

SOCIO-TECHNICAL AND ECONOMIC ANALYSIS OF NON-CONVENTIONAL DESALINATION SYSTEMS IN COASTAL THAILAND: A STRATEGIC RESPONSE TO WATER SCARCITY CHALLENGES

ANALYSE SOCIO-TECHNIQUE ET ECONOMIQUE DES SYSTEMES DE DESSALEMENT NON CONVENTIONNELS DANS LES ZONES COTIERES DE THAÏLANDE: UNE REPOSE STRATEGIQUE AUX DEFIS LIES A LA PENURIE D'EAU

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ABSTRACT

Thailand's dominant agricultural water consumption, rapid urbanization, industrial growth, and tourism-driven development are placing pressure on its blue- and green-freshwater resources. At the same time, climate variability and seasonal droughts are making traditional water sources less reliable. In this changing climate, increasing water use efficiency and desalination are no longer optional – these technologies are reshaping how the country secures water for the future and becoming central to sustainable water management. Current trend in shifting from linear water use to circular systems marks a significant water evolution for longer-term sustainability in Thailand's water management, starting with modern industrial water sector. Seawater desalination employing various salt removal technologies (thermal, membrane, etc.) is gaining interests in Thailand as a strategic response to water stress in tourism hubs, industrial corridors, and urban developments. While re-using/up-cycling addresses internal water efficiency, desalination provides an external source of supply—particularly for coastal regions and island communities. Thus, the socio-technical and economic analysis of seawater desalination project is conducted to address water scarcity challenges. Various desalination technological performance is investigated and compared using multi criteria decision analysis based on preliminary feed (sea) water characteristics. Since, the financial and operational sustainability of desalination systems in coastal Thailand is shaped by a complex interplay of socio-economic, technical, and environmental factors, findings from this study suggest that integration of desalination to support regional productivity and economic development requires balancing technological, economic, and environmental trade-offs. Modern practical desalination systems for Thailand should be readily designed for (i) high energy efficiency through optimized performance of reverse osmosis (RO) systems; (ii) integration with renewable energy sources; (iii) blending with reclaimed water to reduce overall treatment costs; (iv) water trading mechanisms among water sectors (e.g., trading water between agricultural sector and industrial sector) for economic viability; and (v) government subsidies, shared water infrastructure (e.g., direct pipelines from desalination plants to users), public-private partnerships investment can lead to cost effectiveness for desalination systems. Further analysis provides macro- and micro-level insights to inform policy and strengthen the sustainability of desalination systems in climate-vulnerable coastal regions of Thailand. By combining desalination with reclaimed water, Thailand can build a diversified and resilient water portfolio along the EEC coastline. Future research should examine the environmental impacts of brine disposal and the feasibility of zero-waste desalination systems and integrating remineralization technologies to address health risks from demineralized water. This study offers actionable insights for policymakers and practitioners to strengthen resilient, equitable, and sustainable water supply systems in climate-vulnerable coastal regions, contributing to Sustainable Development Goal 6 (target 6.1). By leveraging innovation, policy support, and international cooperation, desalination can become a sustainable and transformative solution for water security.

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Keywords: Socio-Technical and Economic Analysis; desalination technological performance; Seawater desalination; sustainable water management; economic development.

RESUME

La prédominance de la consommation d'eau agricole en Thaïlande, conjuguée à l'urbanisation rapide, à la croissance industrielle et au développement dominé par le tourisme exerce une pression sur ses ressources en eau douce bleue et verte. Parallèlement, la variabilité du climat et les sécheresses saisonnières rendent les sources d'eau traditionnelles moins fiables. Dans ce contexte de changement climatique, l'amélioration de l'efficacité de l'utilisation de l'eau et le recours au dessalement ne sont plus facultatifs – ces technologies transforment la façon dont le pays assure l'approvisionnement en eau pour l'avenir et deviennent essentielles à une gestion durable de l'eau. La tendance actuelle de passage d'une utilisation linéaire de l'eau à des systèmes circulaires marque une évolution significative de l'eau pour la durabilité à long terme de la gestion de l'eau en Thaïlande, à commencer par le secteur industriel moderne de l'eau. Le dessalement de l'eau de mer utilisant diverses technologies d'élimination du sel (thermique, membrane, etc.) suscite un intérêt croissant en Thaïlande en tant que réponse stratégique au stress hydrique dans les centres touristiques, les couloirs industriels et les développements urbains. Bien que la réutilisation et le recyclage des eaux répondent à une question d'efficacité interne, le dessalement constitue une source externe d'approvisionnement — en particulier dans les régions côtières et les communautés insulaires. Ainsi, l'analyse socio-technique et économique du projet de dessalement d'eau de mer est menée pour relever les défis liés à la pénurie d'eau. Diverses performances technologiques de dessalement sont étudiées et comparées à l'aide d'une analyse décisionnelle multicritères basée sur les caractéristiques préliminaires de l'eau de mer. Puisque la durabilité financière et opérationnelle des systèmes de dessalement dans les zones côtières thaïlandaises est façonnée par une interaction complexe de facteurs socio-économiques, techniques et environnementaux, les résultats de cette étude suggèrent que l'intégration du dessalement pour soutenir la productivité régionale et le développement économique nécessite de rechercher un équilibre entre les compromis technologiques, économiques et environnementaux. Les systèmes de dessalement modernes et pratiques pour la Thaïlande devraient être facilement conçus pour garantir (i) une efficacité énergétique élevée grâce à des performances optimisées des systèmes d'osmose inverse (RO); (ii) une intégration avec des sources d'énergie renouvelables; (iii) un mélange avec l'eau mise en valeur afin de réduire les coûts globaux de traitement; (iv) des mécanismes d'échange d'eau entre les secteurs de l'eau (par exemple, l'échange d'eau entre le secteur agricole et le secteur industriel) pour assurer la viabilité économique; et (v) des subventions gouvernementales, une infrastructure d'eau partagée (par exemple, des pipelines directs reliant les usines de dessalement aux utilisateurs), des investissements dans des partenariats public-privé peuvent conduire à une rentabilité des systèmes de dessalement. Une analyse plus approfondie apporte des perspectives aux niveaux macro et micro pour éclairer les politiques et renforcer la durabilité des systèmes de dessalement dans les régions côtières vulnérables au climat de la Thaïlande. En combinant le dessalement avec l'eau mise en valeur, la Thaïlande peut créer un portefeuille d'eau diversifié et résistant le long du littoral de la zone économique orientale (EEC). Les recherches menées à l'avenir devraient examiner les impacts environnementaux de l'élimination des eaux salées et la faisabilité des systèmes de dessalement avec zéro déchet, ainsi que l'intégration des technologies de reminéralisation pour répondre aux risques sanitaires liés à l'eau déminéralisée. Cette étude offre des perspectives concrètes aux décideurs et aux praticiens afin de renforcer les systèmes d'approvisionnement en eau résistants, équitables et durables dans les régions côtières vulnérables au climat, contribuant ainsi à l'Objectif de développement durable 6 (cible 6.1). En optimisant l'innovation, le soutien politique et la coopération internationale, le dessalement peut devenir une solution durable et transformatrice pour assurer la sécurité de l'eau.

