LIST OF ACRONYMS / ABBREVIATIONS USED IN THIS DOCUMENT

Acronym / abbreviation	Definition
ACC	Air Cooled Condenser
CCGT	Combined Cycle Gas Turbine
CFD	Computational Fluid Dynamics
CSP	Concentrated Solar Power
DNI	Direct Normal Irradiance
DoW	Description of Work
EC	European Commission
GE	General Electric
IP	Intellectual Property
IPR	Intellectual Property Rights
LCA	Life Cycle Analysis
LDA	Laser Doppler Anemometry
LSV	Laser Surface Velocimeter
MACC	Modular Air Cooled Condenser
MENA	Middle East and North Africa
MS/RA	Method Statements and Risk Assessments
PIV	Particle Image Velocimetry
PM	Person Month
PTC	Parabolic Trough Collector
RANS	Reynolds Averaged Navier Stokes
SME	Small to Medium Enterprise
WP	Work Package
WPS	Welding Procedure Specification
WT	Wind Tunnel

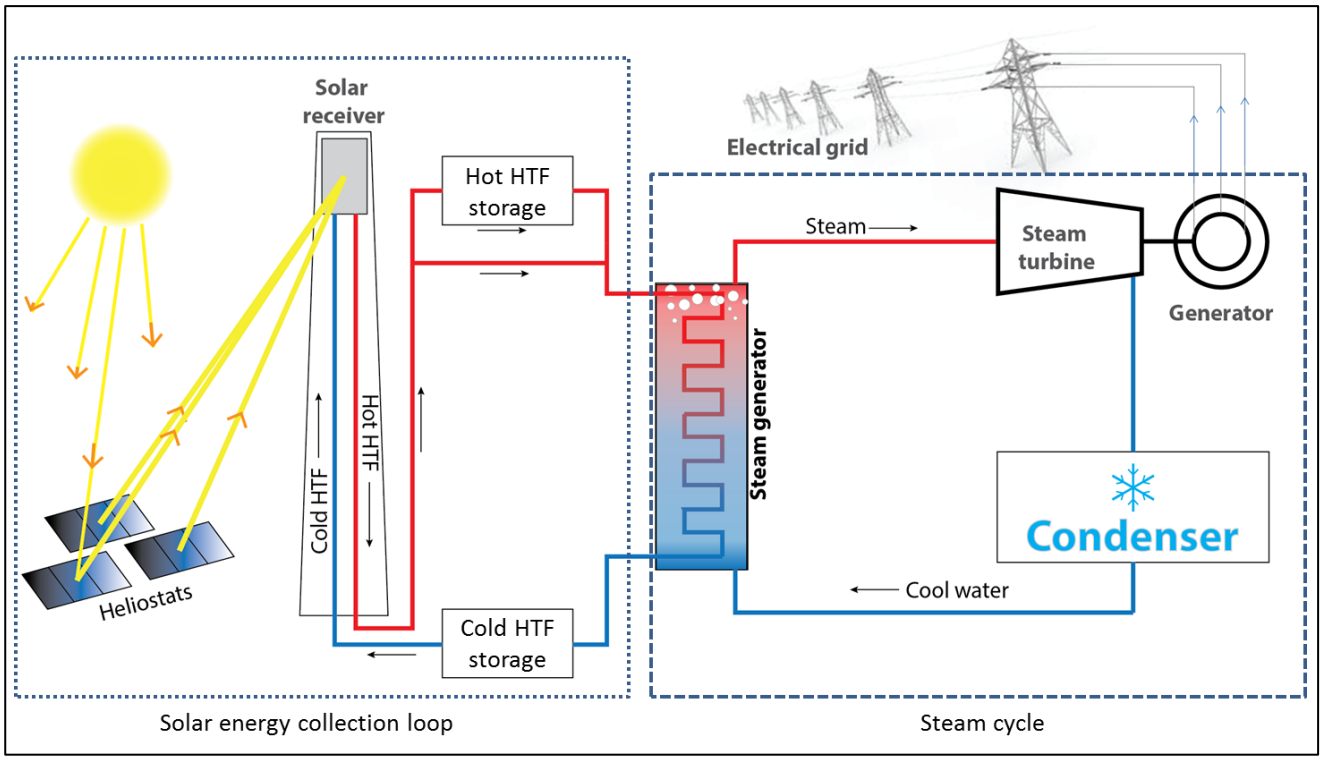


Figure 1. Schematic of CSP plant steam cycle

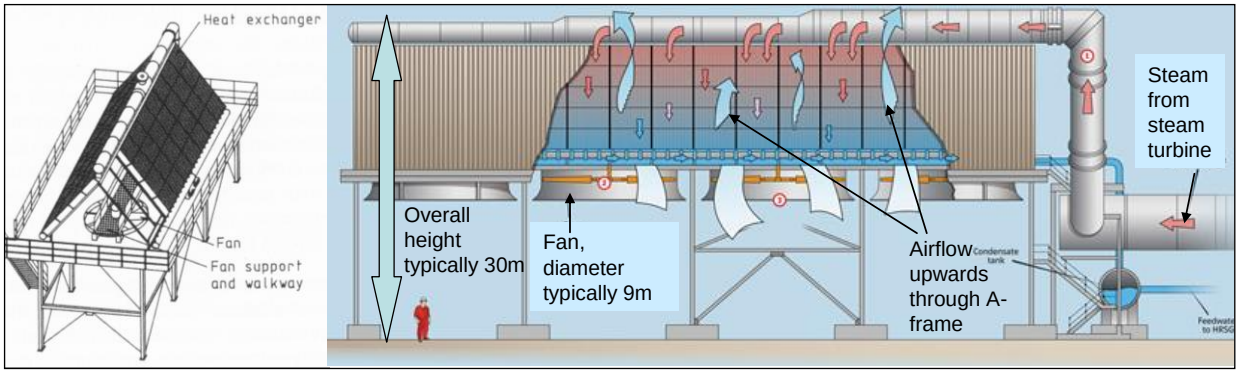


Figure 2. Conventional ACC.

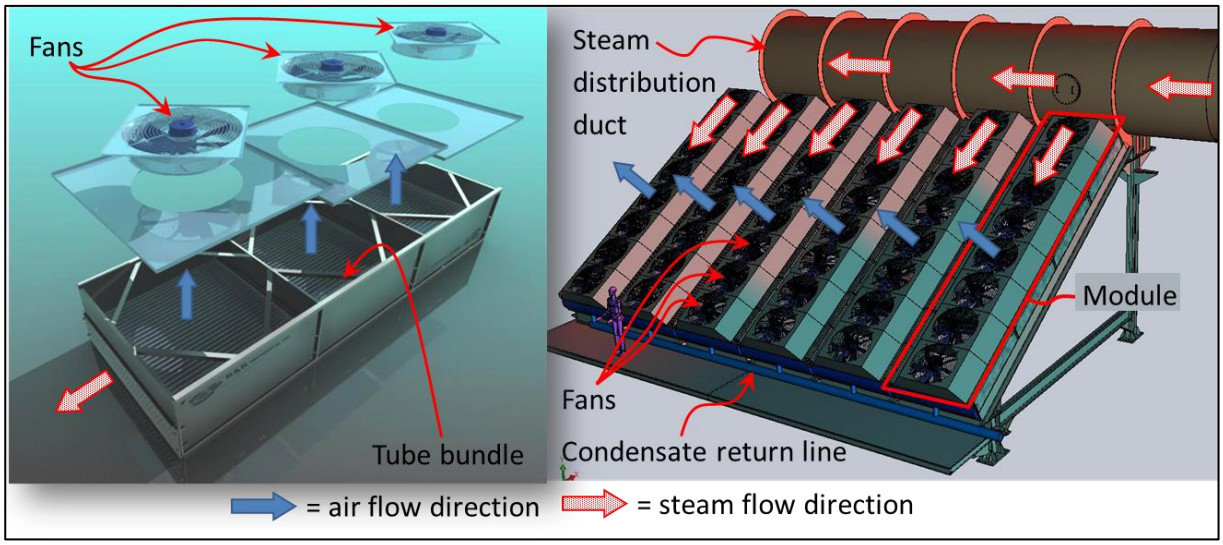


Figure 3. Left: single MACC module. Right: multiple MACC modules assembled and connected to a steam distribution duct and a condensate return line.

