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The Potential of Salinity Gradient Energy Using Reverse Electrodialysis to Generate Electricity for Seawater Desalination Plants, an example from Western Australia

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Received: 24 January 2024; Accepted: 6 March 2024; Available online: 13 March 2024

ABSTRACT: Seawater desalination plays a vital role in addressing the increasing global demand for freshwater. However, the energy-intensive nature of desalination processes and the generation of brine by-products pose environmental challenges. In Western Australia (WA), approximately 48% of freshwater is supplied by two seawater desalination plants employing the energy-intensive seawater reverse osmosis (SWRO) method. These plants are powered by a combination of renewable and conventional energy sources. Typically, the most efficient approach for desalination plants involves a blend of renewable energy sources. Salinity gradient energy (SGE) harnessed through the reverse electrodialysis (RED) system, which derives energy from mixing waters with varying salinities, has emerged as a potential solution. RED utilizes ion-exchange membranes to convert the chemical potential difference between two solutions into electric power. The net specific energy of SGE, calculated based on the Gibbs free energy associated with mixing seawater and wastewater, is estimated at approximately 0.14 kWh per cubic metre of brine for SWRO desalination plants. The combined SGE potential of WA's two desalination facilities theoretically amounts to approximately 87.4 MWh of energy. However, due to the inherent limitations of the RED system's current energy efficiency, only about 2.5% of the desalination plant's energy requirements can be met through this technique. This paper addresses a significant gap in the literature by analyzing the technical and economic constraints of utilizing salinity gradient energy (SGE) through the reverse electrodialysis (RED) system for seawater desalination plants. This marks the first examination of its kind, shedding light on both the technical feasibility and economic challenges of SGE-RED application in this context. The scientific contribution lies in its innovative approach, integrating technical and economic perspectives to provide an understanding of SGE-RED technology's potential drawbacks and opportunities. By identifying and tackling these challenges, this paper aims to pave the way for optimizing SGE-RED systems for practical implementation in seawater desalination plants.

Keywords: Salinity Gradient Energy (SGE); Reverse Electrodialysis (RED); Seawater desalination; Renewable clean energy; Western Australia desalination plants

1. Introduction

The adverse impact of global climate change on all aspects of our lives has prompted the urgent need for a transition to cleaner and renewable energy sources. By utilizing available clean energies, industries that have traditionally relied on burning fossil fuels can reduce their carbon footprint to a more sustainable future for all. Renewable energy sources such as geothermal energy, biomass and biofuels, solar energy, wind energy, ocean energy, hydropower, nuclear energy, and natural hydrogen [1] are becoming increasingly important to meet our global energy needs, reducing our dependence on fossil fuels and mitigating the impact of greenhouse gas emissions on the environment.

A significant reduction in drinkable water availability has been witnessed globally in recent years. Many regions around the world face water scarcity due to factors such as arid climates, population growth, inadequate rainfall, and overexploitation of freshwater sources. Seawater desalination offers an abundant alternative water source, as oceans cover about 71% of the Earth's surface. Seawater reverse osmosis (SWRO) which is the preferred technology for seawater desalination due to the reliability and maturity of the technique is very energy intensive. SWRO is a desalination process that uses high pressure to force seawater through a semi-permeable membrane and produce freshwater and brine (wastewater). The major operating cost (OPEX) for different desalination methods is energy consumption in the form of electricity or thermal energy. For electricity-driven desalination, such as SWRO plants, electricity cost is more than 51% of the OPEX [2].

As the costs of renewable technologies continue to decline, they become economically more attractive to be utilized in energy-intensive industries. Using locally available renewable energy resources for desalination is likely to be a cost-effective solution, for freshwater production, but this needs to be carefully analysed for its practicality and economic feasibility.

Perth, the capital of Western Australia, has a population of approximately 2.1 million and its water supply is heavily reliant on desalinated seawater (around 48%) and groundwater (approximately 40%). The Perth region desalinated water is currently supplied from two plants, namely the Perth Seawater Desalination Plant with a daily capacity of 144,000 m^3 [3] and the Southern Seawater Desalination Plant with a daily capacity of 274,000 m^3 [4] with a combined output of up to 152 billion litres of potable water per year. The plants are designed to operate continuously, drawing ocean water with an input salinity of 35,000 mg/L to 37,000 mg/L at 16 °C to 24 °C and the concentrate brine outflow salinity is about 70,000 mg/L. Electricity for the Perth Seawater Desalination Plant which has an overall 24MW requirement is supplied from a wind farm. However, the Southern Seawater Desalination Plant since 2011, has been powered by a combination of renewable energy (wind and solar, 57%) and grid [4].