Mots-clés : Analyse socio-technique et économique; Performance technologique de dessalement; Dessalement d'eau de mer; Gestion durable de l'eau; Développement économique.

Introduction

Water resources are a basic human need and are of vital importance for economic security and the environment. At the same time. Water resources are scarce and must therefore be managed in an economically efficient way. Thailand has a long history of climate variability with major droughts punctuated by rapid flooding. The country is considered one of the most drought-affected countries in the Asia-Pacific region, with more than 40 million people have been impacted. Although it experiences the 2nd highest frequency of droughts after Indonesia however, it suffers the most extensive damage. In addition to climate variability and seasonal droughts, water scarcity is worsening due to population growth, climate change, water quality degradation, overexploitation, and growing water demand, significantly affecting people of Thailand across all sectors, i.e., agricultural water consumption, rapid urbanization, industrial growth, and tourism-driven development.

The Royal Thai Government has initiated the Eastern Economic Corridor (EEC) since 2017 to serve as an area-based development aiming to revitalize economic, physical, and social development as well as uplifting the country's competitiveness by transforming the region into high-tech industrial, logistics, and innovation hub. The EEC is locating along the coastline in the east of Thailand, is a major special economic zone spanning the Eastern provinces of Chonburi, Rayong, and Chachoengsao. The region has faced a long overdue water stress problem driven by rapid intensification of industrialization, high population growth, surging water demand from recent data center boom, hydrological and climatic stressors from erratic rainfall and recent increasing in both frequency and severity of droughts and El Niño consistently placing pressure on its traditional blue- and green-freshwater resources. Water demand frequently eclipses limited freshwater reservoir supplies, making water scarcity mitigation a major regional priority. To generate the new water source into the system to serve domestic consumption, high-value agriculture, tourism, and industrial outputs and buffer the EEC against long-term water bankruptcy in this changing climate, the government and major private operators have rolled out aggressive adaptations. They are no longer optional but rather are reshaping how the country secures water for the future and becoming central to sustainable water management, including (i) water grid optimization -- by managing hundreds of kilometers of water transmission pipelines and dynamically balancing water reserves between provinces.; (ii) increasing water use efficiency and wastewater reuse -- by mandating wastewater recycling, ensuring that treated water is circulated back for industrial cooling and agricultural use rather than relying solely on fresh supplies; and (iii) desalination projects -- by generating non-conventional freshwater from seawater and supplying to major coastal industrial hubs, insulating manufacturers from seasonal reservoir depletion.

Desalination is already considered a global momentum with consolidated technologies well implemented in many countries with vulnerable water scarcity problems worldwide, especially when advances in renewable energies nowadays produce potential synergies that have aroused more cost-effective freshwater prices. In the case of EEC Thailand, desalination is considered a potential necessity option as water demand already exceeds available traditional resources, while economic development is still highly expected. The financial and operational sustainability of desalination systems in Thailand is shaped by a complex interplay of technological advancement, socio-economic dynamics, and environmental balance and trade-offs. To our knowledge, no comprehensive studies currently exist on the feasibility of socio-technical and economic analysis of non-conventional desalination systems in Thailand as a strategic response to water Scarcity challenges. Critical research gaps persist concerning the evidence-based strategies for resilient operational and financial viability of large-scale seawater desalination systems, the roles of stakeholder perceptions and behavioral factors in adoption, implementation desalination as a sustainable and transformative solution for water security in Thailand. The socio-technical and economic analysis of seawater desalination project is thus conducted herein to address water scarcity challenges. Various desalination technological performance is investigated and compared using multi criteria decision analysis (MCDA) based on preliminary feed (sea)water characteristics. The study therefore aims to comprehensively explore social perception and barriers to further identify and understand social risks in sweater desalination development and investment as an alternative solution to combat water scarcity challenge in intensive water consumption EEC region Thailand. This study also employs semi-structured interviews and grounded theory to summarize the

qualitative factors and conceptual framework of stakeholders' perceptions on desalination system, especially concerning the desalinated water pricing which is generally substantially costly for more vulnerable water users (i.e., agricultural sectors) and is typically viable for high-value & high-profit industrial users, cash crops, and urban domestic consumption. Findings from this study provide macro- and micro-level insights to inform policy and strengthen the sustainability of desalination systems in climate-vulnerable coastal regions of Thailand. By combining desalination with reclaimed water, Thailand can build a diversified and resilient water portfolio.

