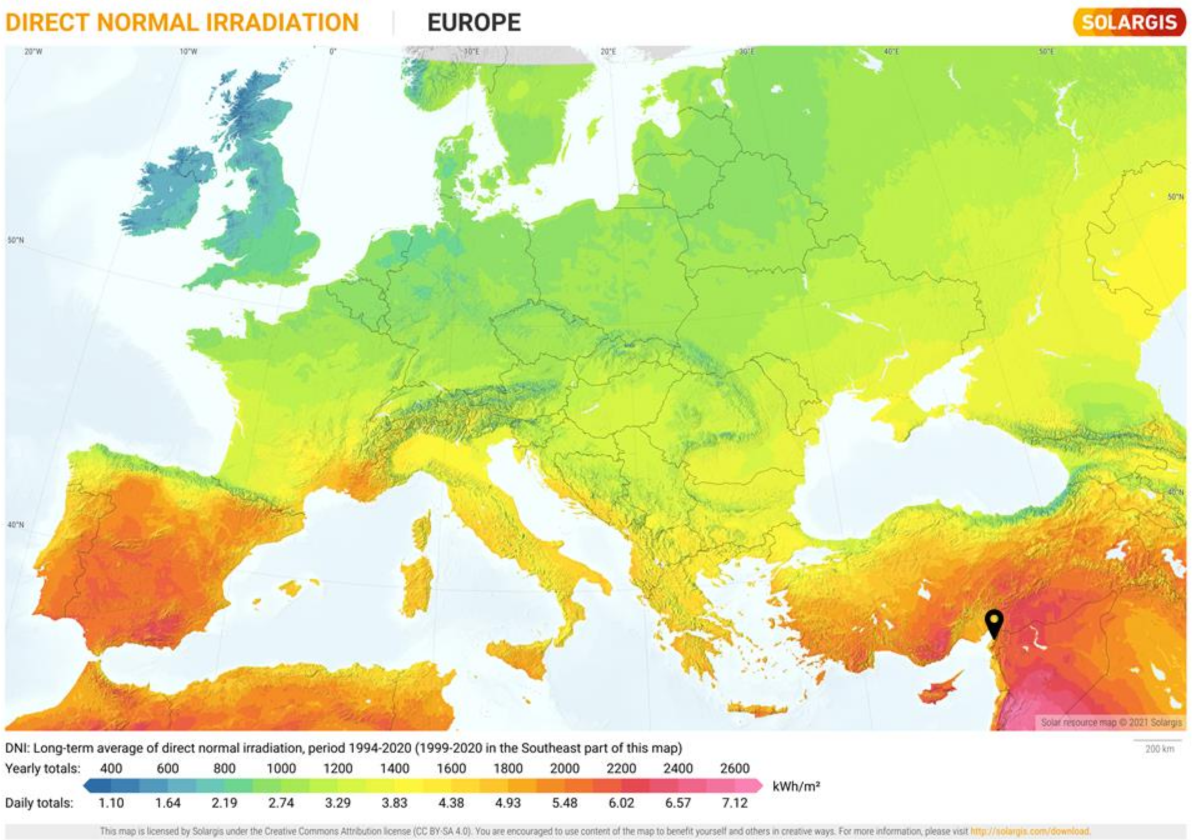


Methodology: Parabolic Trough Collectors

- Using a custom tool to optimize PTC array layouts, balancing land use with shading minimization
- Factoring in optical and thermal losses to compute collector efficiency and heat collection
- Employing clear sky model and TMY data in an annual simulation to determine the best spacing for maximum energy yield