Despite the availability of pressure exchanger energy recovery devices that can significantly reduce energy consumption, the SWRO requires a substantial amount of energy, with an input of between 2.5 and 4 kWh for every cubic metre of the desalted water. At the nominal capacity and with an overall water recovery rate of 42%, the Perth desalination plant consumes about 3.9 kWh/m^3 including pre-treatment, post-treatment, and all electrical losses [5]. The cost of supplying potable water from seawater is approximately AUD1.17/m^3 [3].

The feasibility of using salinity gradient energy (SGE) as a renewable energy source for seawater desalination in Western Australia (WA) can determine the cost of seawater desalination utilizing SGE-RED (reverse electrodialysis). SGE capture through reverse electrodialysis (RED) is an emerging technology that aims to replace conventional water-intensive energy sources in the desalination industry [6]. The cost of SGE-RED depends on the operational parameters and the specific layout of the RED plant. To evaluate the feasibility and cost-effectiveness of SGE-RED, various factors need to be considered. Tristan et al. [6] conducted a detailed assessment of an upscaled RED system in seawater reverse osmosis (SWRO) desalination plants. They evaluated the optimal working conditions for an industrial-scale RED unit by considering factors such as feed concentration, feed flow rate, and temperature. They also estimated the SGE recovery potential of a RED plant in SWRO plants worldwide. Additionally, they investigated different layouts of RED plants in a specific SWRO plant to enhance energy yield. A systematic evaluation, including optimization of the hybrid process configuration at both the plant and RED unit scales, is necessary to determine the potential for SGE recovery from waste streams in SWRO plants. It is important to note that while SGE-RED shows promise as a renewable energy source for seawater desalination, further research and development are needed to optimize the design, reduce costs, and minimize the environmental impact. The objective of this study is to assess the technical feasibility, economic viability, and environmental impact of implementing SGE-RED for seawater desalination in WA.

2. Methods of Harvesting Salinity Gradient Energy (SGE)

SGE is a renewable and sustainable source of clean energy. The mixing of waters with varying salinities results in a change in Gibbs free energy, which can be harnessed as electrical energy. The theoretical potential of SGE is enormous, and the technologies for extracting this energy are advancing toward commercialization. This source of renewable energy was introduced many years ago and has undergone various evaluations over time. Post et al., [7] used the Gibbs free energy equation for mixing waters of different salinities and calculated that when mixing 1m^3 of seawater and 1m^3 of river water, at constant pressure and temperature, 1.36 MJ, equivalent to 0.377 kWh, can be produced. Although the energy density of SGE is low compared to the energy density of hydrocarbons, comparing this energy to other methods that generate energy from water, such as wave and tidal energies, it is relatively high. This energy is equivalent to the energy obtained from a volume of 1 cubic meter of water falling from a 139-meter-high waterfall.

Pattle [8] was the pioneer to propose the idea of generating power from the mixing of freshwater and seawater using a membrane-based process. Based on [9] global annual amount of freshwater continental discharge entering the oceans is about 39.3 trillion m^3 on average. In theory, about 0.55 kWh/m^3 can be extracted for the mixing of 1 m^3 of seawater with 1 m^3 of fresh water using Equation (1) in this paper. This means that theoretically there is a potential of harnessing about 21.9 TWh energy. However, since all the small and major rivers are not practical to extract energy from them, the reported estimates for SGE power of major river outfalls with seawater around the world are estimated between 1.4 TW to 2.6 TW [10,11]. Considering the current technological status, about 0.98 TW is producible from this technique [12].

The use of SGE was further developed by researchers who investigated the utilization of reverse electrodialysis (RED) [13–16], pressure-retarded osmosis (PRO) [17–19], and capacitive mixing (CAPMIX) [20,21], for seawater desalination and electricity generation [12,22–25]. CAPMIX is a process that uses the capacitive energy generated by the mixing of waters of different salinities to generate electricity. CAPMIX converts the SGE into electrical energy by using the voltage changes caused by varying the salt concentration of the solution. Although it does not require membranes to function, the power densities achieved by the method are too low to be commercially viable [26].