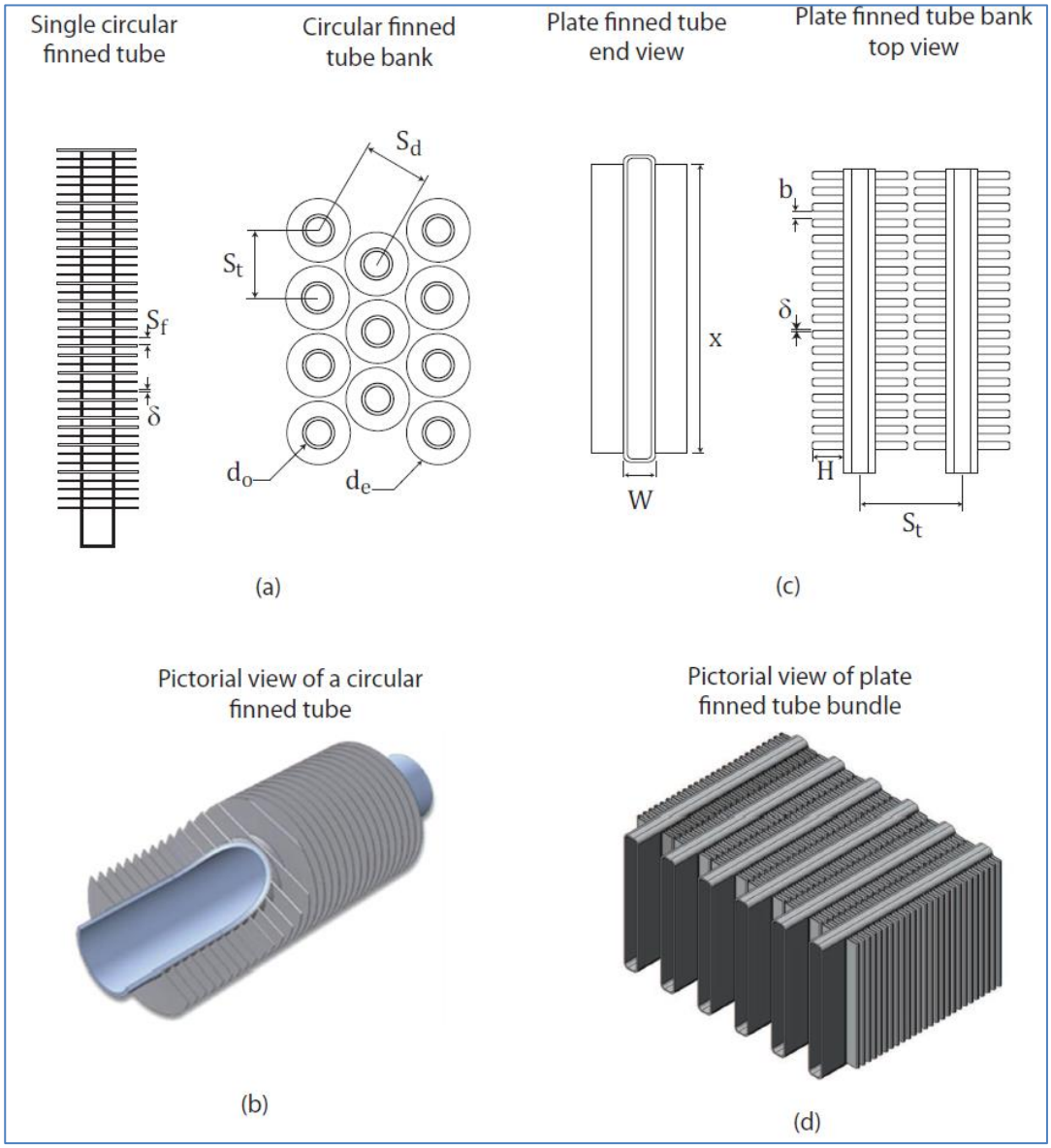
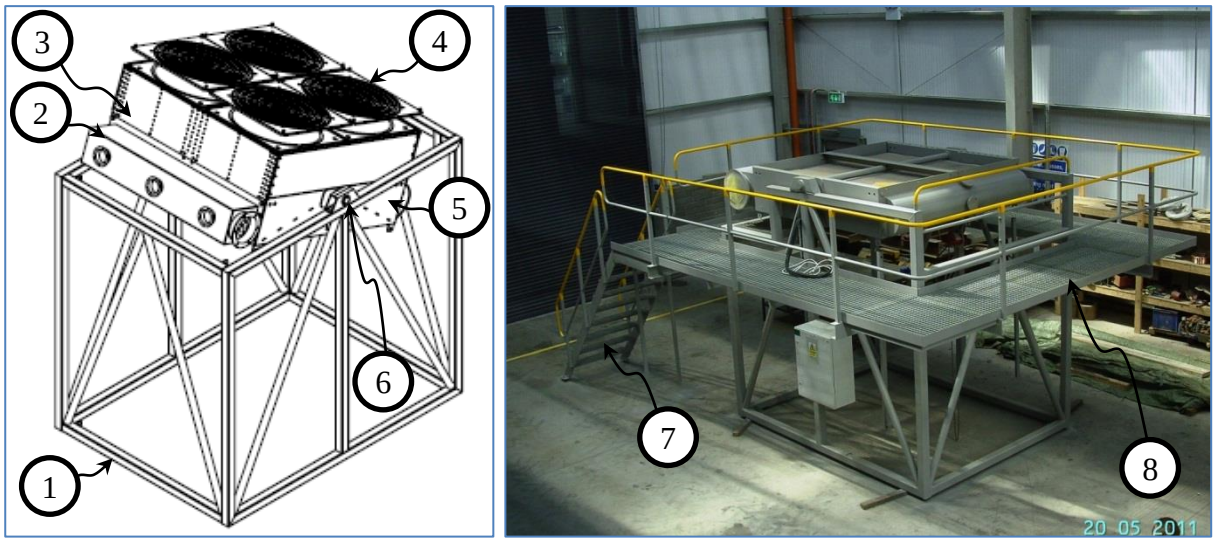


Figure 4. Sample of candidate condenser tube designs: (a) a multi-row circular finned tube bank; (b) pictorial view of circular finned tube; (c) a single row of rectangular plate finned tubes and (d) pictorial view of plate finned tube bundle.



(a) (b)

1	Mounting frame	5	Tube bundle cabinet
2	Inlet steam manifold	6	Support pivot
3	Fan support box section	7	Access steps
4	Fans	8	Walk way

Figure 5. (a) CAD drawing of MACC prototype with support frame (b)MACC prototype mounted on frame with access steps and walk way.

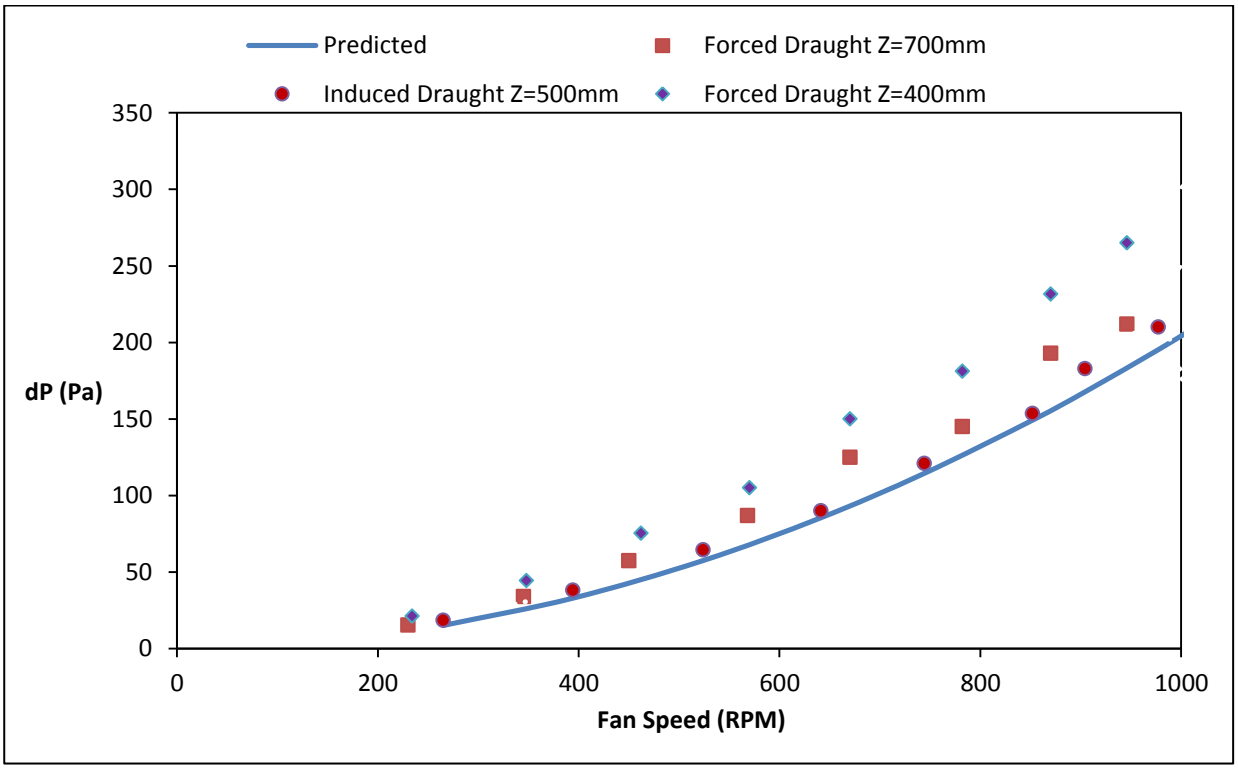


Figure 6. Tube bundle pressure drop versus fan speed for induced draft and forced draft fan configurations.

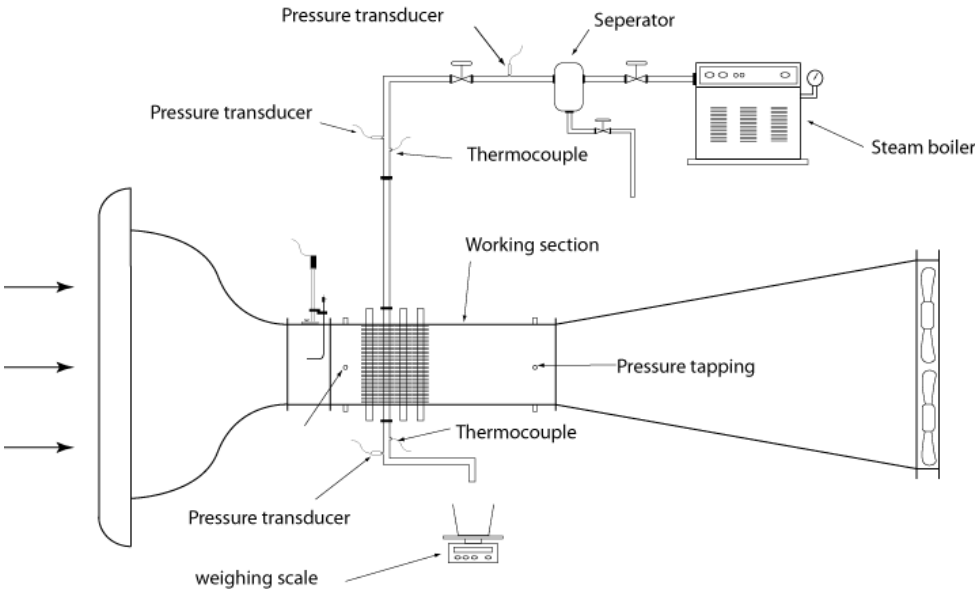


Figure 7. Wind tunnel facility for performing measurements on aerodynamic and thermal performance characteristics of candidate MACC finned tube designs. Also illustrated is the steam supply used to heat the tubes to perform the thermal measurements.

