



Thermal Response of OTEC Cold-Water Pipes: A COMSOL Multiphysics® Study

Heat gain along the cold-water pipe can substantially reduce the temperature difference available to the OTEC cycle, particularly in long onshore systems, causing system performance to be overestimated if it is neglected.

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Abstract

Ocean Thermal Energy Conversion (OTEC) systems rely on the relatively small temperature difference between warm surface water and cold deep seawater. Heat gain along the cold-water pipe (CWP) can therefore significantly reduce the thermal potential available to the cycle. A transient one-dimensional model was developed in COMSOL Multiphysics® 6.3 to investigate the effects of CWP length, diameter, mass flow rate, material, and onshore/offshore configuration.

The model accounts for internal convection, pipe-wall conduction, depth-dependent seawater temperature, and temperature- and pressure-dependent seawater properties. For a 10 km onshore pipe, with seawater intake at 4.5 °C reached the condenser at approximately 8.7 °C, reducing the available cycle temperature difference by 22.7%. The results demonstrate the importance of integrating thermal and hydraulic modelling when selecting CWP geometry, operating conditions, and OTEC system configuration.

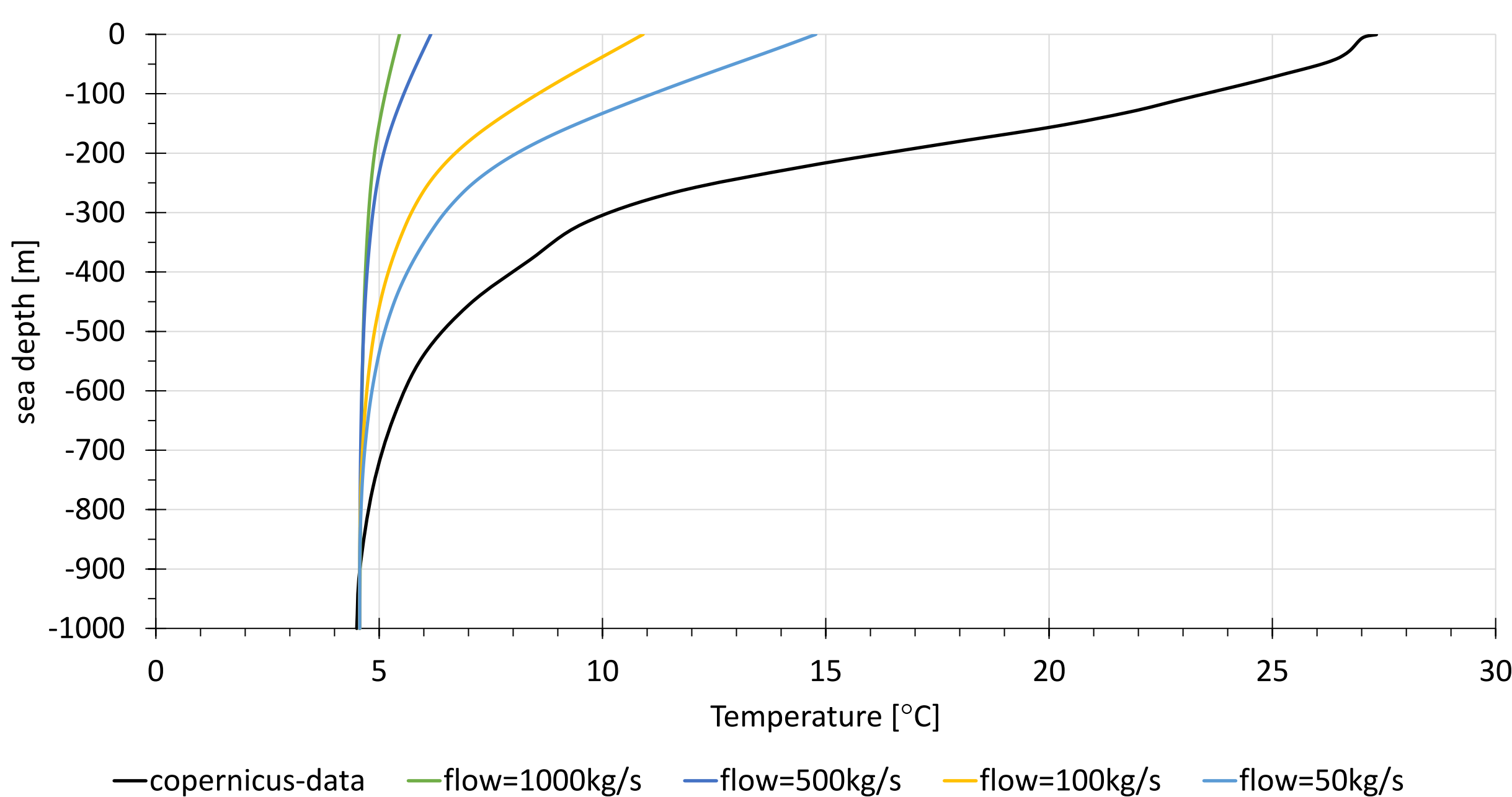


FIGURE 1. Sea depth effect on temperature for a 10 km-long CWP at various mass flow rates.

Methodology

A transient one-dimensional CWP model was developed using the Heat Transfer in Pipes interface. The model accounts for internal convection, conduction through the pipe wall, and heat transfer from the surrounding seawater, whose temperature varies with depth. Temperature- and pressure-dependent seawater properties were included, with density calculated using the TEOS-10 formulation.