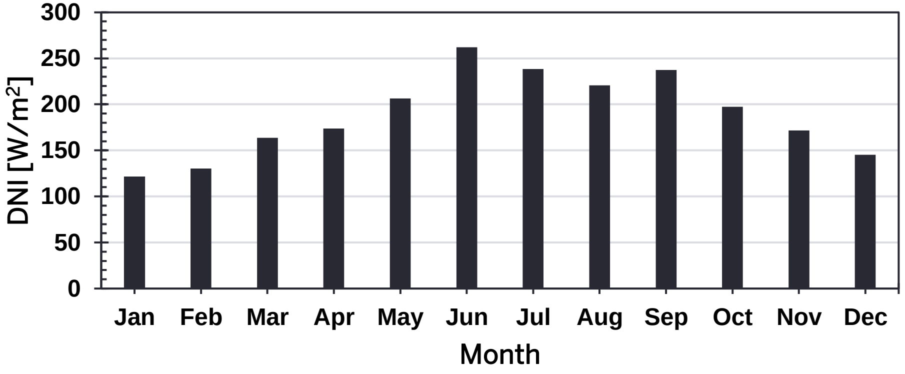


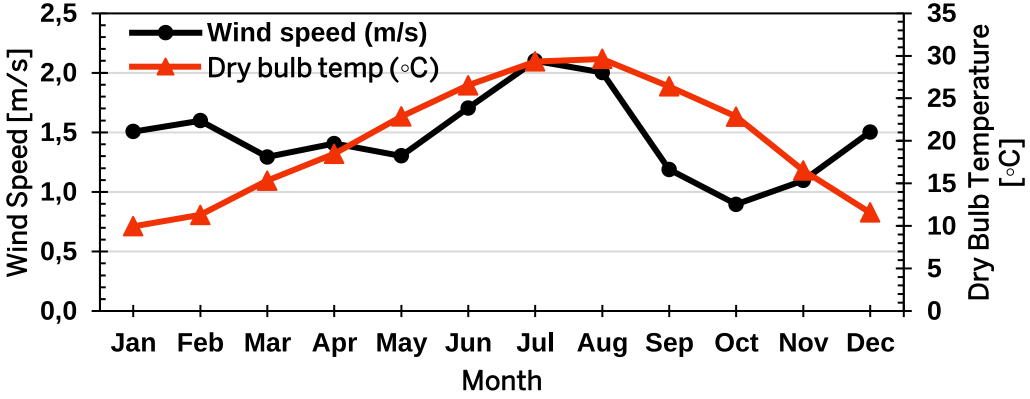
Methodology: Case Study



Retrieved from SolarGIS. http://solargis.info/

Monthly Averaged Meteorological Data for Installation Location





Latitude	Longitude	Time Zone
36°44'41.71"N	36°13'23.46"E	GMT +3

Methodology: Case Study

Simulation Parameters for ST Modelling

Parameter	Value / Name
Heat Transfer Fluid (HTF)	Molten Binary Solar Salt (60% $NaNO_3$ – 40% KNO_3 by weight)
Number of Heliostats	2570
Tower Height	110 m
Square Heliostat Dimension	8.0 m
Receiver Height	14.8 m
Receiver Diameter	7.74 m
HTF Receiver Temperature Range	290 – 565 °C
Heliostat Mirror Reflectance	0.97
Receiver Coating Absorptance	0.94

Simulation Parameters for PTC Modelling

Parameter	Value / Name
Heat Transfer Fluid (HTF)	Syltherm 800
Collector Type	SkyFuel – SkyTrough™
Number of Modules	1398
Module Length	13.9 m
Collector Aperture Width	6.0 m
Aperture Area	83.4 m^2
Mirror Material	ReflecTech® PLUS
Temperature Range	200 – 500 °C
Optical Efficiency	0.77

Methodology: Case Study

Parameters used in the Economic Analysis

Parameter	Unit	Solar Tower	Parabolic Trough
Collector Capital Cost	EUR/kW	-	509
Tower Capital Cost	EUR/m²	55.2	-
Receiver Capital Cost	EUR/m²	204.8	-
Heliostat Capital Cost	EUR/m²	130	-
Fixed Operating Cost	EUR/kW	-	7.27
Variable Operating Cost	EUR/kWh	0.004	0.001
Discount Rate	%	7	7
Lifetime	year	30	30