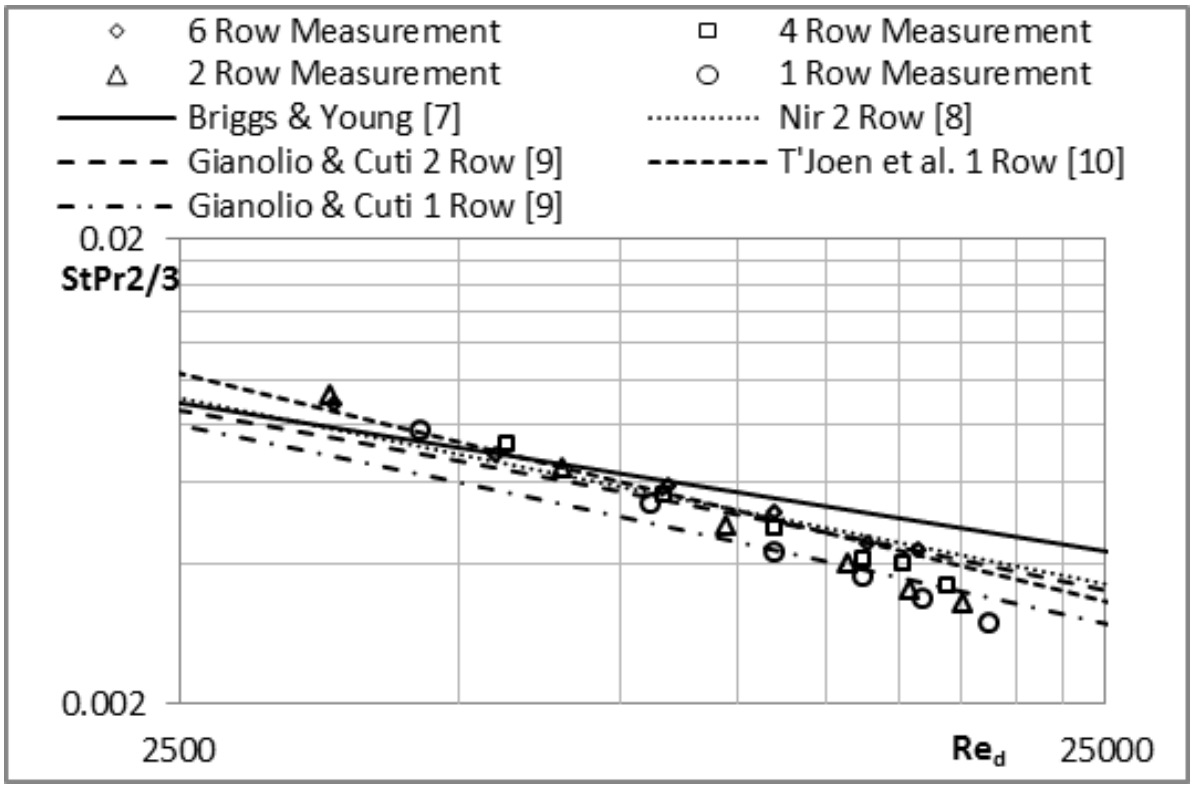


Figure 8. Dimensionless heat transfer coefficient for a range of finned rube designs versus Reynolds number from relevant literature correlations and measured data.

Figure 9: Operational MACC prototype on-site

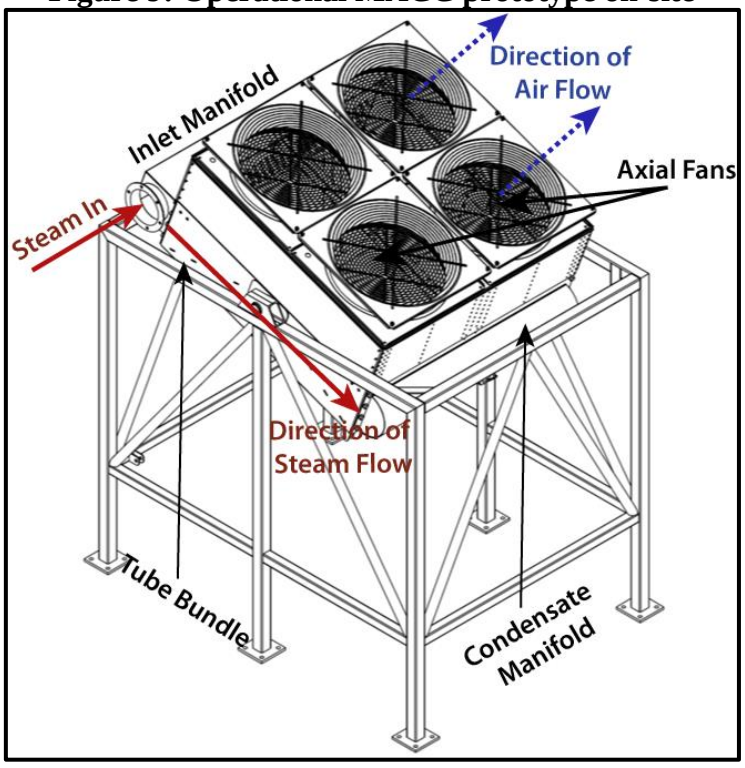


Figure 10: Labelled schematic of MACC prototype

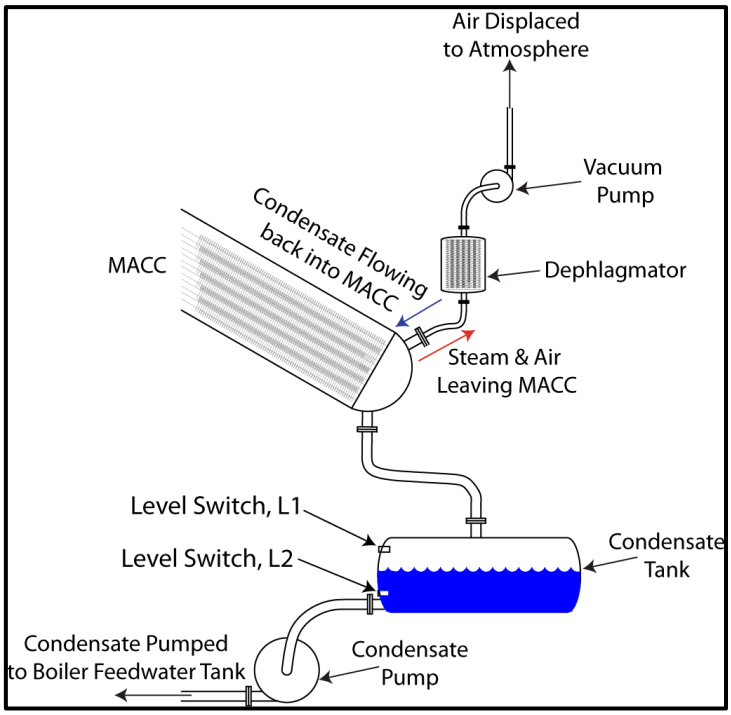


Figure 11: Dephlegmator & vacuum pump arrangement

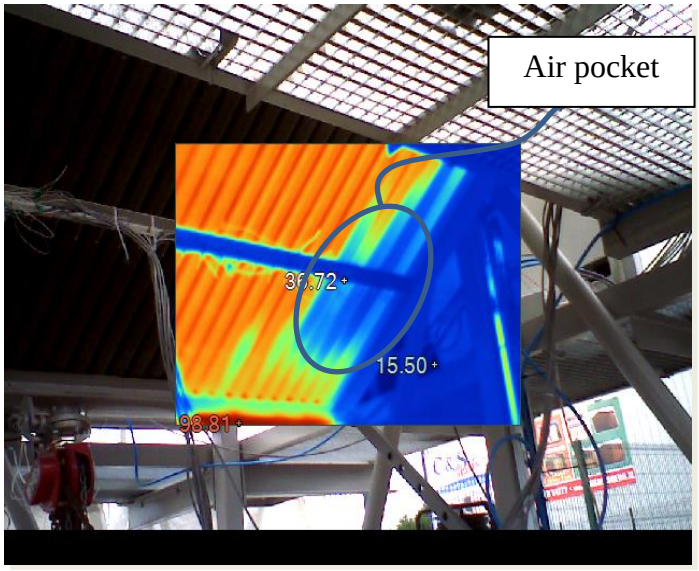


Figure 12: IR Image of MACC Tubes with Air Pocket Formed (In Blue)