RED and PRO are the two well-recognised technologies used for SGE harvesting. They operate on different principles and have different operational requirements. According to [27,28], RED technology generates electricity by utilizing the potential energy difference between two saline solutions with different concentrations of ions. This is achieved by separating the solutions with an ion-selective membrane and connecting them with electrodes. The ion-selective membrane permits only certain ions to pass through, generating a voltage difference that can be collected as electrical energy. RED is a low-pressure process, typically operating at less than 10 bar [13,29]. In contrast, PRO technology produces electrical energy by exploiting the osmotic pressure differential between two solutions with varying salinity levels, as described by [23]. The method entails isolating two solutions with differing salt concentrations using a semi-permeable membrane that enables water molecules to traverse but restricts the passage of salt ions. This generates a pressure gradient that propels water molecules from the lower salinity solution to the higher salinity solution, generating a force that can be harnessed via a turbine to generate electrical energy. PRO operates at high pressures, typically over 50 bar, and requires a higher salt gradient than RED [30].

The concept of using SGE as a source of energy from seawater desalination plants has been studied by many researchers [6,23,31–35]. One way to use SGE to produce electricity for seawater desalination plants is through pressure-retarded osmosis (PRO) [17–19]. According to a study by [36], PRO has the potential to achieve high energy efficiency and low environmental impact in seawater desalination. Based on a study by [37] about 7% of the energy requirements of WA's desalination plants can be provided by the PRO method.

The primary application of RED is centred around using river water as a dilute solution and seawater as a concentrated solution, primarily due to the abundance of these resources, particularly in estuaries. RED has also been considered an approach to extracting sustainable energy from desalination plants. Technically a RED system is a stack of repeating cells that consist of alternating cation exchange membranes (CEM) and anion exchange membranes (AEM). Ion exchange membranes (IEMs) are composed of a polymer matrix embedded with negatively and positively charged groups for CEM and AEM respectively [38]. The feed waters, such as brine (high-salinity water) and seawater (low-salinity water), flow alternately through the feed compartments between the membranes (Figure 1). The voltage difference created by the salinity gradient over each IEM, known as the Donnan potential, serves as the driving force for the RED process. When the RED stack is connected to an external load, this driving force results in an ion flux through the membranes. To enable this ionic flux, both ends of the membrane stack are in contact with an electrode, and a redox couple recirculates between the electrodes to convert the ionic flux into an electrical current.

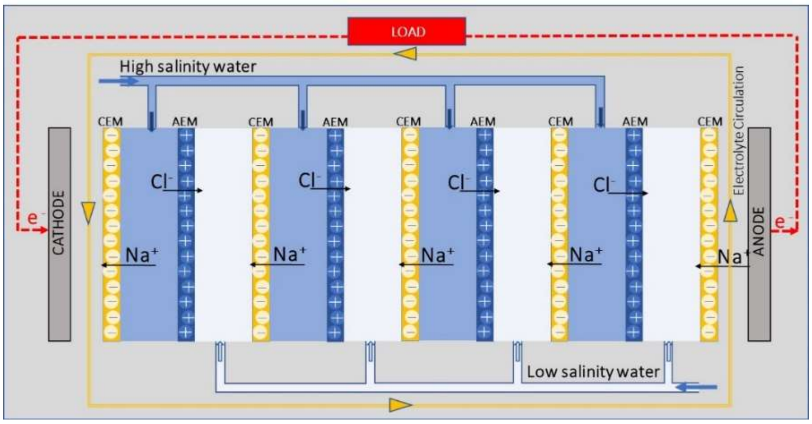

Figure 1. A diagram showing the process of salinity gradient power generation through reverse electrodialysis (RED). The high-salinity and low-salinity compartments are separated by alternated sequences of cation exchange membranes (CEMs) and anion exchange membranes (AEMs). Electrical energy is produced through redox reactions taking place on the two electrodes positioned at the ends of the membrane stack.