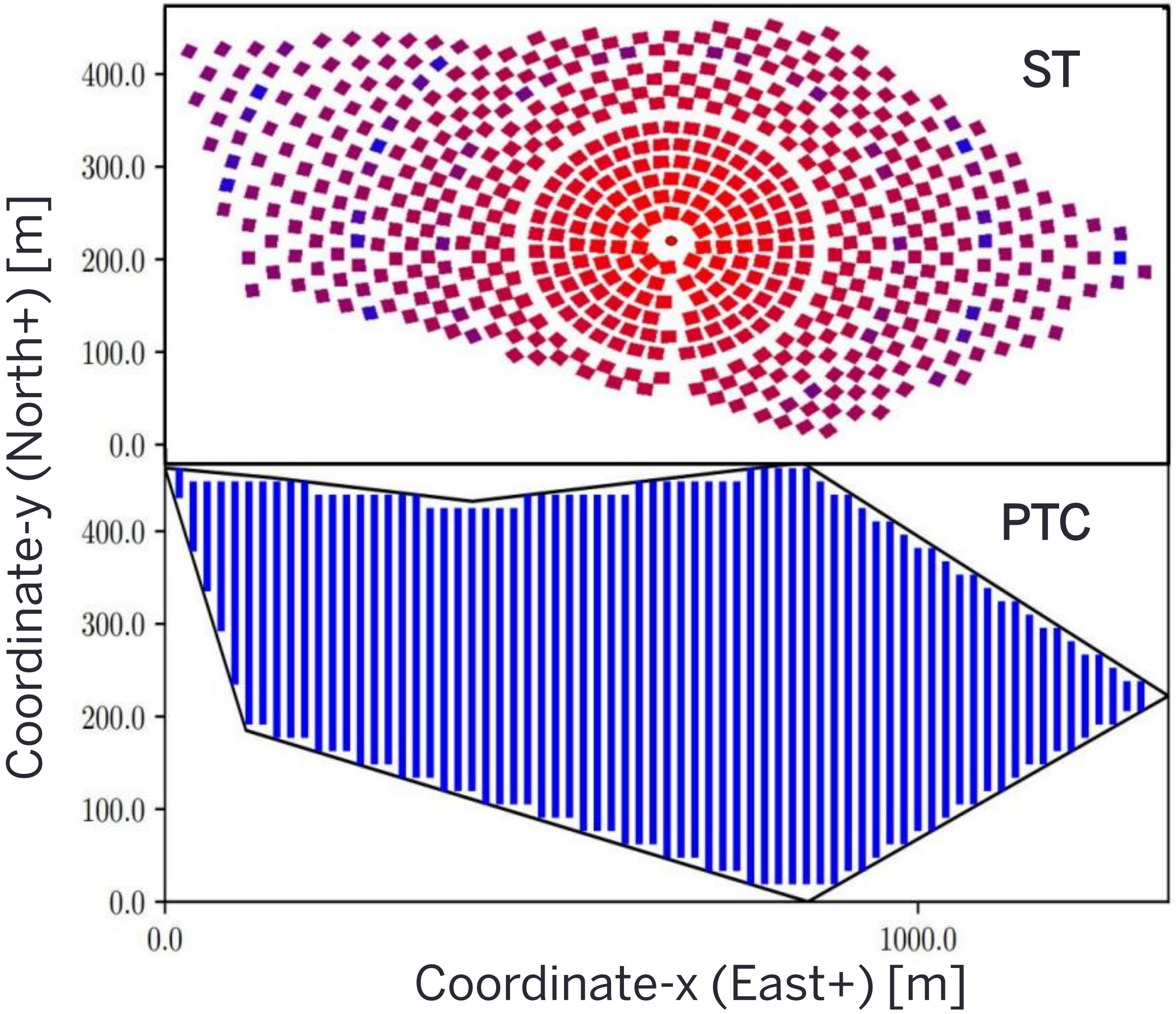
- Process requires to heat up 100 kilo-tonnes/year of water to have steam at 40 bar and 435°C using PTC and ST systems corresponding to monthly thermal energy demand of 7.9 GWh

$$LCOH = \frac{C_{tot} + \sum_{i=1}^{n} \frac{M_i}{(1+r)^i}}{\sum_{i=1}^{n} \frac{E_{ann,i}}{(1+r)^i}}$$