Materials and Methods

Study Area

The EEC covers 13,285 km² spanning 3 provinces at the country's eastern seaboard: Rayong, Chonburi, and Chachoengsao, as illustrated in **Figure 1**. According to the National Statistical Office (as of December 31, 2019), Chonburi Province is the most populous province in the eastern region, with a population of 1,558,301, followed by Rayong Province with 734,753 people and Chachoengsao Province with 720,113 people. It is the special economic zone and regional development project designed to boost economic growth and investment and serve as a critical production base for advanced industries including petrochemicals, smart electronics, and electric vehicles, in the eastern part of Thailand and transform Thailand to high-income country. The program was announced by the Thai government in 2017 and was officially established in May 2019 which is considered as a cornerstone of the government's "Thailand 4.0" strategy. The ambitious goal of EEC is to transform the eastern seaboard region into a hub for industry and innovation. Additionally, the region is a source of high-value agricultural exports, and it is also emerging as a prominent destination for tourism, particularly in Chonburi. As part of Thailand 4.0 strategy, the EEC's goal is set to become a world-class smart city and an investment destination for a range of critical sectors, including digital technology, health, smart logistics, and decarbonization. The 4 pillars of this strategy are economic prosperity, social well-being, raising human values and environmental protection. The growth plan envisions the creation of over 200,000 jobs by 2032. To achieve these objectives, EEC needs stable and resilient infrastructure to underpin well-functioning city mechanisms such as sufficient and reliable energy, water, and other public goods supply networks. Above all, water security and disaster risk management are requisites for this ambition to materialize as several water challenges coexist.

Desalination Stage and Technologies Review

Desalination, as a complementary strategy within the multi-stage framework, stands out as one of the viable solutions to combat water scarcity challenges, with over 18,500 desalination plants worldwide producing over 90 Mm³/day (Dweiri et al. 2018). With rich technology history dating back to 18th and 19th centuries, with modern advancements leading to its widespread adoption globally, seawater desalination is known as the process of eliminating dissolved minerals and salts to produce drinkable water, producing high quality water in large quantities necessitates a significant energy input, reaching up to 70 kWh/m³ in some processes (Prado de Nicolas et al. 2023). The efficiency of desalination technologies has gradually improved in recent years. Nevertheless, several concerns have increasingly emerged in desalination systems, including waste (concentrated brine) discharging and environmental pollution from feed fossil fuels consumption (Marini et al. 2017). Two main technological approaches for seawater desalination, i.e., thermal and membrane groups are reviewed for the technology pros and cons based on the seawater quality characteristics collected from related governmental agencies and annual environmental monitoring report provided by private companies in the region.



Figure 1. Study Area: EEC Region.

Multi Criteria Decision Analysis (MCDA)

Given the diverse desalination technological advancement that can be powered by different RE sources, ranking, identifying, and selecting the most appropriate technologies for the desalination process among multiple alternatives become necessitate and challenging. Decision-makers and investors need to comprehensively evaluate alternatives integrating relevant aspects, including economic feasibility, environmental impacts, technological efficiency, and social responsibility before making an economically and financially viable investment decision. Therefore, selecting the proper desalination technique is better defined using multidimensional criteria integrative qualitative and quantitative Multi-Criterion Decision-Making (MCDM) methods to rank and prioritize the desalination technologies ensuring a comprehensive assessment of the available desalination system options in Thailand.

MCDM is one of the most used decision methods to perform mathematical optimization in different fields of application. In complex and challenging decision processes, MCDM is a tool that allows decision-makers to make fast, accurate, and efficient decisions by optimizing and sorting multiple criteria to select the best alternative, in this case the desalination technical option based on the evaluation structure shown in **Figure 2** and criteria. The weighted summation method of the MCDA (Ronald et al. 1997) is used, where the utility of each alternative U_j is determined by the summation of weighted numerical values (scores) of each criterion (**Eq. (1)**). The alternative which has the greatest utility is the best alternative, **Eq. (2)**.