3. Results and Discussion

SGE-RED can be explained by Gibbs free energy concept that is generated when two solutions with different salinities are separated by IEMs [39–42]. The Gibbs free energy change of the system is a measure of the maximum amount of work that can be obtained from this condition. A simplified Gibbs free energy [43] is used in this study. According to the laws of thermodynamics, the maximum amount of work that can be obtained from a mixing system at constant temperature and pressure is equal to:

$$E_{mix} = 2RT\left[C_d V_d * \ln\frac{C_d(V_d + V_c)}{C_d V_d + C_c V_c} + C_c V_c * \ln\frac{C_c(V_c + V_d)}{C_d V_d + C_c V_c}\right] \quad (1)$$

in which E_{mix} is Gibbs free energy (kJ) of mixing, R is the universal gas constant (8.3145 J·mol^{-1}. K^{-1}), T is the temperature (K), C is the concentration (mol/m^3), V is the volume (m^3), subscripts d and c stand for dilute and concentrated solutions, respectively.

The WA desalination plants draw ocean water with a salinity of about 35,000 mg/L and diffuse back the brine wastewater of about 70,000 mg/L to the ocean at a temperature of about 24 °C. Equation (1) gives about 502 kJ energy equivalent to about 0.14 kWh for the mixing of 1 m^3 of seawater with a salinity of about 35,000 mg/L with 1 m^3 of desalination plant wastewater with a salinity of about 70,000 mg/L at 24 °C (Table 1).

The wastewater generation of the Perth and the Southern Seawater Desalination Plants are about 216,000 m^3 and 411,000 m^3 respectively. Using Equation (1), this means the daily net specific energy production of SGE for these plants would be around 30.1 MWh and 57.3 MWh respectively (Table 1). Considering the average energy consumption of 3.9 kWh per m^3 of freshwater production, the Perth and the Southern Seawater Desalination Plants' daily energy consumptions are approximately 561.6 and 1068.6 MWh respectively. Since generally the desalination plants' wastewater is volumetrically about 1.5 times more than the produced freshwater [44], theoretically about 5.4% of the desalination plants' energy consumption may be potentially produced by the SGE.

Figure 2 illustrates the variation of Gibbs free energy generated when freshwater or seawater is mixed with other water sources with different salinities using Equation (1).

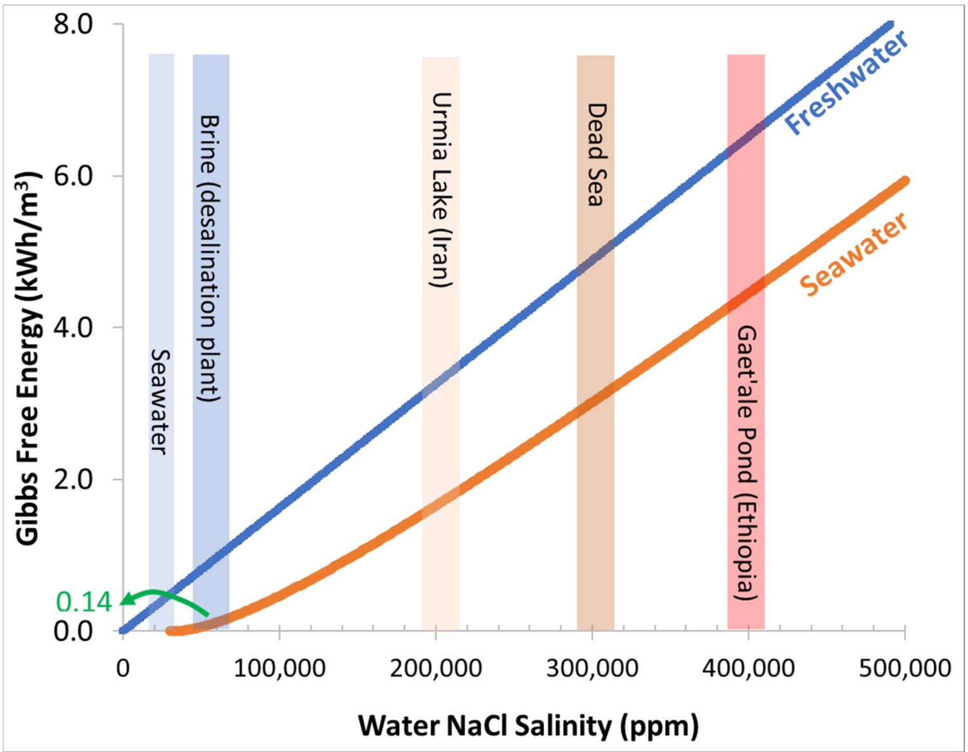

Figure 2. Variation of Gibbs free energy when freshwater or seawater are mixed with other water sources with different salinities. With increasing salinity differences the generated energy increases. For example, if freshwater or seawater is mixed with Dead Sea water, it can produce about 5 to 3 kWh of energy per cubic metre of water respectively. The salinity difference between seawater and brine from SWRO plants is not very high, compared to other sources. The maximum salinity gradient energy (SGE) harvestable in SWRO plants is about 0.14 kWh (green arow) per cubic metre of desalted water, which is about 5.4% of the energy required by the plants.