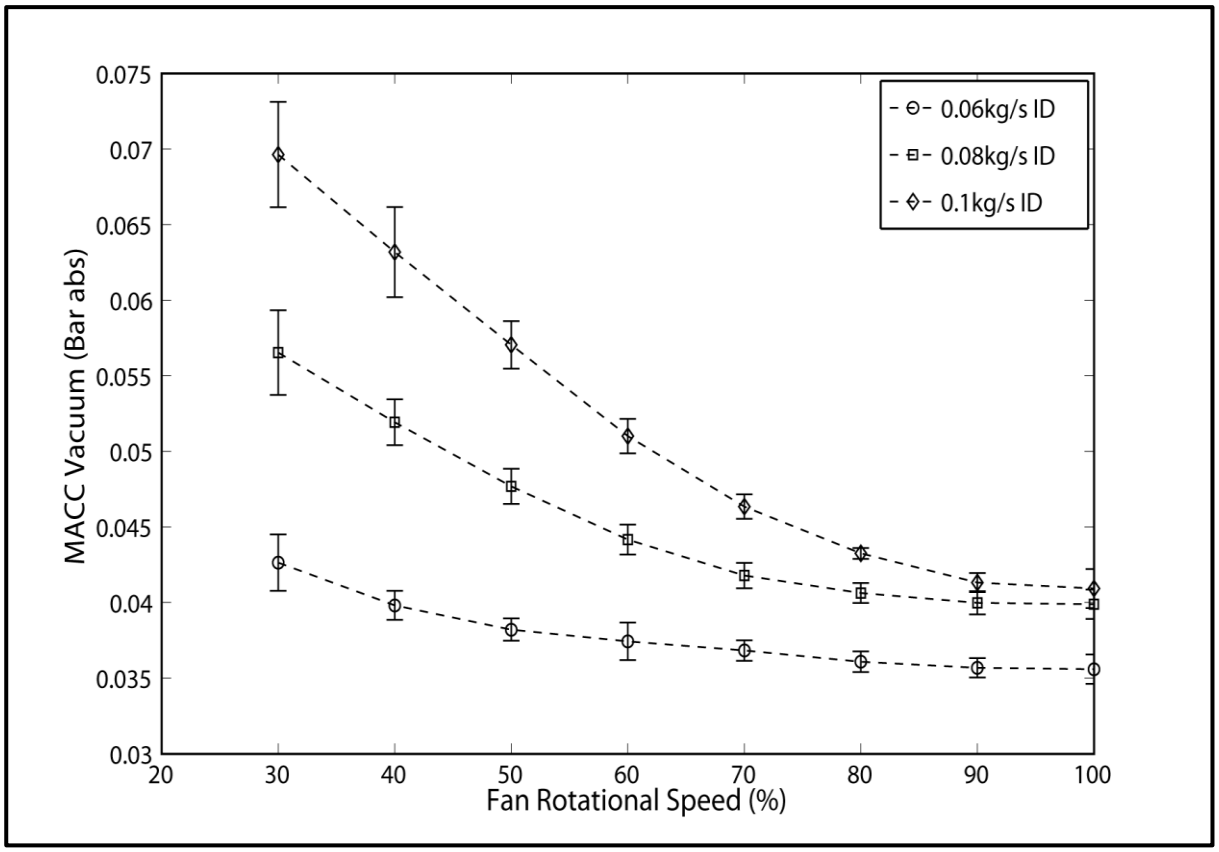


Figure 13 Variation of MACC pressure with fan rotational speed

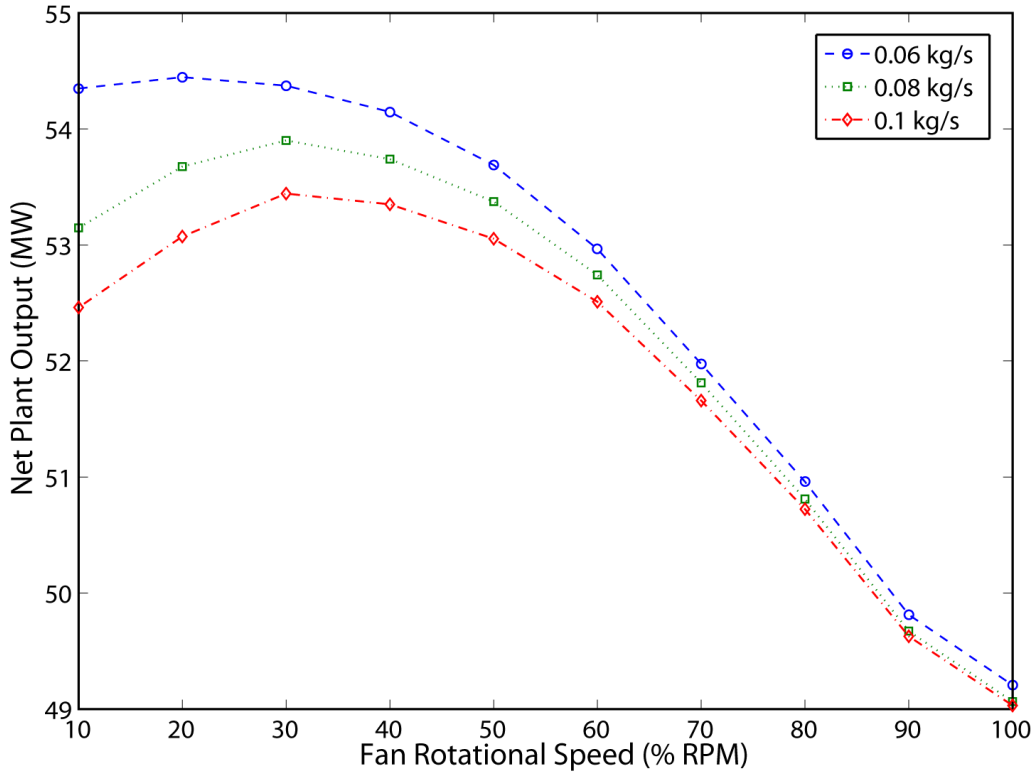


Figure 14. Variation of a 50MW plant net output with MACC fan rotational speed

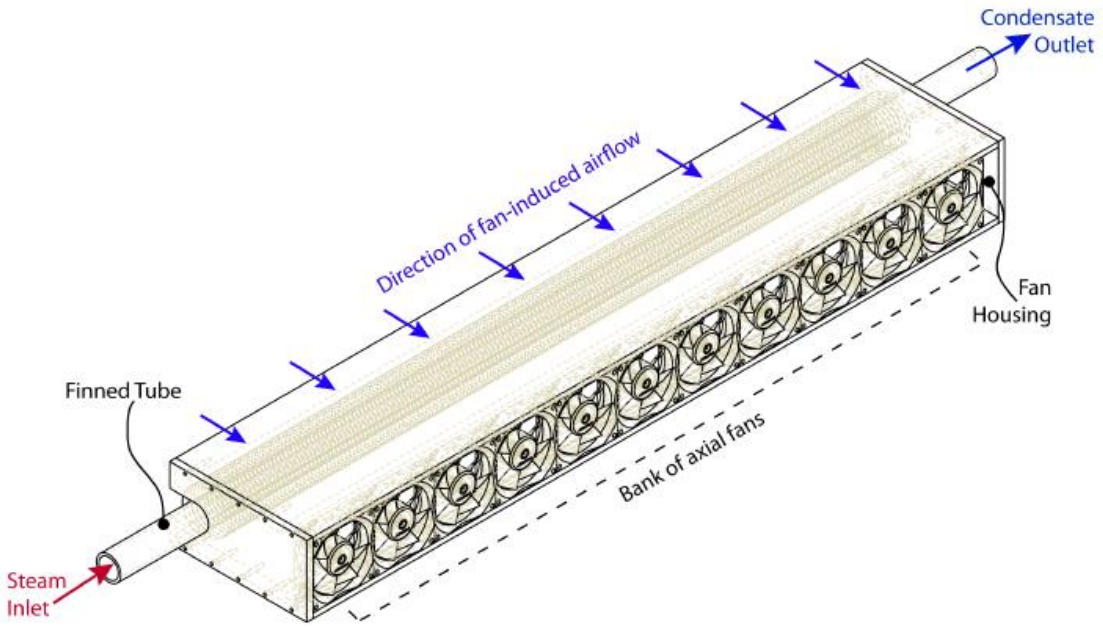


Figure 15. Schematic of lab-scale air-cooled condenser

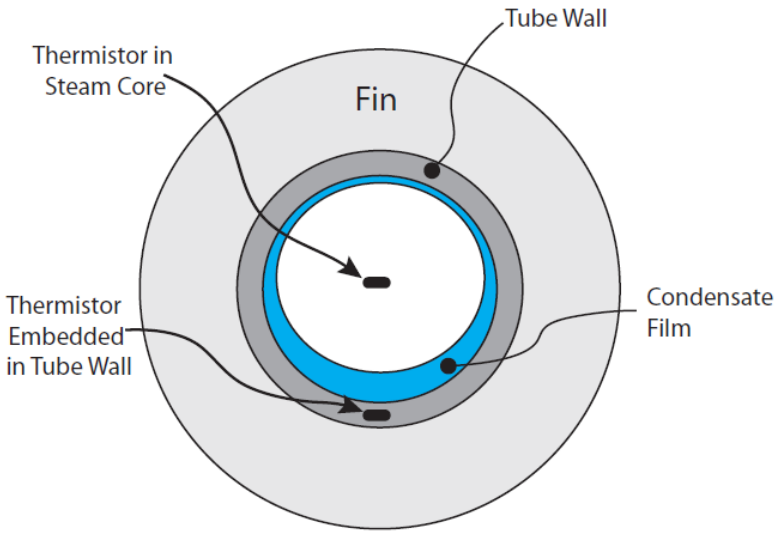


Figure 16. End-view of thermistor pair arrangement

$$R_{th,i}\frac{T_{s,i}-T_{w,i}}{d\dot{Q}_i}$$ Equation 1

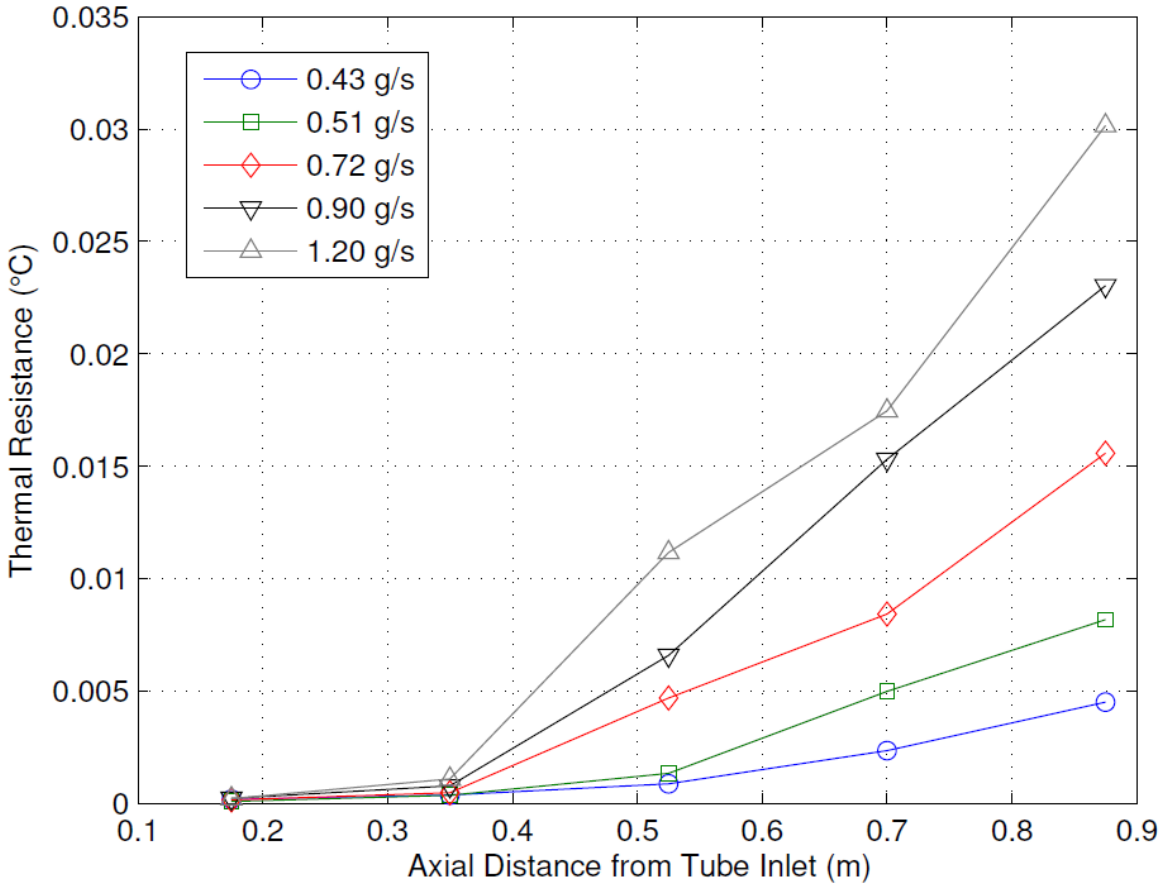


Figure 17. Local variation of thermal resistance along the length of condenser tube for a range of flow rates