$$U_j = \sum_{i=1}^m W_i \times S_{ij} \text{ for all } j \quad (1)$$

$$U_{optimal} = U_j \text{ for all } j \quad (2)$$

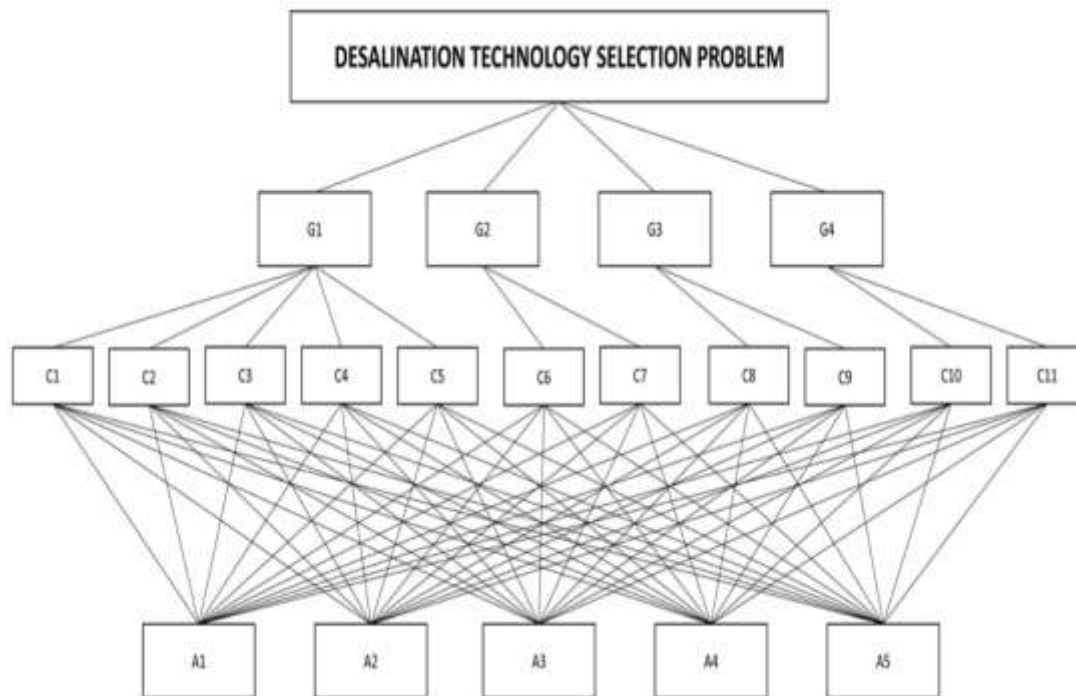


Figure 2 MCDA Evaluation Criteria for Desalination Selection

Qualitative Stakeholders Interview and Questionnaires Survey

In this study, stakeholders from government agencies, non-governmental organizations, water industries, water users, representative local people/residents, and desalination business developers were interviewed for their different prioritizing perspective to foster water security and achieve sustainable water resource management in the EEC. Data collection involved in-depth interviews and questionnaires to gather comprehensive information.

The quantitative questionnaire was designed to investigate the stakeholder's perception on the development of desalination plants. The closed-ended questions were divided into 4 parts. The first part was aimed at surveying the public's views on current and future water resources in the study. The second part examined the public's position on the development and their awareness of desalination systems and related technological advancement. The third part surveyed the public's opinions on the stakeholder perception of desalinated water and their willingness to pay at the local level for improved water security from the development of desalination systems. Lastly, the fourth part investigated the public's perceptions of the environmental impact and energy consumption caused by the desalination plant. The total quantitative questionnaire samples were approximately 400 sets. The questionnaire data are analyzed using the software Statistical Product and Service Solutions (SPSS) ver. 17.0 for Windows. The overall information on the public's perception and socio-demographic variables is analyzed through descriptive statistics.

Results and Discussion

Regional Hydro-Meteorological Conditions

Monthly average rainfall in the EEC region falls between 5.4-284.2 mm with minimum rainfall in December and maximum rainfall in September - October. Annual average rainfall is approximately 1,308.5 mm (lower than the nation-wide average) with distribution patterns shown in **Figure 3**.

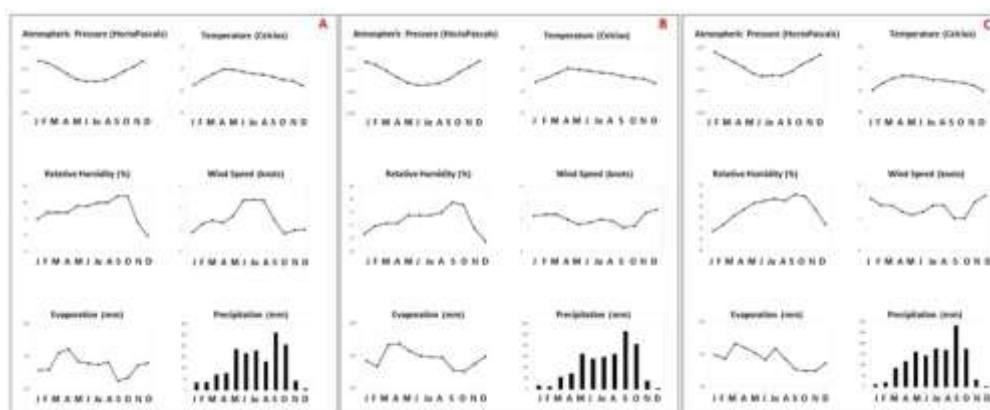


Figure 3. Observed daily climatic data for EEC region for the period from 1987-2017 for (A) Rayong province; (B) Chonburi province; and (C) Chachoengsao province.



Figure 4. Global Sea Level Rise Record from 1993-2026.

The Intergovernmental Panel on Climate Change reports that global sea level rise associated with climate change is expected to be between 8-16 mm/year in the 21st century with the latest observation of 10.5 mm/year in 2026 illustrated in **Figure 4**. Due to global climate change, sea level in the inner part of the Gulf of Thailand is expected to further increase with the increment in wind speed especially of the monsoons that blow into the Gulf (The World Bank Group 2021).

Water Resources and Management in EEC

Thailand is recognized as highly vulnerable to climate variability and change due to increasing natural hazards including heavy rainfall, floods, drought, and threatening sea level rise along the country's coasts, ranking Thailand the 31st position in National Water Security Index among 49 Asian and Pacific countries mainly due to its low water urban security and high climatological risks (Asian Development Bank 2020). Thailand is one of the 193 member countries that signed the pledge promising to achieve various sustainable development goals (SDGs) by 2030 (United Nations 2015). The Agenda serves as a roadmap for future environmental and development work in line with the United Nations' SDGs, which comprise a total of 17 goals and 169 objectives.