Results and Discussion

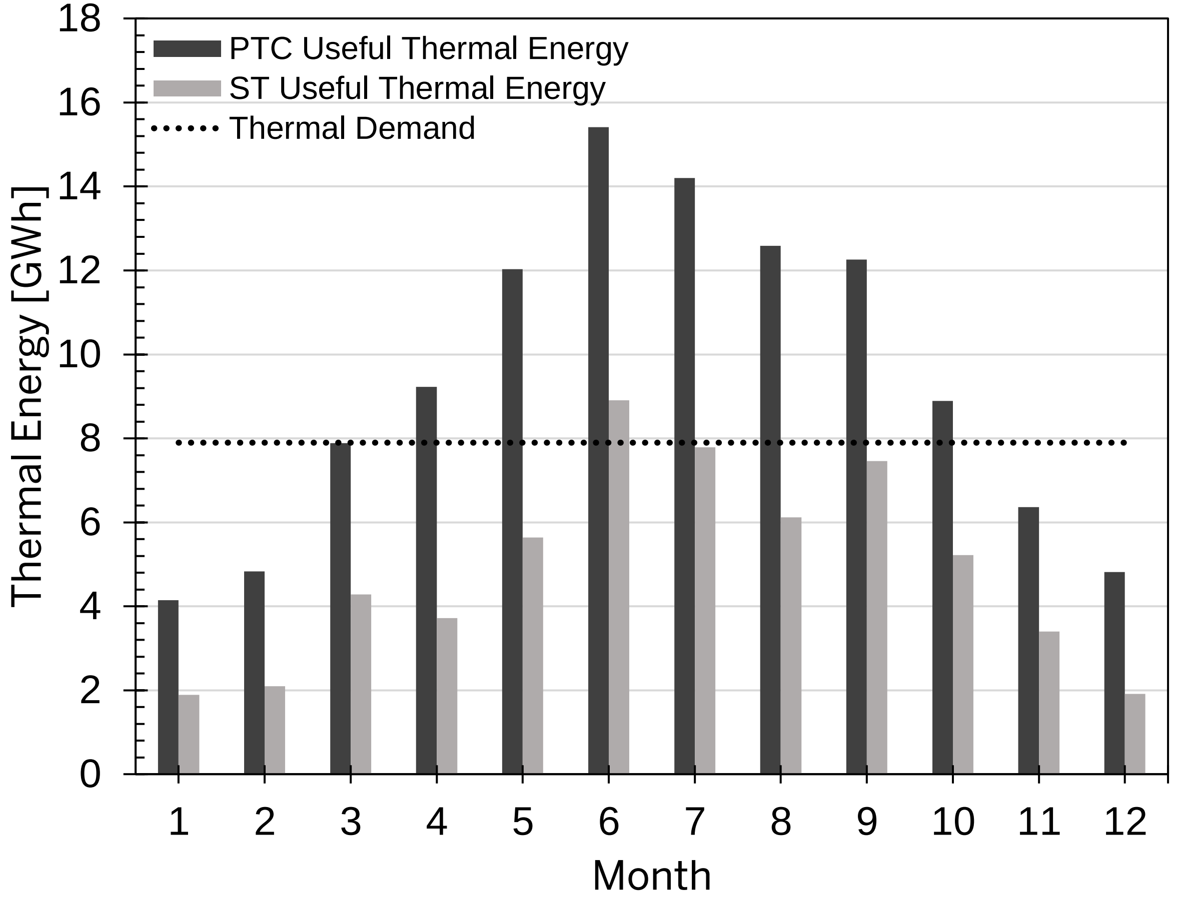
Installation Land Area

Optimized CST Layouts



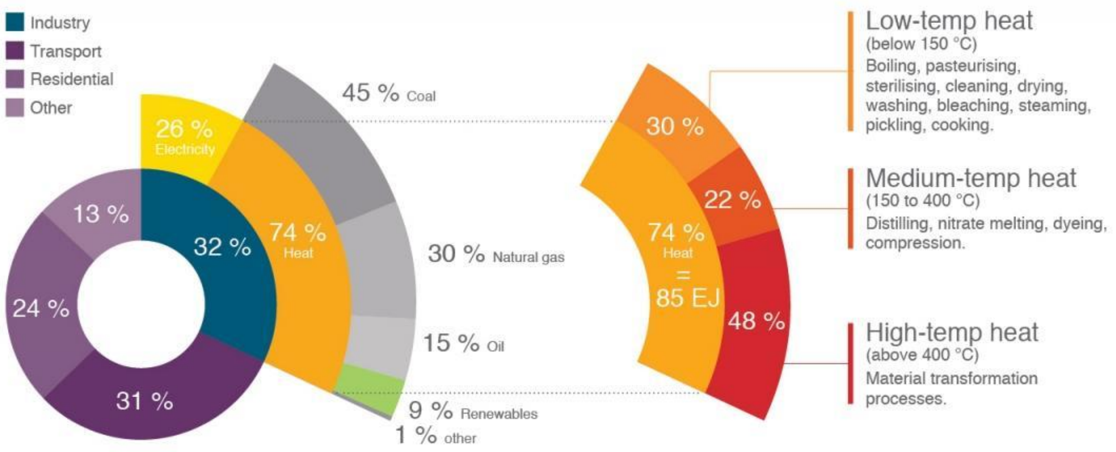
Results and Discussion

- Thermal demand of 7.9 GWh, monthly
- PTC system to outperform ST, generating 112 GWh vs. 76 GWh annually
- PTC covers 118% of energy demand; ST meets 80%, both within the same land area
- Maximum monthly output in June: PTC at 15.4 GWh, ST at 9.6 GWh
- Lowest production in January: PTC at 4.15 GWh, ST at 3.37 GWh due to lower solar irradiance
- PTC benefits from vacuum layer reducing convective losses, especially in summer
- LCOH: 36.9 EUR/MWh for PTC and 68.9 EUR/MWh for ST, whereas utility: 39.8 EUR/MWh

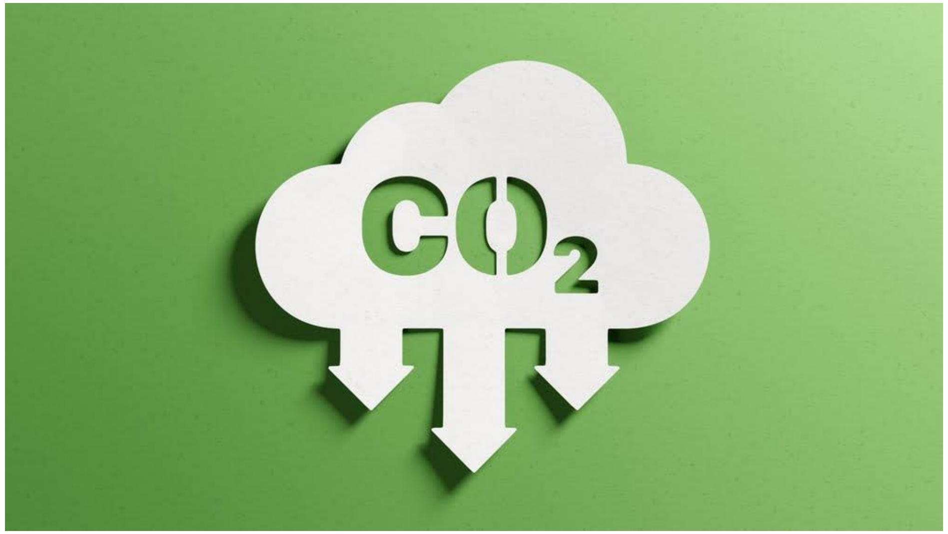


Conclusions

- PTC producing 112.7 GWh/year, 18% above demand; suggests integrating thermal storage for non-winter months