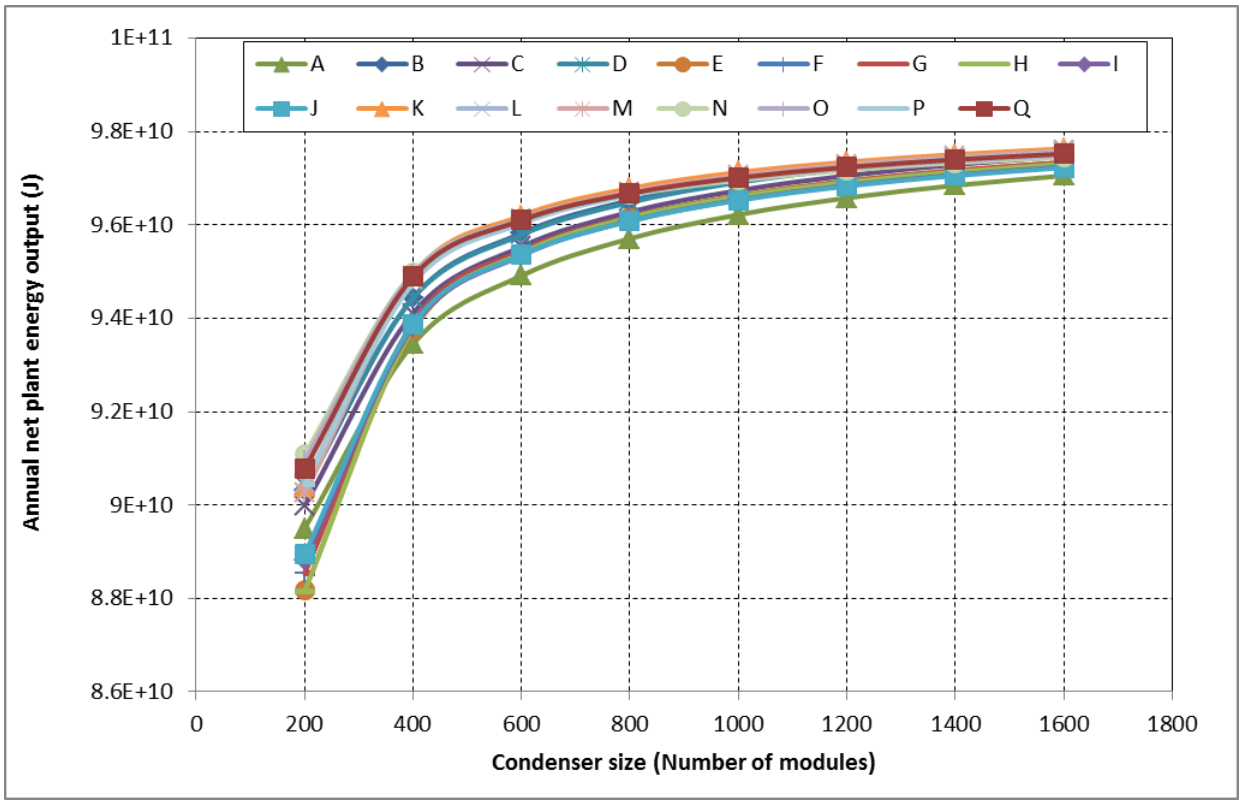


Figure 18. Annual power plant net energy output versus condenser size for geometries A to Q.

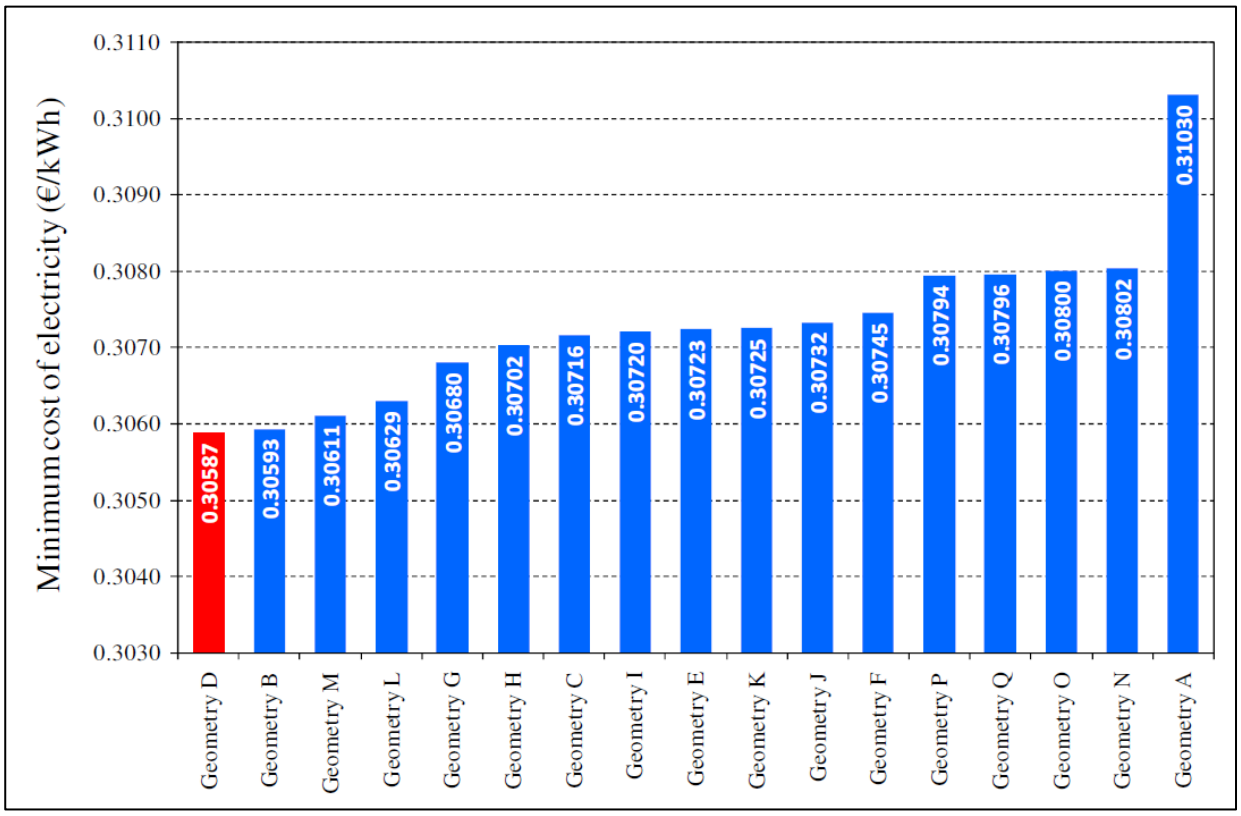


Figure 19. Minimum cost of electricity for MACC geometries A to Q.

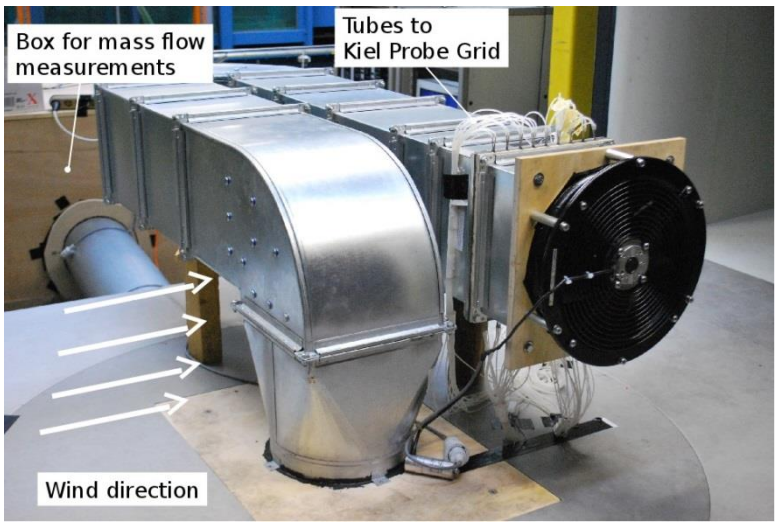


Figure 20. Fan test rig inside wind tunnel

$$\Psi = \frac{dp_{static}}{0.5\rho(nD_o/2)^2} \qquad \text{Equation 2}$$

$$\Phi = \frac{\dot{V}}{0.25\pi^2 n D_a ({D_o}^2 - {D_i}^2)} \qquad \text{Equation 3}$$

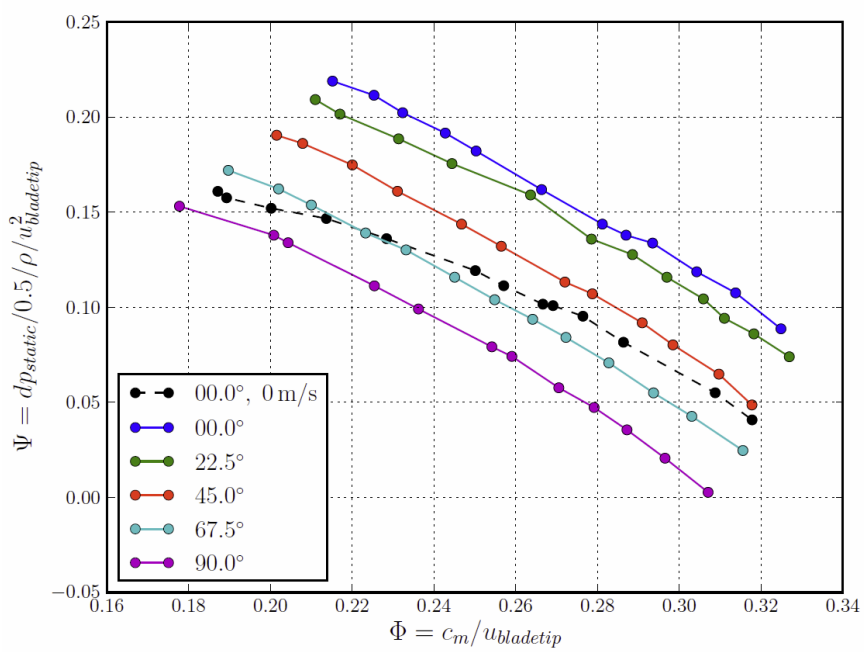


Figure 21. Characteristic fan curves with a 10m/s wind at the inlet to the fan for a range of wind angles.