The Royal Thai Government has laid out a 20-Year Strategy for Thailand to achieve high-income status by 2036. The strategy includes a wide range of top-down initiatives, especially in infrastructure and human development, to transform Thailand into a nation that can compete against wealthier, more

knowledge-based economies. The EEC Development Plan is set to bring about substantial growth and transformation in Thailand's physical and social infrastructure within the region. Predictions by various agencies suggest that the EEC multi-dimension development projects and the economic growth of the eastern region will lead to urban expansion and an increase in the workforce by 100,000 people annually. This is due to the expansion of the industrial sector in provinces such as Chonburi, Rayong, Chachoengsao, and Chanthaburi, including existing industrial estates and new industrial estates. At this growth rate, it is already affecting on agriculture, services, and large-scale businesses, resulting in an increased demand for water. It is estimated that by the year 2027, the water demand in the entire EEC area will exceed 3,000 million cubic meters per year, and by 2037, this demand will rise more than 3,600 million cubic meters per year as tabulated in **Table 1**. Assuming average water supplies are similar to average actual hydrological conditions in the decade leading up to 2023, it is projected that in 2037 the EEC will face a supply shortfall of almost 40 percent. The situation in dry years will be even more precarious, with the shortfall increasing to 72 percent. The government is aware that, given the current water management situation, EEC's future development cannot be realized without addressing water scarcity challenges and securing additional water supply.

Table 1 Projected Annual Water Demand and Water Balance in the EEC Region (in Million Cubic Meters, MCM).

Area	2024		2027		2037	
	Demand	Deficit	Demand	Deficit	Demand	Deficit
Chachoengsao	1237	-897	1171	-811	1115	-379
Chonburi	794	-412	894	-464	1228	-729
Rayong	924	-170	1047	-139	1272	-292
EEC Total	2955	-1479	3112	-1414	3615	-1400

Source: Water Balance Report for the Eastern Economic Corridor, Office of the Eastern Economic Corridor, August 2024.

Note: Demand and deficit values are based on average water supply scenarios as opposed to dry or wet years, and the average scenario assumes water supplies similar to the average actual hydrological situation for the period 2013–2023.

Royal Thai government executed by National Office of Water Resources Thailand (ONWR) has tirelessly initiated the water master plan for the EEC composed of 38 comprehensive water projects to be developed during Year 2020 to 2037 shown in **Figure 5**, bringing additional 872 million m³ freshwater yearly to meet projected demand, ensure water security, and support growth in both the economic and social aspects to the region. While increased variability in precipitation may lead to an increase in the vulnerability of water supplies (Bates et al., 2008; Kundzewicz et al., 2008; Gleick et al., 2014; Jimenez Cisneros et al., 2014; Delpla et al., 2020), demand management can also play a significant role in managing water supply given that water productivity in Thailand remains low compared with global and regional benchmarks (World Bank Group 2025), in contrast to focusing solely on increasing freshwater supply. Measures to promote more efficiency and circularity in water use can also potentially complement supply augmentation by investment in water demand management of various sectors and circularity via treatments and reuse of wastewater. Currently, more than 60% of EEC wastewater goes untreated, and it is single largest untapped source of new water supplies for the region. Moreover, as the digital infrastructure expands, the influx of water-hungry facilities from recent anticipated massive boom in hyperscale data center investments in the EEC is heavily straining local existing water grids, with projections indicating that total regional water demand could surge up to 5 million m³ per day, and posing even major sustainability challenge.



Figure 5 Water Development Projects in EEC Year 2020-2037

Desalination Stage and Technology Review

The long-term forecast for the EEC indicates that the area is exposed and vulnerable to climate change. Rising sea levels can also introduce new, or exacerbate existing, saltwater intrusion into freshwater resources, both groundwater and surface water. The water resources supplying from reservoirs and water infrastructure in the area are limited due to the climatic-topographic conditions, making it almost impossible to develop any large scaled *in situ* water reservoirs. For EEC Thailand, there is a need to integrate desalination projects into the existing water management system by shifting from pure supply management towards integrated supply-demand management, allying investment in non-traditional desalination system, water conveyance grids, along with water reclamation. The necessity for desalination, where and when it is needed remains undeniable, mainly due to economic viability and environmental impacts rather than its operational and technological context. Desalination needs a high energy demand, which has significant costs.

Table 2 Required Energy Use of Distinct Water Sources for 1 m³ of Drinking Water.

Water Supply Alternative	Energy (kWh/m ³)
Conventional treatment of surface water	0.20–0.40
Groundwater	0.48
Wastewater treatment	0.62–0.87
Wastewater reuse	1.00–2.50
Brackish water desalination	1.00–1.50
Seawater desalination	2.58–8.50

Desalination, as a complementary strategy within the multi-stage framework, stands out as one of the viable solutions to combat water scarcity challenges, with over 18,500 desalination plants worldwide producing over 90 Mm³/day (Dweiri et al. 2018). With rich technology history dating back to 18th and 19th centuries, with modern advancements leading to its widespread adoption globally, seawater desalination is known as the process of eliminating dissolved minerals and salts to produce drinkable water, producing high quality water in large quantities necessitates a significant energy input. The extensive literature review demonstrated that desalination technology requires an 8–20 times greater energy intensity than conventional surface water treatment technology in **Table 2**.