- ST’s solar share is 80% to replace current process in mid-year months, significantly decarbonizing steel production
- PTC system LCOH at 36.9 EUR/MWh aligning with 2023's natural gas cost, making it a cost-effective decarbonization option for the steel industry, despite ST's higher LCOH of 68.9 EUR/MWh
- PTC meets steel plant's steam needs for two-thirds of the year, ST for one-third, reducing CO_2 emissions by 19.1 and 12.7 kilo-tonnes, respectively



Retrieved from https://https://www.solar-payback.com/



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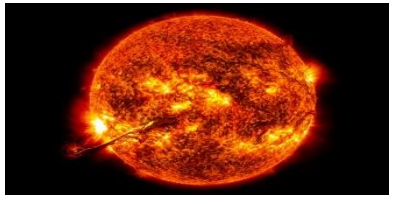

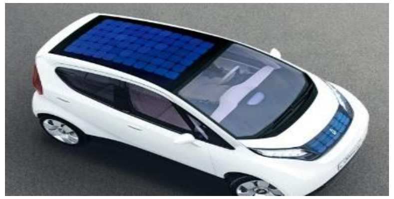

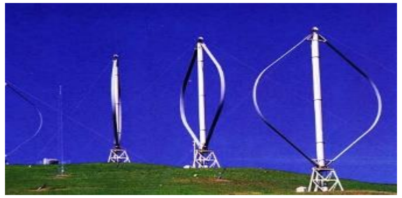
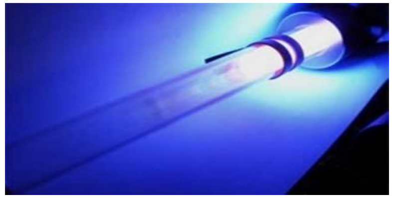

THANK YOU!

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