Table 1. The daily theoretical net specific energy production of SGE for two WA desalination plants and for other different scenarios. *C* is the concentration (ppm), *V* is the volume (m^3), and subscripts D and C stand for dilute and concentrated solutions, respectively. As can be expected, the process of mixing freshwater with brine shows to generate approximately ten times more energy compared to mixing seawater with brine.

Source of Water	C_D (ppm)	C_C (ppm)	V_D (m^3)	V_C (m^3)	*E* (kJ)	*E* (kWh)
Seawater and Brine	35,000	70,000	1	1	502.54	0.14
Fresh and Seawater	100	35,000	1	1	1998.13	0.56
Freshwater and Brine	100	70,000	1	1	4042.53	1.12
Perth Plant	35,000	70,000	216,000	216,000	108,548,81	30,152
Southern Perth Plant	35,000	70,000	411,000	411,000	206,544,273	57,373

3.1 Power Density of SGE-RED

Power density is a metric for comparing the electricity production capacity of different energy sources. It is defined as the electrical power produced per unit surface area which can be measured in W/m^2. The power density varies among energy sources due to differences in their energy content and availability. As can be seen in Figure 3, fossil fuels and nuclear energy have high power densities compared to renewable energy sources. Fossil fuels and nuclear contain concentrated energy that can be efficiently converted into electricity, whereas, renewable energy sources have lower power densities since they rely on harnessing energy from natural phenomena like sunlight, wind, and water, which are less concentrated and more diffuse.

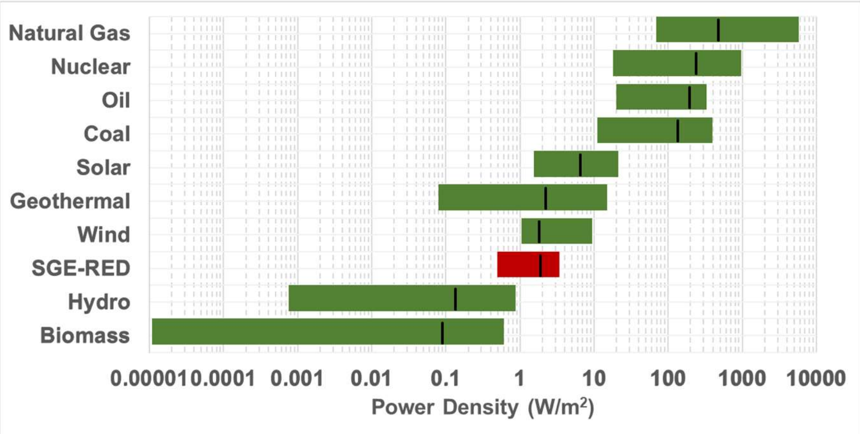

Figure 3. The range and median of power density for different energy sources (Modified from [45]). Typical SEG-RED power density is less than most renewable energies such as solar, geothermal and wind but is more than hydropower and biomass.

The net power density of the RED system is the amount of electric power that can be obtained per unit area of the membrane after subtracting the Ohmic losses and the pumping power consumption. The net power density depends on several factors, such as the salinity gradient, the flow rate, temperature, the membrane area, the stack configuration, and the properties of the IEMs [46,47]. Among all these parameters, IEMs used in RED play an important role to impact the power density [48]. The IEMs which are selectively permeable to either cations or anions allow the passage of ions from the high-salinity stream to the low-salinity stream and generate a potential difference across the stack (Figure 1). The IEMs also prevent the mixing of the high-salinity with the low-salinity water, which would reduce the salinity gradient and power output. One of the key properties of IEMs that affects the performance of SGE-RED is ionic resistance which depends on several factors, such as the membrane thickness, the fixed charge concentration, the ion exchange capacity, and the type and concentration of ions in the feed streams [49]. The high ionic resistance of membranes used in RED systems reduces overall power production.