A parametric analysis examined pipe lengths of 1–10 km, internal diameters of 0.7608–4.0 m, HDPE and FRP materials, and different seawater mass flow rates. Hydraulic losses were calculated using the Darcy–Weisbach and Colebrook formulations, assuming a pump efficiency of 85%. The coupled thermal and hydraulic results were used to evaluate the condenser inlet temperature, CWP temperature gain, and pumping-power requirement for onshore and offshore configurations.

Results & Design Implication

Heat gain along the CWP can substantially reduce the temperature difference available to the OTEC cycle. For a 10 km onshore pipe, seawater entering at 4.5 °C reached the condenser at approximately 8.7 °C, reducing the available cycle temperature difference by 22.7%.

Shortening the CWP produced clear thermal benefits: compared with the 10 km case, temperature losses were reduced by 22%, 39%, and 59% for pipe lengths of 7, 5, and 3 km, respectively, and by up to 86% for a 1 km offshore configuration.

Increasing the mass flow rate reduced thermal losses but increased pumping power almost sevenfold, while increasing pipe length raised pumping power by up to 88%. Pipe diameter on the other hand changed the outlet temperature by only 3–4%.

Overall, CWP design requires a balance between maintaining a low condenser inlet temperature and limiting the parasitic energy required for seawater pumping.

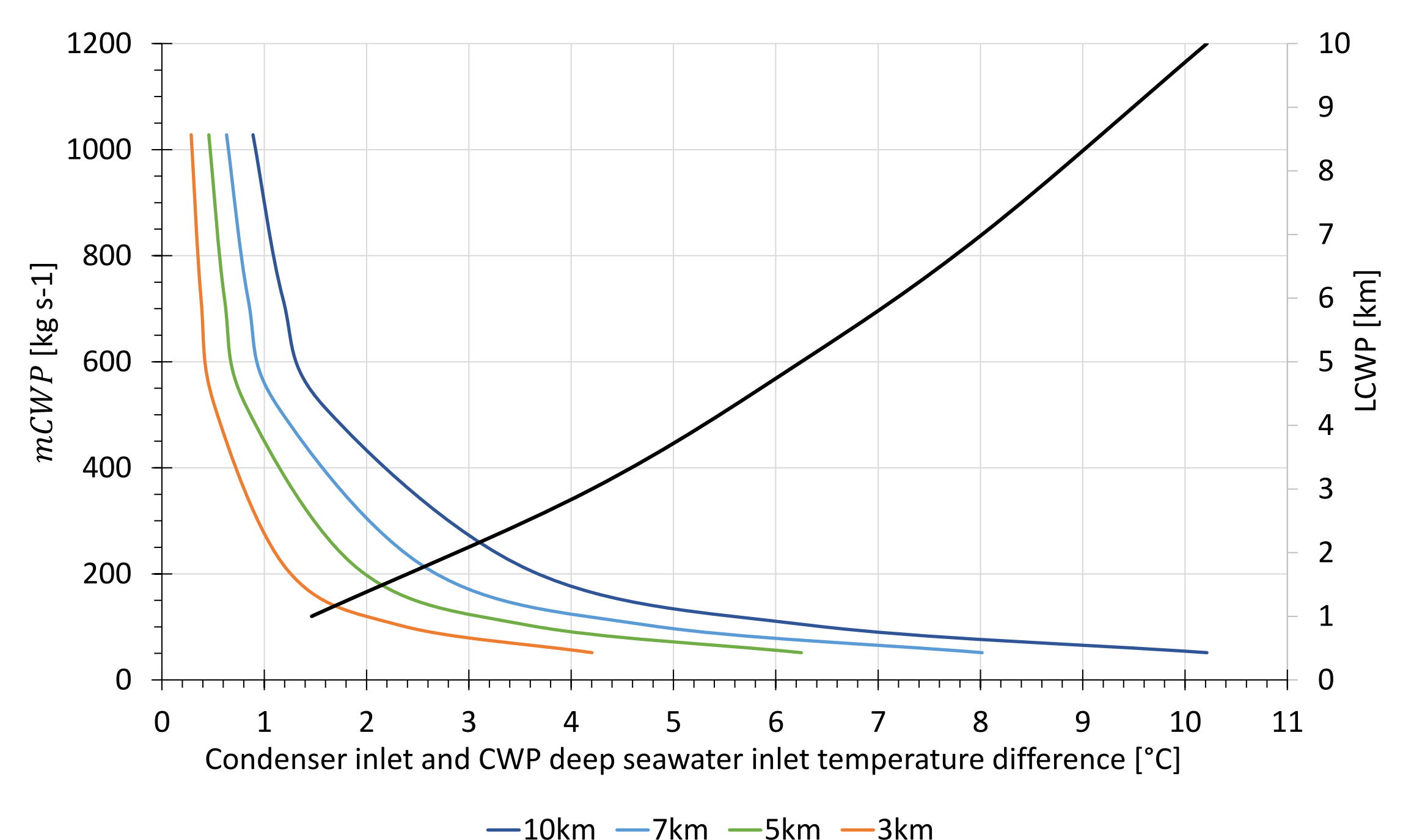


FIGURE 2. Coupled thermal trade-off: reducing allowable CWP warming requires higher flow, while longer pipes shift the design toward larger temperature losses.

REFERENCES

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