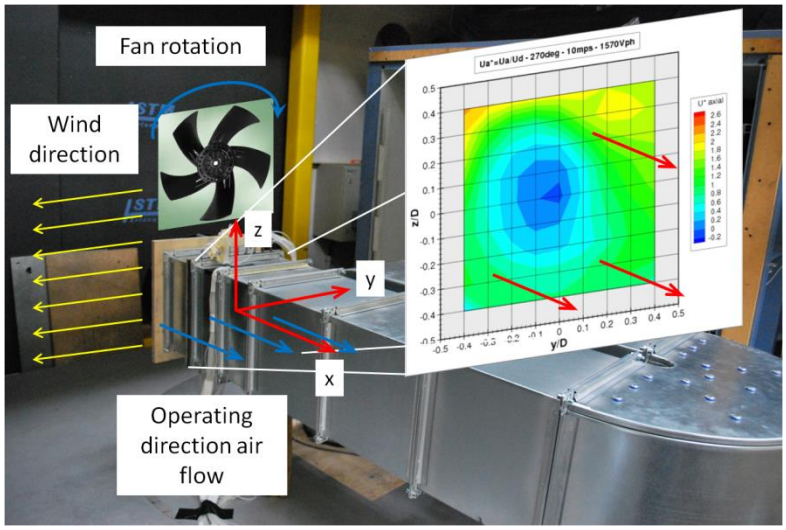


Figure 22. LDA measurements of flow field in duct behind fan, forced draft configuration

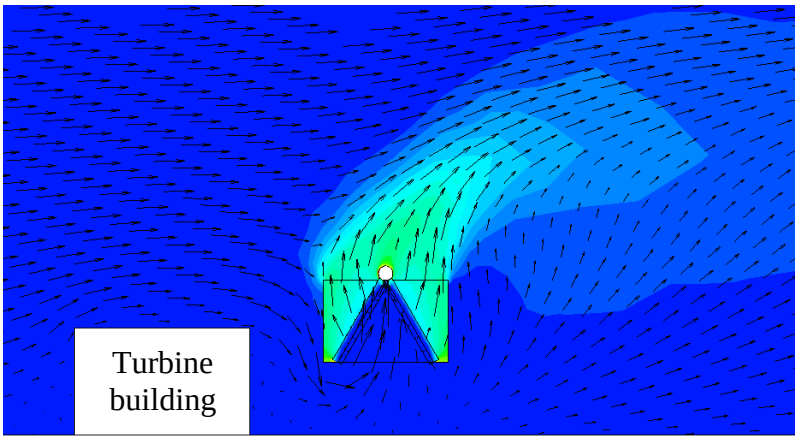


Figure 23 - Numerical contour plot of temperature and velocity vector field of a MACC in cross wind

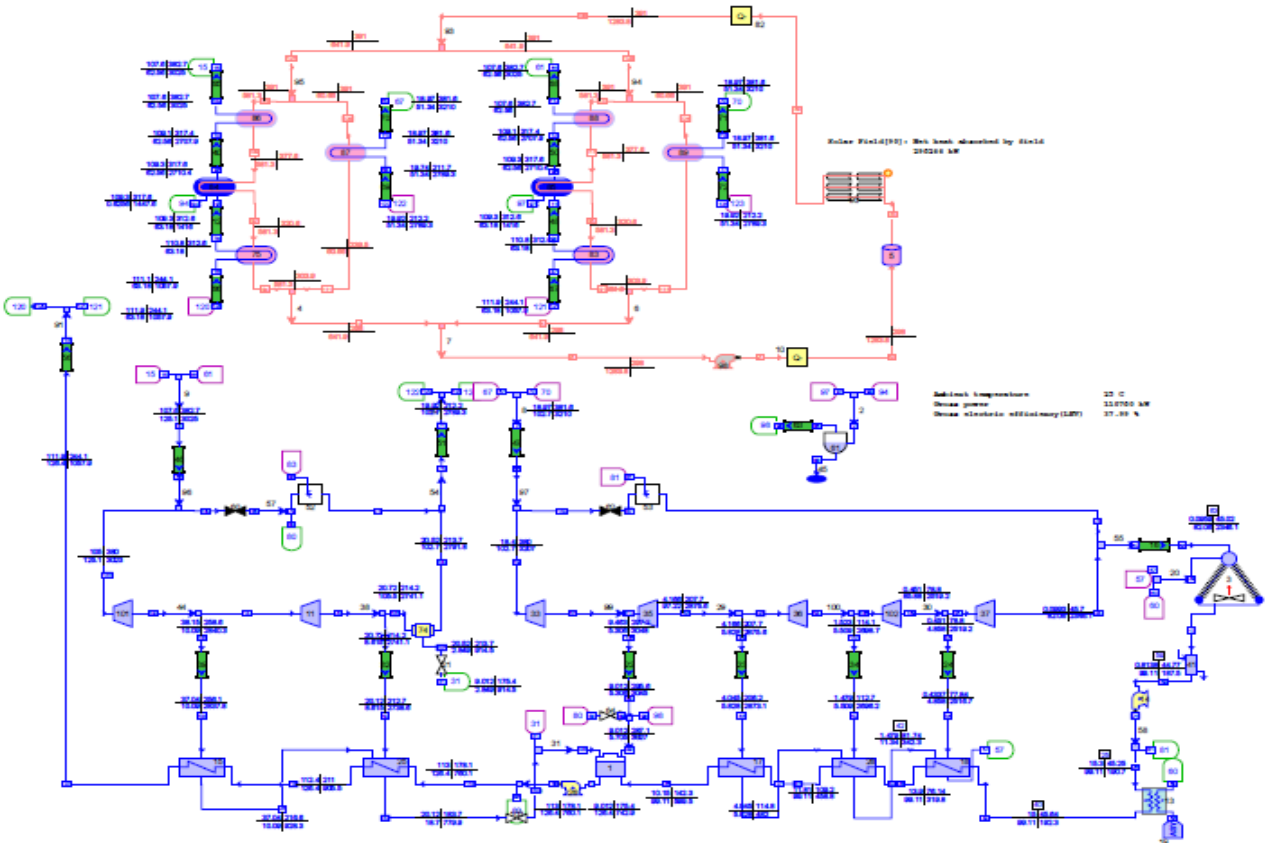


Figure 24. Thermodynamic model for a thermoelectric power plant

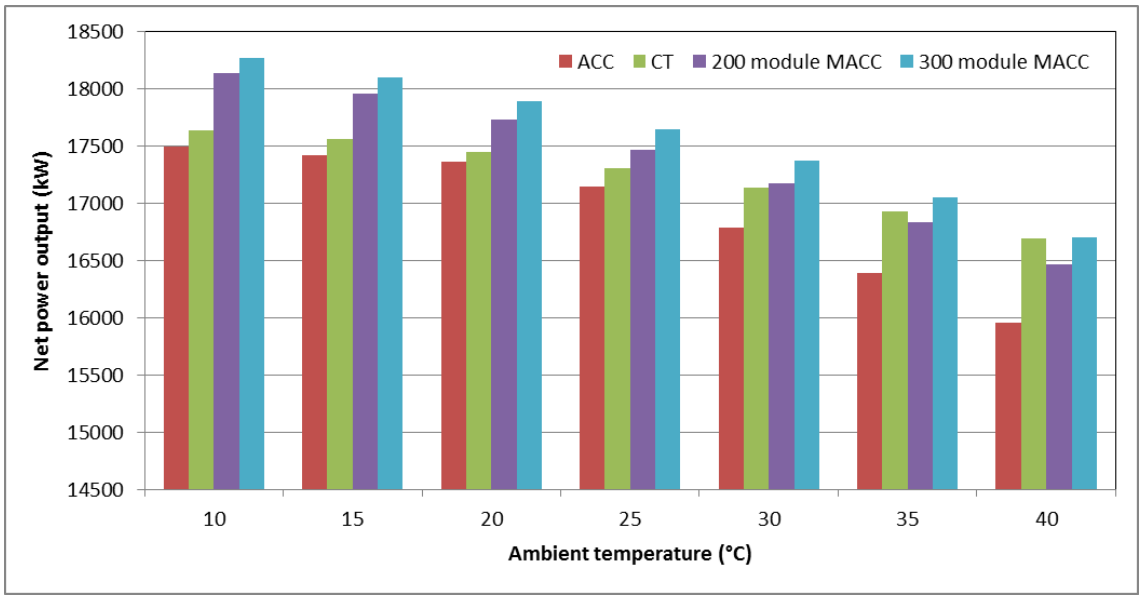


Figure 25. Comparison of power plant net power output with a conventional ACC, a water cooling tower and two different sized MACC condensers, at a range of ambient temperatures.