Research studies have shown a wide variation of achievable power density per membrane surface area. The variation of power density reported in different experimental studies is rooted in variations of operating conditions such as the feed concentration, flow rate, temperature, number of cell pairs, spacer design, and most importantly the types of IEMs (Figure 4). As highlighted by [29,32] optimizing these factors, higher power density can be achieved in RED cells, thereby improving their efficiency in generating electricity. Based on [7,50] the power densities of the conventional RED method mostly range from 0.05 to 1.18 W per square metre of membrane. According to [51] the highest net power density, using parameters that are typical for the current state of technology, is 2.7 W/m^2 and a net power density close to 20 W/m^2 is also possible by reducing membrane resistance and modifying the RED cells.

Laboratory experiments by [52] reported power densities of around 2.9 W/m^2. According to [46], the theoretical maximum net power density obtainable from RED stacks with profiled membranes is about 2.7 W/m^2. Ciofalo et al., [46] through a simulation study reported a net power density of the RED system of about 2.3 W/m^2 at nearly the same conditions as WA's desalination plants. The maximum gross power output of 0.96 W/m^2 and 1.46 W/m^2 were also reported by [53] for the natural and model freshwater and seawater feed solutions, respectively. The reduction of power output for natural freshwater and seawater was explained by the presence of divalent ions in the natural solution [53]. Li and colleagues [54] reported that the power density of mixing wastewater brine from desalination plants with seawater was 0.49 W/m^2, which was slightly less than that of mixing seawater with fresh water (0.50 W/m^2), and much less than that of mixing brine with fresh water (1.28 W/m^2).

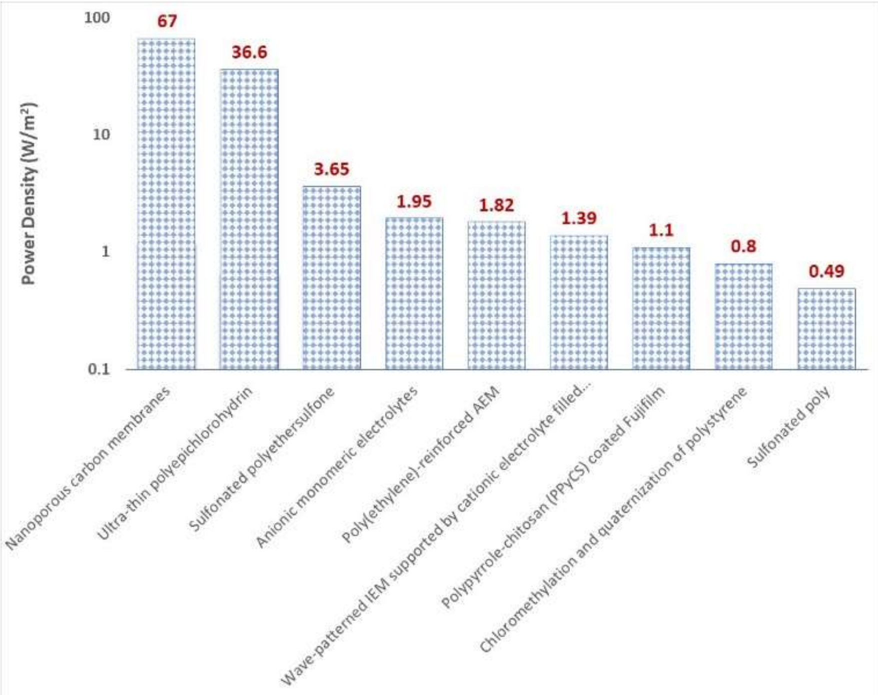

Figure 4. Power density variations of some IEMs used in RED and NRED (data from [55]).

The power generation of RED has been recently improved by creating nanopores and nanofluidic membranes that have superior properties for water and/or ion transport [56]. Nanofluidic reverse electrodialysis (NRED) uses nanofluidic membranes with charged nanopores that enhance the power density of SGE conversion [57–60]. The charged nanopores can selectively transport ions based on the electrical double-layer effect, and the larger pore size can reduce the ionic resistance. Some studies have reported that NRED can achieve power densities up to 18.3 W/m^2 by using artificial solutions with high salinity gradients [61]. Liu and colleagues [62] introduced ultrathin ion-selective membranes for use in NRED systems with a power density of 67 W/m^2 the highest achieved so far by using membranes.