The efficiency of desalination technologies has gradually improved in recent years to produce high quality water with total dissolved solids (TDS) of 5 to 50 ppm. However, they have the disadvantage of

requiring high energy, resulting in. Nevertheless, several concerns have increasingly emerged in desalination systems, including waste (concentrated brine) discharging and environmental pollution from feed fossil fuels consumption (Marini et al. 2017 and high operational costs (Ghaffour et al. 2013). There are two main technological approaches for seawater desalination summarized in **Figure 6**, i.e., thermal approaches: (i) thermal desalination (relatively traditional); and (ii) membrane approaches. The properties of thermal and membrane techniques are summarized in **Table 3** and **Figure 6**.

Table 3 Overview of Desalination Technologies.

Classification	Thermal	Membrane
Desalination technologies	MED, MSF, MVC, TVC	MF, UF, NF, MB, MD, ED, RO
Separation mechanism	Phase change	Diffusion
Main type of energy requirements	Thermal	Electricity
Driving force	Heat	Pressure/Electricity
Specific energy consumption	High	Low

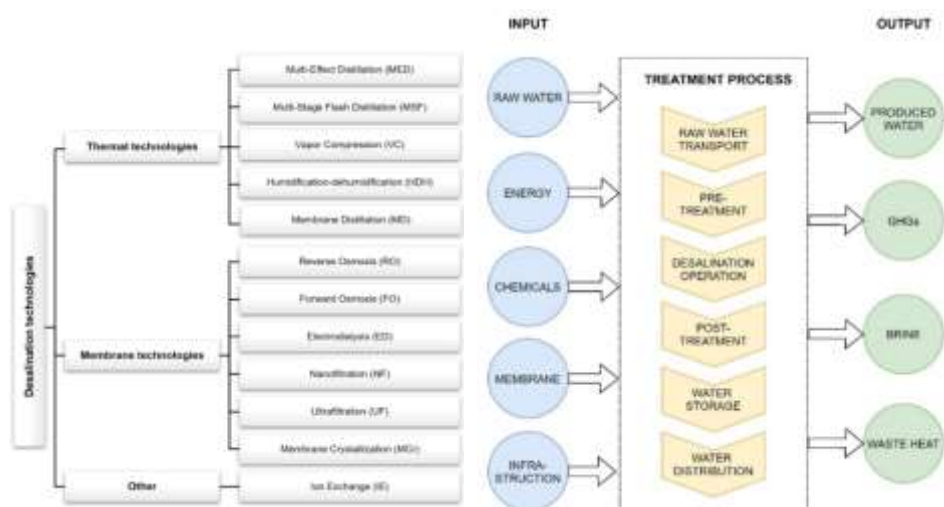


Figure 6 (A) Desalination Technology Classification (B) Desalination Process

The thermal process is a phase-changed method in which the feedwater is heated under an operating temperature and pressure. Water vapor condenses as pure water, leaving behind salts and other non-volatile substances. The thermal technologies include multi-effect distillation (MED, **Figure 7**), mechanical vapor compression (MVC), multi-stage flash distillation (MSF, **Figure 7**), and thermal vapor compression (TVC).

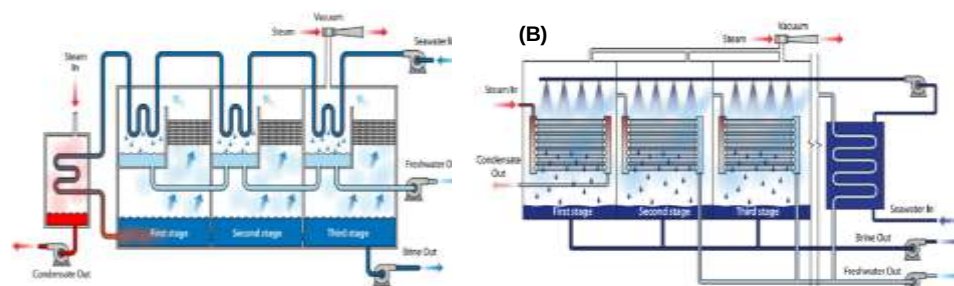


Figure 7 (A) Multi-Stage Flash (MSF) (B) MED Multi-Effect Distillation

Desalination System In contrast to the thermal processes, the membrane technology (e.g., reverse osmosis: RO in **Figure 8**) is not subject to any phase change and therefore requires less energy. The semi-permeable membranes selectively separate water or salt from the feedwater, allowing only pure water to remain in the liquid phase.

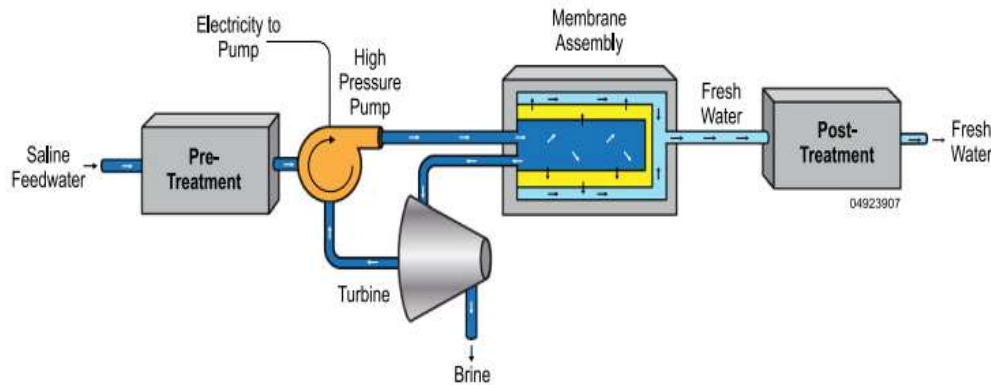


Figure 8 Reverse Osmosis (RO) Desalination System

Table 4 Comparison of Desalination Technologies.