Table 1. Characteristics of the location considered

Data	France	Spain	Arizona
Latitude	43° N	37° N	32° N
Longitude	5° E	5° E	110° E
DNI (kWh/m²*year)	1.500	2.100	2.500
Eligibility for CSP plants	Moderate	High	Very high
Water stress conditions	Moderate	Medium	High

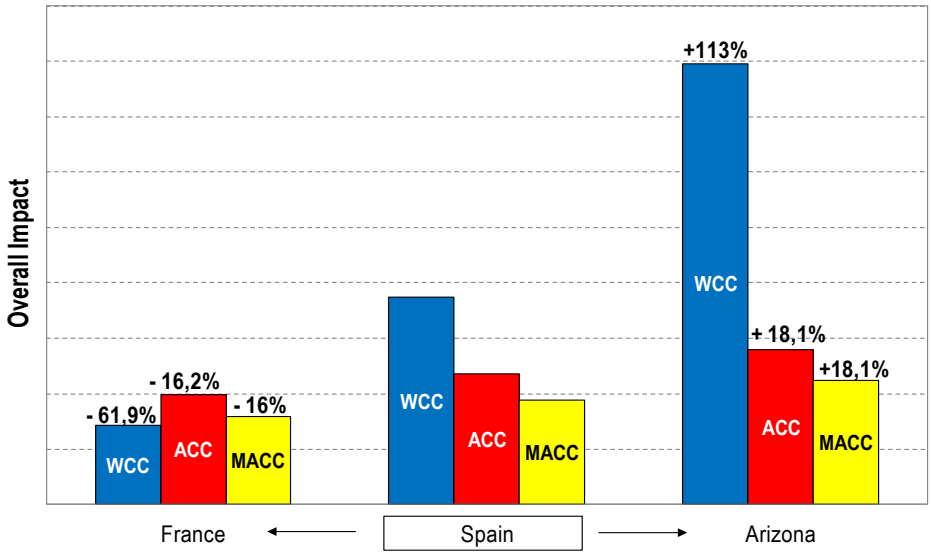


Figure 26. Condensers impact variation vs. water stress conditions variation

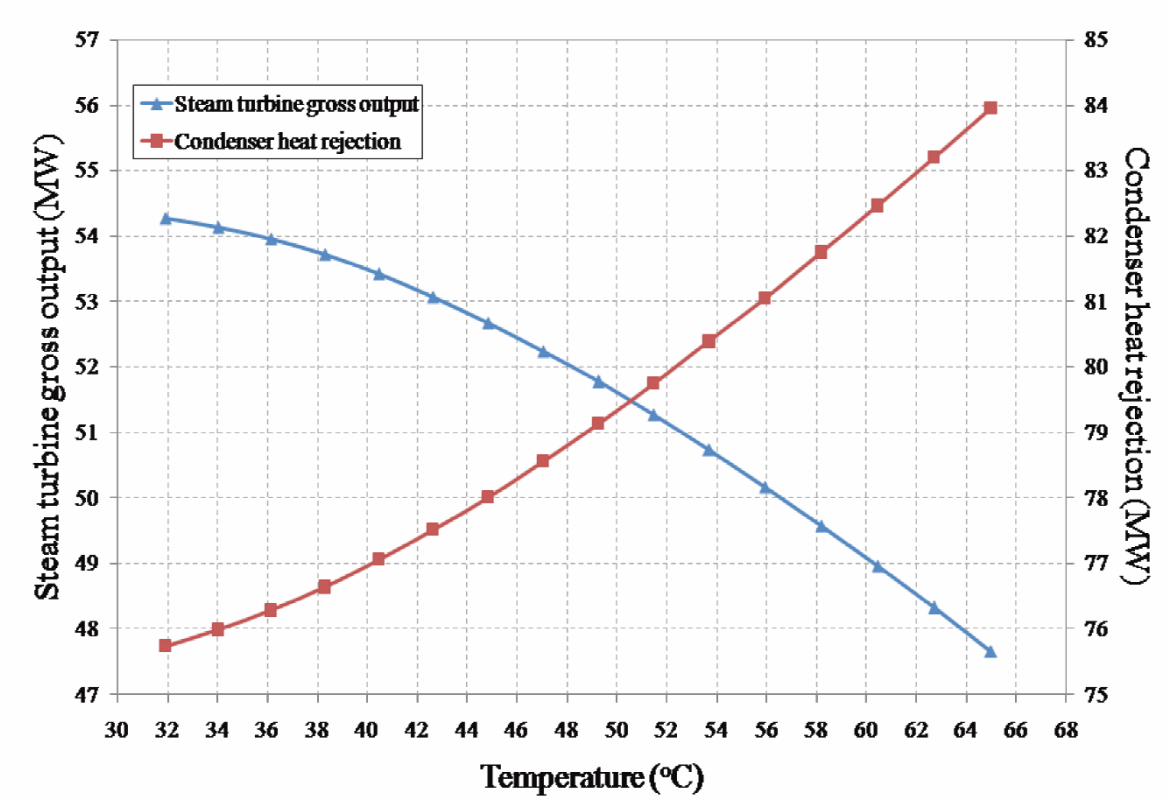


Figure 27. Steam turbine gross power and heat rejection versus condenser temperature

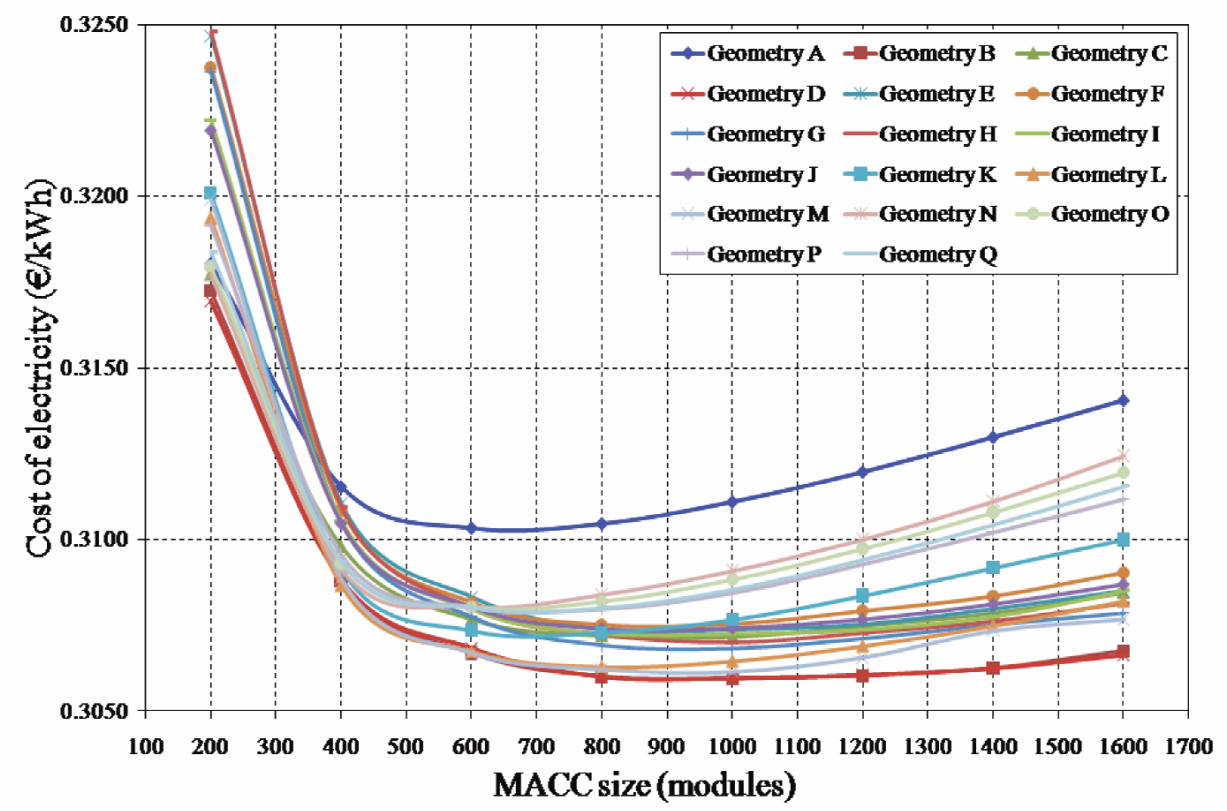


Figure 28. Cost of electricity versus condenser size for seventeen candidate MACC geometries

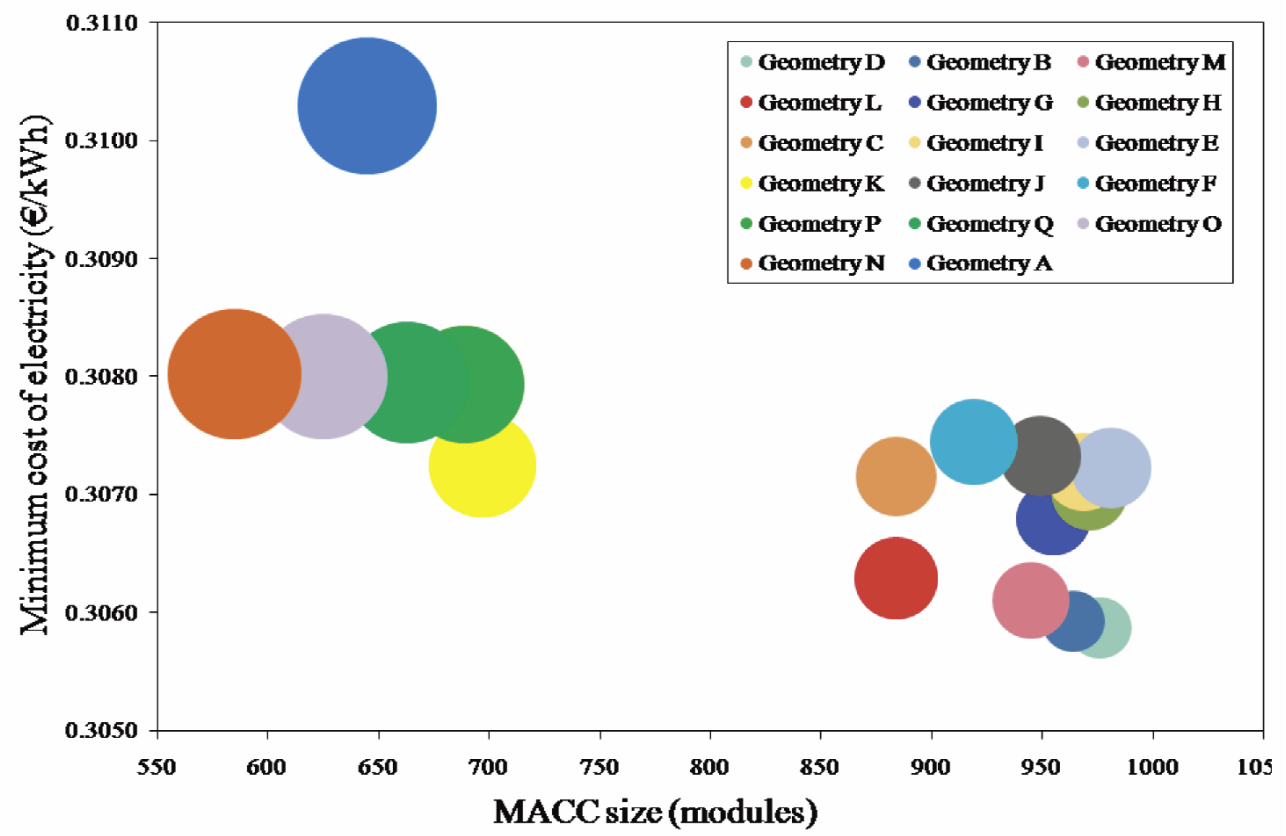


Figure 29. Bubble chart comparing each configuration in terms of minim CSP plant electricity unit cost, corresponding MACC size and capital cost per module (indicated by bubble size.