3.2. The Levelized cost of Electricity (LCOE) for the SGE-RED System

LCOE showed in Equation (2) determines the full lifetime cost of electricity including investment, operation and maintenance (O&M), charging, and end-of-life cost divided by electricity discharged during the investment period. It assumes all investment costs are incurred in the first year and sums ongoing costs in each year (n) up to the system lifetime (N), discounted by the discount rate (r).

$$\mathrm{LCOE}\left[\frac{\$}{\mathrm{MWh}}\right]=\frac{\text{Investment cost}+\sum_{n}^{N}\frac{\text{O\&M cost}}{(1+r)^{n}}+\sum_{n}^{N}\frac{\text{Charging cost}}{(1+r)^{n}}+\frac{\text{End-of-life cost}}{(1+r)^{N+1}}}{\sum_{n}^{N}\frac{\text{Electricity discharged}}{(1+r)^{n}}} \quad (2)$$

The levelized cost of electricity (LCOE) is a metric used to evaluate the average cost of generating electricity for a specific system over its lifetime. It is used to compare different methods of electricity generation consistently and to assess the economic viability of a project. LCOE for SGE-RED technology is calculated by dividing the total cost of the RED stack over its lifespan by the total amount of electrical energy generated during that same period. To compete with other renewable energies, such as solar and wind, at the current stage of technology the LCOE for the SGE-RED method needs to be less than 0.04 USD/kWh (see Figure 5 for LCOE of several energy sources).

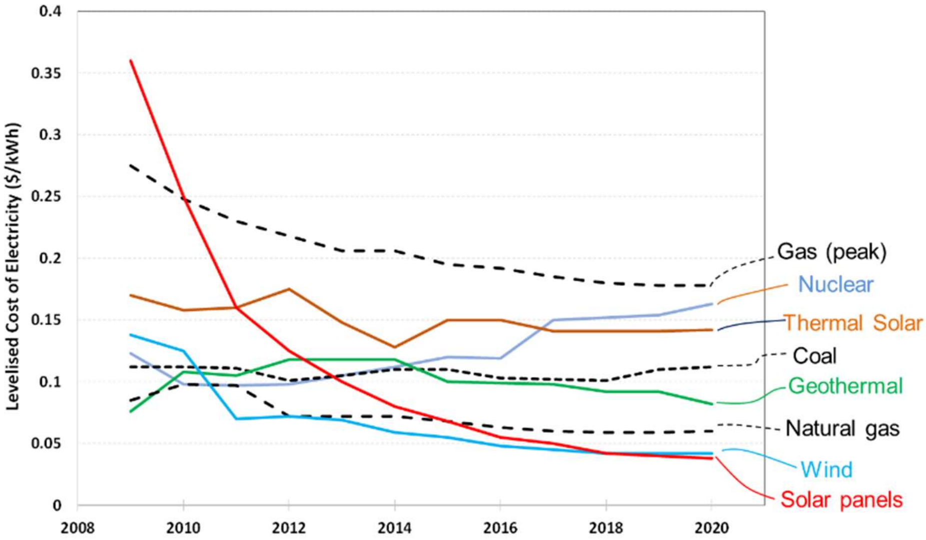

Figure 5. Illustration of levelized cost of energy (LCOE) for different energy sources (data from [63]).

The membrane costs account for 50–80% of total capital costs of SGE-RED system. There are few reports in the literature on the economic evaluation of RED technology in real environments. Turek et al. [64] used an experimental power density of 0.92 W/m^2 of cell pair and assumed a total investment cost of 100 USD/m^2 for the installed membrane. They obtained a very high specific cost of 6.79 USD/kWh. Assuming an installed membrane price of 2 €/m^2 and power density of 2 W/m^2, Post et al. [7] presented a prospective cost of 0.08 €/kWh in their analysis. An economic analysis for RED applications was carried out by Daniilidis et al. [65] indicating that the LCOE of the current RED units is higher than that of other competing technologies. They proposed that a future improvement of the membranes to reach a higher power density of 2.7 W/m^2 and a future reduction of their cost to 4 €/m^2 could lower the LCOE to 0.16 €/kWh for the case of seawater-river water. Giacalone et al. [48] presented a techno-economic assessment of the RED process and reported that a competitive LCOE lower than 0.10 €/kWh can be achieved by future low-cost improved membranes. Based on [28], the maximum power densities for electrodialysis are calculated to be around 4.7 W/m^2 of the membrane, at 25 °C. This requires the membrane price to be lower than 2.9 USD/m^2 to achieve competitive economic energy (in the EU) with this power density [28]. Experimental lab-scale studies by [66] reported that a highly efficient RED stack with the highest net specific energy conditions (0.06 kWh/m^3) would be cost-competitive (LCOE < 0.02 USD/kWh) if the price of the membrane becomes less than 20 USD/m^2.