Factors	Desalination Technology		
	Thermal		Membrane
	MSF	MED	RO
Water Type	Seawater or Brackish	Seawater or Brackish	Seawater or Brackish
Operation Temperature (°C)	90-110	70	Ambient
Electrical Energy Consumption (KJ/kg)	4-6	1.5-2.5	5-9
Thermal Energy Consumption (KJ/kg)	190-390	230-390	none
Electrical Equivalent for Thermal Energy (kWh/m ³)	9.5-19.5	5-8.5	none
Total Electric Equivalent (kWh/m ³)	13.5-25.5	6.5-11	5-9
Maximum Value of CO ₂ Emissions (kg CO ₂ /m ³)	24	19.2	8.6
Distillate Quality – TDS (ppm)	~10	~10	<500
Unit Product Cost (USD/m ³)	0.52-1.75	0.52-1.01	0.52-0.56

We reviewed previous studies comparing MED MFC and RO desalination technologies focusing on electrical/thermal/total energy consumption, technology conditions, environmental impacts, product quality, and product cost shown in **Table 4**. In general, membrane technology is optimal based on a combination of both energy consumption and CO₂ emissions. However, the unit cost of products is close to that of thermal technology because of its higher operating and maintenance costs. Currently, conventional fossil fuels are the energy source for 99% of the desalination process (**Washahi and Gopinath 2017**)

MCA Desalination Technology

Three desalination technologies were compared and evaluated using MCDA approach based on 4 decision criteria characteristic groups (C1-C4), i.e., technical, energy, environment, and economic with sub-criteria (SC1-SC13) listed in **Table 5**. Some of these criteria need to be maximized and some have to be minimized simultaneously for obtaining a mathematical/scientific index. The criteria selection process was conducted to include only the criteria which are complete, operational, and non-redundant. Analysis from the decision hierarchy of the desalination technology selection in MCDA environment represented in **Figure 2** using relative weights of the individual criteria with respect to each other based on experts' opinion are illustrated in matrix in **Table 5**.

Table 5 Criteria of the Desalination Technology Selection.

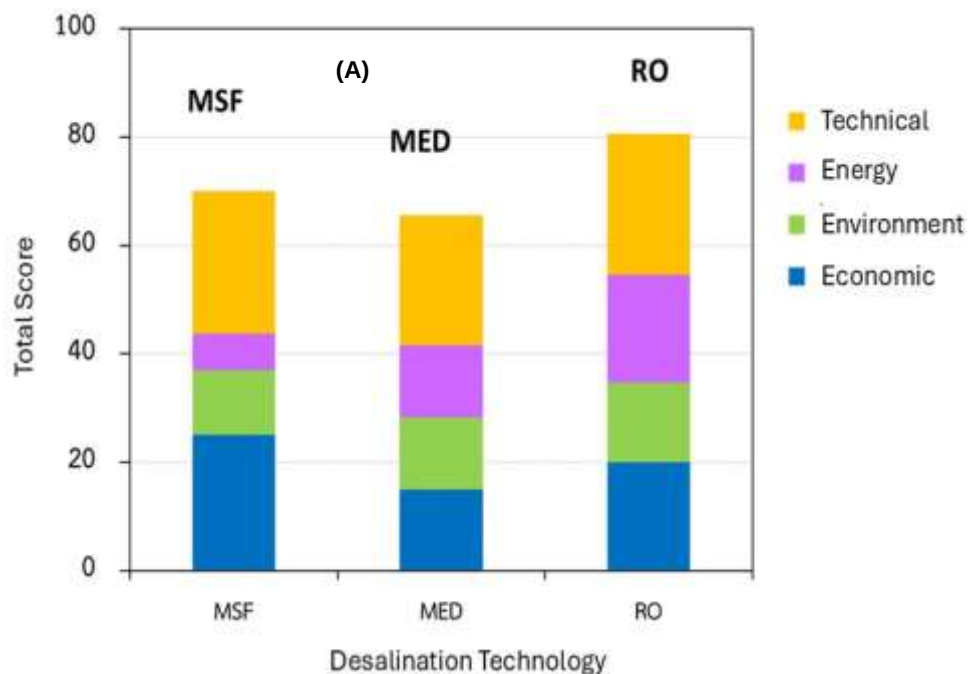
Evaluation Criteria Group	Sub-Criteria
Technical (C1)	Complexity Degree (SC1)
	Stability (SC2)
	Effluent Water Quality (SC3)
	Lifetime (SC4)
	Water Recovery Ratio (SC5)
	Scalability (SC6)
	Compatibility with Other Technologies (SC7)
Energy (C2)	Energy Consumption (SC8)
	Compatibility with Renewable Energy (SC9)
Environment (C3)	Waste and Brine Management (SC10)
	Pollution Discharge (SC11)
Economics (C4)	Capital Cost (SC12)
	Operating Cost (SC13)

Table 6 MCDA Analysis Matrix for MSF MED and RO Desalination Technology Selection

