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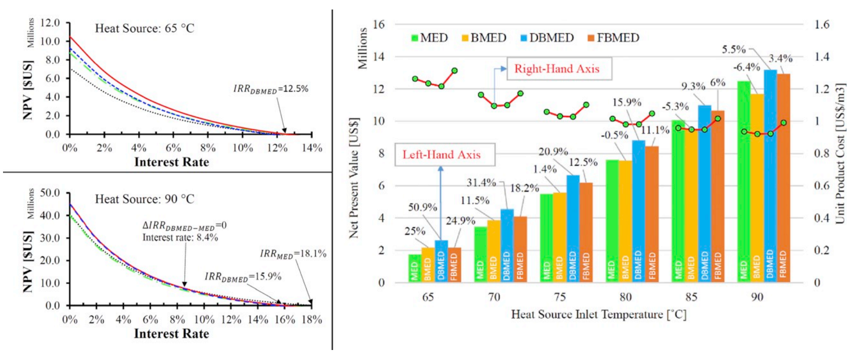
Thermo-economic analysis of low-grade heat driven multi-effect distillation based desalination processes

Hamid Rezvani Datsgerdi, Hui Tong Chua*

Department of Chemical Engineering, The University of Western Australia, 35 Stirling Hwy, Perth, WA 6009, Australia

GRAPHICAL ABSTRACT

The distributed boosted multi-effect distillation (DBMED) powered with low grade heat resources has been compared against MED, Boosted MED (BMED) and Flash Boosted MED (FBMED) in both technical and economic aspects.



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ABSTRACT

We examine the economic viability of three multi-effect distillation (MED) based processes against the MED as a benchmark, when they are driven by low grade heat. We model and compare the Boosted MED (BMED), Flash Boosted MED (FBMED) and Distributed Boosted MED (DBMED) processes with the MED in terms of waste heat performance ratio, specific capex and opex. All three new configurations generate significantly higher productions than MED with higher capex and opex investment. We provide the corresponding cash-flow analyses using such financial metrics as the Net Present Value (*NPV*) and Internal Rate of Return (*IRR*). This study leads to the conclusion that the DBMED process is the superior scenario up to an interest rate of 12.5% at 65 °C heat source supply temperature which then drops to 8.4% at 90 °C heat source supply temperature. Also, the analysis shows for the high interest rates (above 8.4% at 90 °C), MED has higher *NPV* compared to other MED based processes.

1. Introduction

A reliable supply of freshwater is undoubtedly a necessity of the modern world. The worldwide water consumption rate had surged from 340 million litter per second in Jan 2016 to 351 million litter per second in March 2018 (an annual increase rate of 1.6%) [1–3]. On the contrary, water resources have been depleting throughout the world due to various reasons such as anomalous irrigation or climate change. For instance, Iran in its pursuit for self-sufficiency in food supply, encourages the farmers to grow thirsty crops such as wheat all over the country thereby resulting in the depletion of water resources [4]. Climate change is another key factor in exacerbating the scarcity of water resources. Several lakes such as the Urmia Lake in Iran (Fig. 1) or Lake Chad (Fig. 2) in South Africa have since been dried out due to climate change or diverting inflow for urban use [5,6].

* Corresponding author.
E-mail address: huitong.chua@uwa.edu.au (H.T. Chua).

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Fig. 1. Lake Urmia, diminished by 90% since 1970s [4].

Desalination and water recycling are the only available commercialised solutions to overcome the water scarcity problem. In the desalination market, the global contracted capacity has augmented from 95.6 million m^3/day in 2016 to 99.8 million m^3/day in 2017 – this is the fourth year of continued growth [8].

Reverse osmosis (RO) desalination and thermal desalination generate > 90% of the desalinated waters globally [9]. RO removes the solid particles from the feedwater using pressure with the help of membrane at the expense of high operating cost, while thermal desalination relies on the available heat source to produce freshwater via evaporation [10].

Electricity and heat source, whether steam or hot liquid, are the main sources of energy for desalination projects. Therefore, any attempt to decrease the operating cost or increase the efficiency of desalination process is important. Among the commercialised steam driven thermal desalination processes, the multi-effect distillation with Thermal Vapour Compression (MED-TVC) process consumes the least electrical energy [11–14].