Based on [67] the estimated price of membranes that ranges from 10–30 €/m^2 needs to be reduced to 2–5 €/m^2 to be competitive with other renewables. A simple cost analysis of the energy production of the RED system [68] reported that the membrane price needs to be around 1.3 and 0.67 USD/m^2 to match the energy price in the EU and the USA, respectively. Krakhella et al., [68] reported the price of some IEMs in the market such as Nafion 117 membrane of about 12,000 USD/m^2, and a Fumatech of about 500 USD/m^2.

4. Conclusions

To evaluate the technical and economic feasibility of SGE-RED as a source of electricity for seawater desalination plants, several key factors need to be considered:

1. The power density of the RED system is not well-established and varies widely in different studies. Excluding NRED, the reported values of power density per membrane area range from 0.49 to 2.9 W/m^2 with an average of 1.88 W/m^2 (See Figure 3). This power density is less than most renewable energies such as solar and wind, and cannot compete with them at the current stage of technology.
2. The cost of the RED system is mainly influenced by the cost of the membranes, but the reported membrane cost is highly variable and uncertain. The membrane cost ranges from 2 €/m^2 to 100 USD/m^2 [7,28,48, 64–66]. According to Krakhella et al., [68], the membrane price would have to drop to about 1.3 and 0.67 USD/m^2 to compete with the energy price in the EU and the USA, respectively. These prices are much lower than the reported prices of high-performance IEMs available in the market.
3. The reported levelized cost of electricity (LCOE) for the RED system [7, 28, 48, 64, 65], even after considering the reduced price of IEMs in the future and considering a power density of IEMs more than the average value, exceeds the LCOEs of other competitive renewable energies such as solar and wind.

4. The theoretical energy efficiency of the RED system has been reported to be 44% [47], and a recent scaled-up multistage indicated energy efficiency values were between 30 and 37 % [69]. This means in the best situation only close to half of the Gibbs free energy of mixing can be converted into electrical energy by a perfect RED system. This indicates that about 2.5% of the desalination plant energy can be produced by the RED system.

In conclusion, RED has demonstrated its potential to harness a substantial amount of clean, renewable energy through the utilization of the mixing process between river and ocean water. However, although RED has gained attention as a potential method for generating power from desalination plants, it is important to acknowledge that the technical and economic feasibility of implementing RED in SWRO desalination plants presents significant challenges and uncertainty and therefore cannot compete with other available sources of clean energy such as wind and solar in the region. The costs associated with the RED system, including membrane cost, the installation of RED modules, specialized equipment, and additional maintenance issues, such as membrane fouling, scaling, biofouling, and corrosion could pose significant financial burdens. Furthermore, although significant progress has been made in enhancing membrane performance and quality to improve the power density, the SGE-RED technique has inherent limitations that restrict its energy generation potential to approximately 2.5% of the energy requirement of the SWRO desalination plants. However, it is important to note that despite the limitations of RED in seawater desalination plants, it can still serve as a valuable tool to mitigate the environmental hazards associated with the disposal of concentrated brine. By utilizing RED to generate electricity, the environmental impact of brine disposal can be partially alleviated during the process. The reduction of brine salinity achieved through RED can contribute to the preservation of marine ecosystems.

As technology advances and costs are further optimized, RED may eventually become a financially viable option, aligning economic benefits with its positive environmental attributes. While the combined power generated by two desalination plants in Western Australia using SGE-RED (87.4 MWh) is not significant enough to be a primary electricity source for the plants themselves, it is capable of supplying power to approximately 15,000 average Australian homes for one hour. The average annual electricity consumption in Western Australia is reported to be approximately 5198 kWh per year.

It is worth noting that in Western Australia, there are several Salina lakes with varying water salinity where SGE-RED can be utilized to generate electricity for remote agricultural farms. The author at Curtin University is currently working on the development of a natural and inexpensive membrane that can be used for these types of purposes.

Ethics Statement

Not applicable.

Informed Consent Statement

Not applicable.

Funding

This research received no external funding.

Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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