Evaluation Criteria			Weight	Scale			Weight x Scale		
				MSF	MED	RO	MSF	MED	RO
Technical)C1) / 30			375				330	300	325
	SC1	Complexity Degree (SC1)	5	2	2	2	10	10	10
	SC2	Stability (SC2)	25	3	3	3	75	75	75
	SC3	Effluent Water Quality (SC3)	15	3	3	2	45	45	30
	SC4	Lifetime (SC4)	30	3	2	2	90	60	60
	SC5	Water Recovery Ratio (SC5)	30	2	2	3	60	60	90
	SC6	Scalability (SC6)	10	3	2	3	30	20	30
	SC7	Compatibility with Other Technologies (SC7)	10	2	3	3	20	30	30
Energy)C2) / 20			75				25	50	75
	SC8	Energy Consumption (SC8)	20	1	2	3	20	40	60
	SC9	Compatibility with Renewable Energy (SC9)	5	1	2	3	5	10	15

Evaluation Criteria			Weight	Scale			Weight x Scale		
				MSF	MED	RO	MSF	MED	RO
Environment)C3) / 20			75				45	50	55
	SC10	Waste and Brine Management (SC10)	20	2	2	2	40	40	40
	SC11	Pollution Discharge (SC11)	5	1	2	3	5	10	15
Economic)C4) / 30			180				150	90	120
	SC12	Capital Cost (SC12)	30	2	1	3	60	30	90
	SC13	Operating Cost (SC13)	30	3	2	1	90	60	30
			Total				550	490	575

MCDA analysis results based on the 4 evaluation criteria groups in this study indicate that RO is more viable technology (compared to MED and MSF) for the desalination application in EEC Thailand as shown in **Figure 9(A)**. Complex stakeholders' perception for desalination systems was conducted using 400 sets door-to-door questionnaire surveying technique and the results are presented in **Figure 9(B)**. The findings reveal that the community significantly responded more positively to the desalination system installation and operation, even if they have to pay more for water, to strengthen water security and address water scarcity challenges in the region.



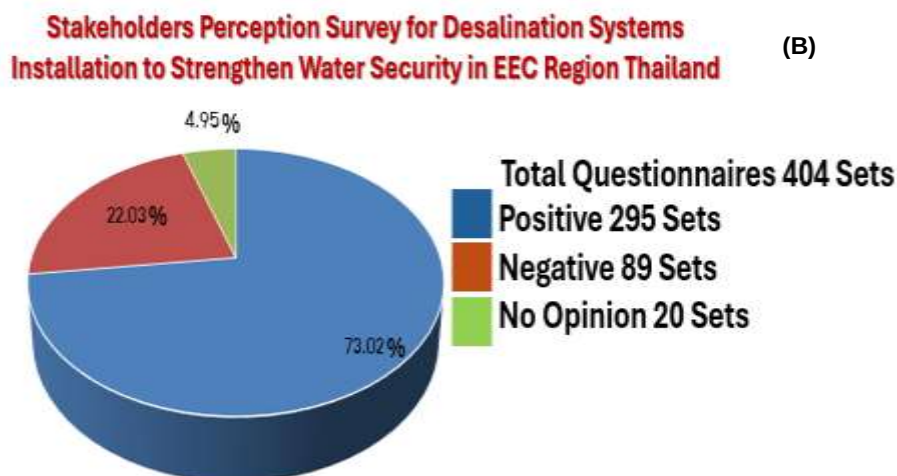


Figure 9 (A) MCDA Analysis Results for MSF MED and RO; (B) Stakeholders' Perception for Desalination Systems Installation and Operation in EEC Thailand.

Conclusions

Current trend is shifting from linear water use to circular systems marks a significant water evolution for longer-term sustainability in Thailand's water management, starting with modern industrial water sector in the eastern economic corridor (EEC) region. The socio-technical and economic analysis of seawater desalination project is conducted to address water scarcity challenges. Various desalination technological performance is investigated and compared using multi criteria decision analysis (MCDA) based on preliminary technology review and feed (sea)water characteristics in EEC region Thailand. MCDA analysis results based on the 4 evaluation criteria groups in this study indicate that Seawater Reverse Osmosis (SWRO) is more viable technology (compared to MED and MSF) for the desalination application in EEC Thailand. Complex stakeholders' perception for desalination systems conducted based on 400 sets door-to-door questionnaire surveying technique revealed that the community significantly valued water security more than water price as they responded more positively to the desalination system installation and operation to strengthen water security and address water scarcity challenges in the region. Findings from this study suggest that integration of desalination to support regional productivity and economic development requires balancing technological, economic, and environmental trade-offs. Modern practical desalination systems for Thailand should be readily designed for (i) high energy efficiency through optimized performance of reverse osmosis (RO) systems; (ii) integration with renewable energy sources; (iii) blending with reclaimed water to reduce overall treatment costs; (iv) water trading mechanisms among water sectors (e.g., trading water between agricultural sector and industrial sector) for economic viability; and (v) government subsidies, shared water infrastructure (e.g., direct pipelines from desalination plants to users), public-private partnerships investment can lead to cost effectiveness for desalination systems. Further analysis provide macro- and micro-level insights to inform policy and strengthen the sustainability of desalination systems in climate-vulnerable coastal regions of Thailand. By combining desalination with reclaimed water, Thailand can build a diversified and resilient water portfolio along the EEC coastline. Future research should examine the environmental impacts of brine disposal and the feasibility of zero-waste desalination systems and integrating remineralization technologies to address health risks from demineralized water. This study offers actionable insights for policymakers and practitioners to strengthen resilient, equitable, and sustainable water supply systems in climate-vulnerable coastal regions, contributing to Sustainable Development Goal 6 (target 6.1). By leveraging innovation, policy support, and international cooperation, desalination can become a sustainable and transformative solution for water security.