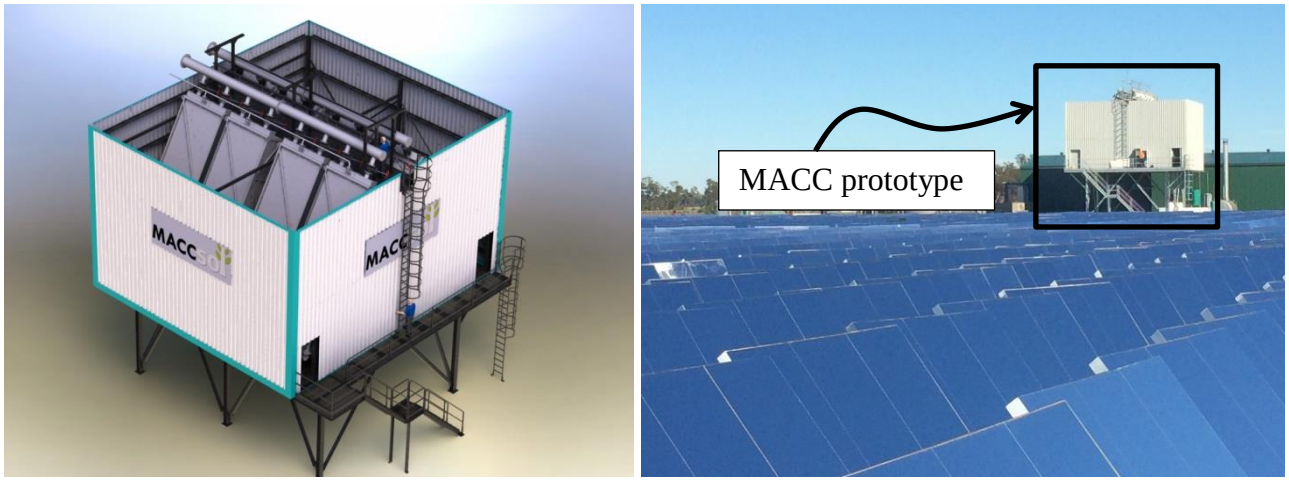


Figure 30. Left: CAD model of MACC; Right: phot of MACC instalation on Vast Solar CSP plant.

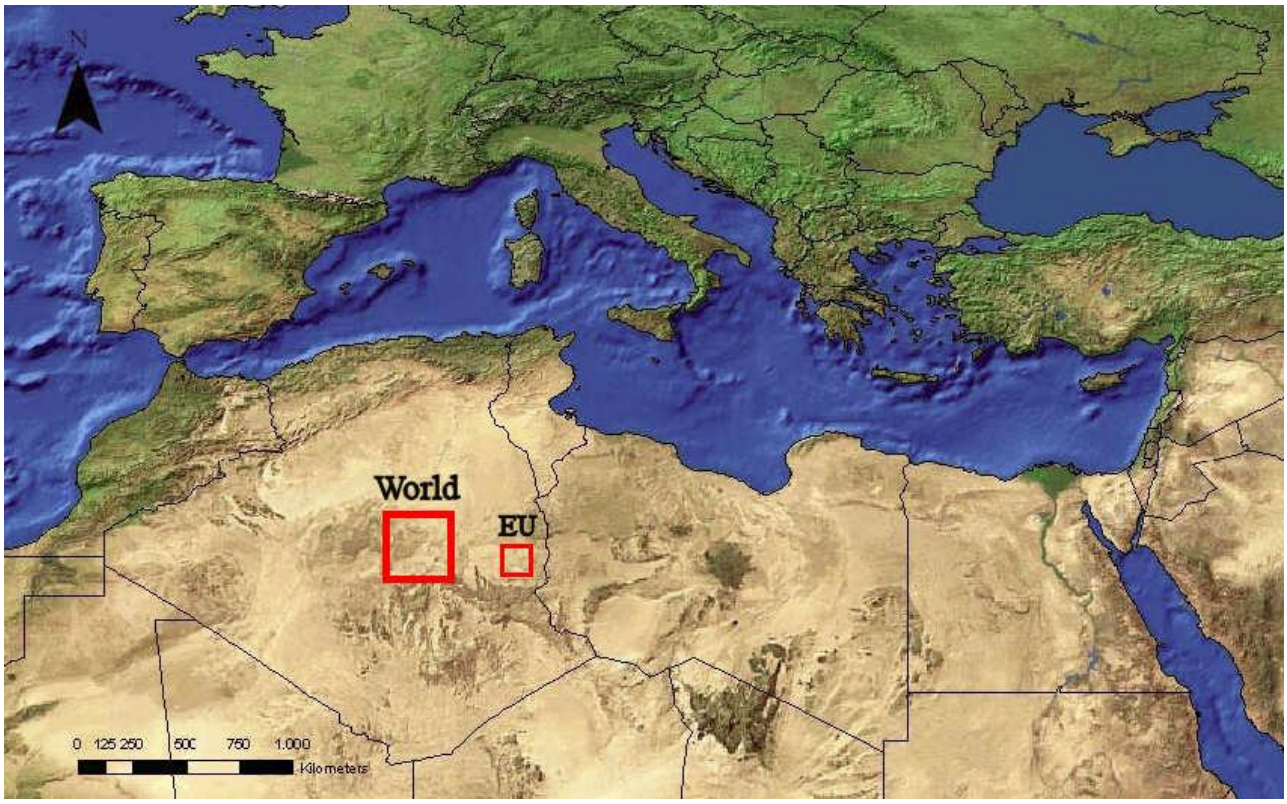


Figure 31. Map of the Mediterranean region. Left: the yearly sum of global irradiation on an optimally inclined surface[i]. Right: the area in this region onto which sufficient solar energy falls to provide electricity to the EU and the world.

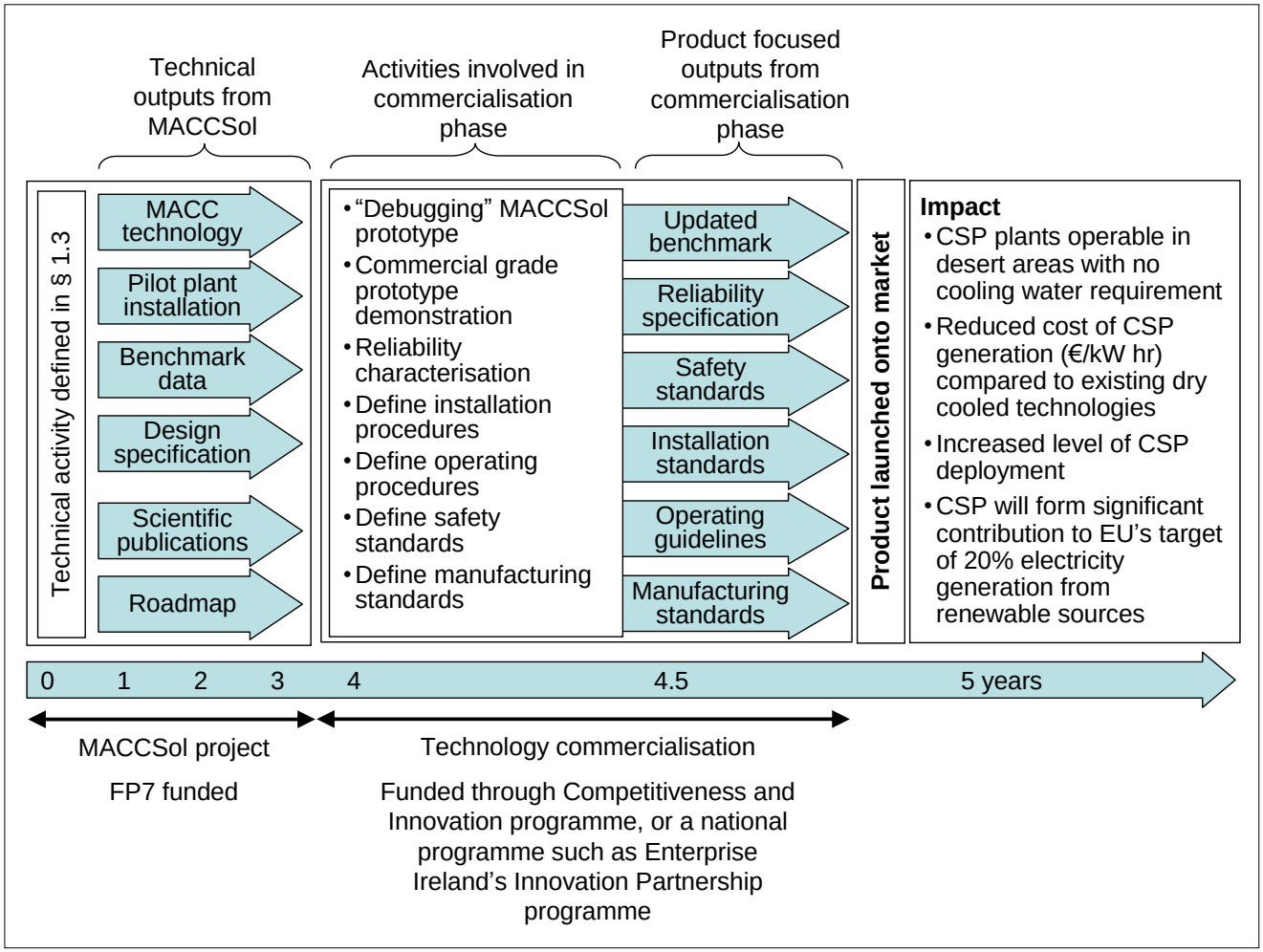


Figure 32. Schematic of expected technical outputs of MACCSol, commercialisation activities necessary to launch the MACCSol product and the impacts of this on CSP deployment and achieving renewable electricity targets.

[i] http://re.jrc.ec.europa.eu/pvgis/cmaps/eur.htm