Based on a case study for an alumina refinery in Western Australia [15,16], the available low grade waste with supply temperature from 65 to 90 °C can be used for water management purposes in the mineral processing industry. So, with respect to the typical 20 to 50% heat lost for industrial processes in general, producing water by utilising industrial waste heat is an attractive opportunity [17]. The key advantage of thermal desalination processes is their capability to use waste heat thereby making their applications very compelling. While the MED-TVC process enjoys the highest performance among all thermal desalination processes [11–14], it is limited to being steam driven. So when only low temperature waste heat is available, the conventional genre of MED technologies is the superior design. The Flash Boosted MED (FBMED), Boosted MED (BMED), and Distributed Boosted MED (DBMED) are the recently developed MED based processes tailored for low grade sensible heat source [3,18,19].

In this paper, we present the thermoeconomic study of the new MED based processes (namely BMED, FBMED and DBMED) benchmarked against an MED process. Low temperature waste heat from 65 to 90 °C, which is generally available in many industrial sites and geothermal fields, is used as the heat source. In those industrial sites, for example in thermally intensive mineral refineries [15,16], the waste sensible heat streams are literally purged into confined recovery lakes, which therefore attract

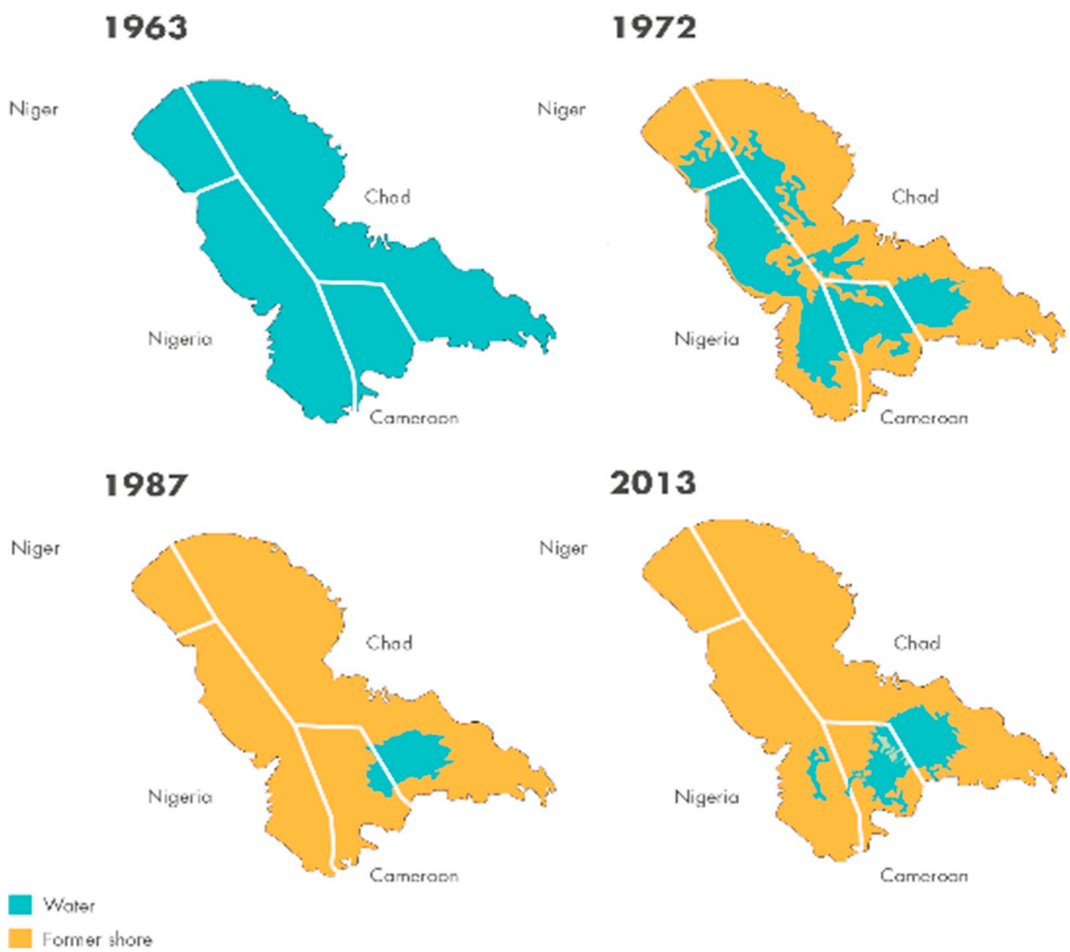

Fig. 2. Lake Chad, ecological catastrophe [7].