PAMEC.Energy Association

CEMIE-Océano Asociación Civil

Universidad del Caribe
2000 CANCUN, QUINTANA ROO, MÉXICO
CONOCIMIENTO Y CULTURA PARA EL DESARROLLO HUMANO

PAN AMERICAN MARINE ENERGY CONFERENCE 2024

Design of an OTWEC-OC plant to produce desalinated water and electricity in Ensenada, B.C.

Leandro Daniel Balan Pool, Lucero Isabel Castro Meneses, Eva Sofia Cetzal Chay, Estela Cerezo Acevedo.

Departamento de Ciencias Básicas e ingeniería - Universidad del Caribe, Cancún, Q. Roo. México.

Content

Introduction

Oceans cover more than 70% of the Earth's surface.

(Parker, G., Paterlini, M. C., & Violante, R. 1997)..

Fig 1. First color image of Earth from the Moon. Source: Anders, 1968.

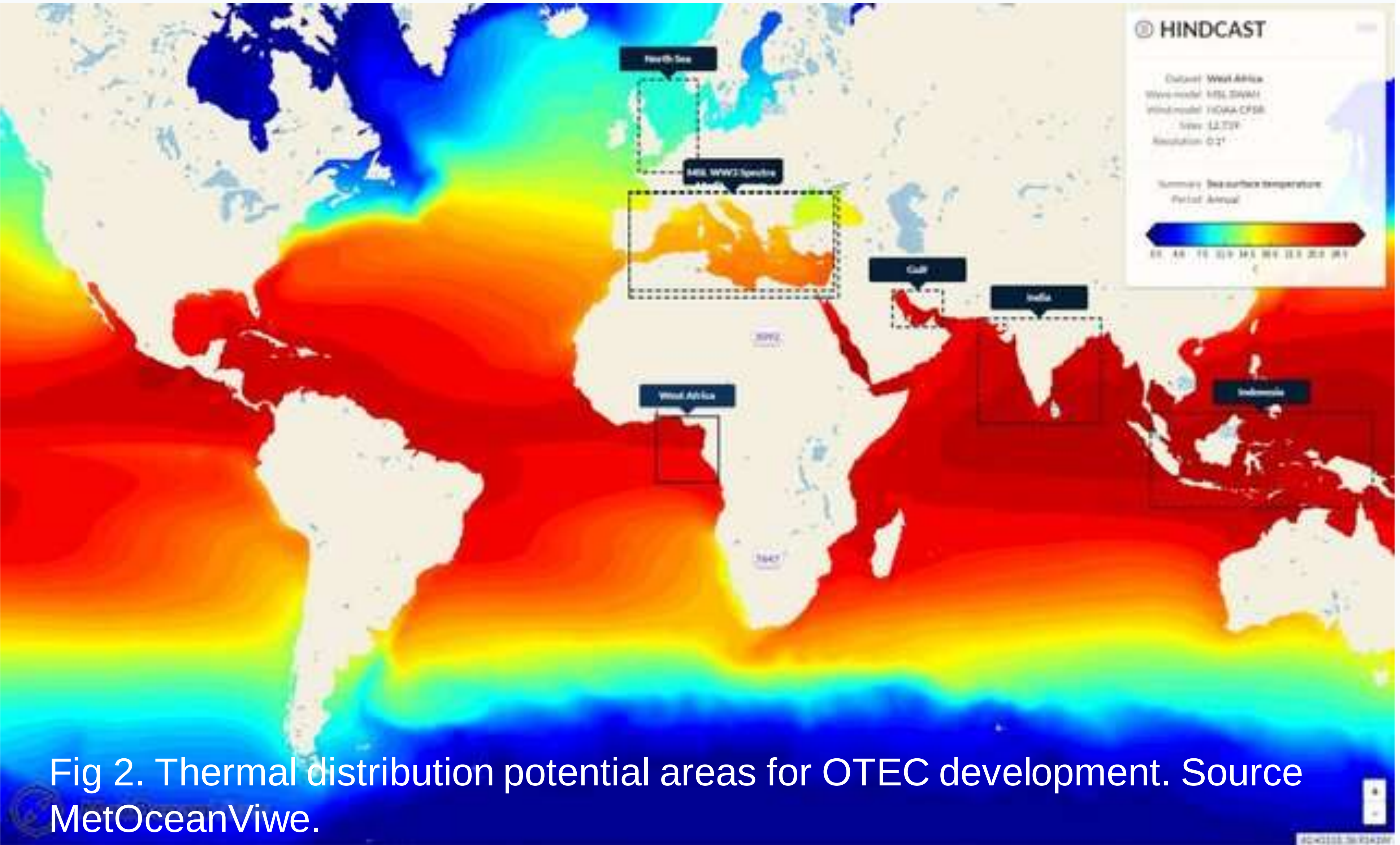


Fig 2. Thermal distribution potential areas for OTEC development. Source MetOceanViwe.

Thermal distribution potential areas for OTEC development

OTEC

OTEC works with the temperature difference between surface water and cold water deep in the ocean to generate electricity trough a thermodynamic cycle .

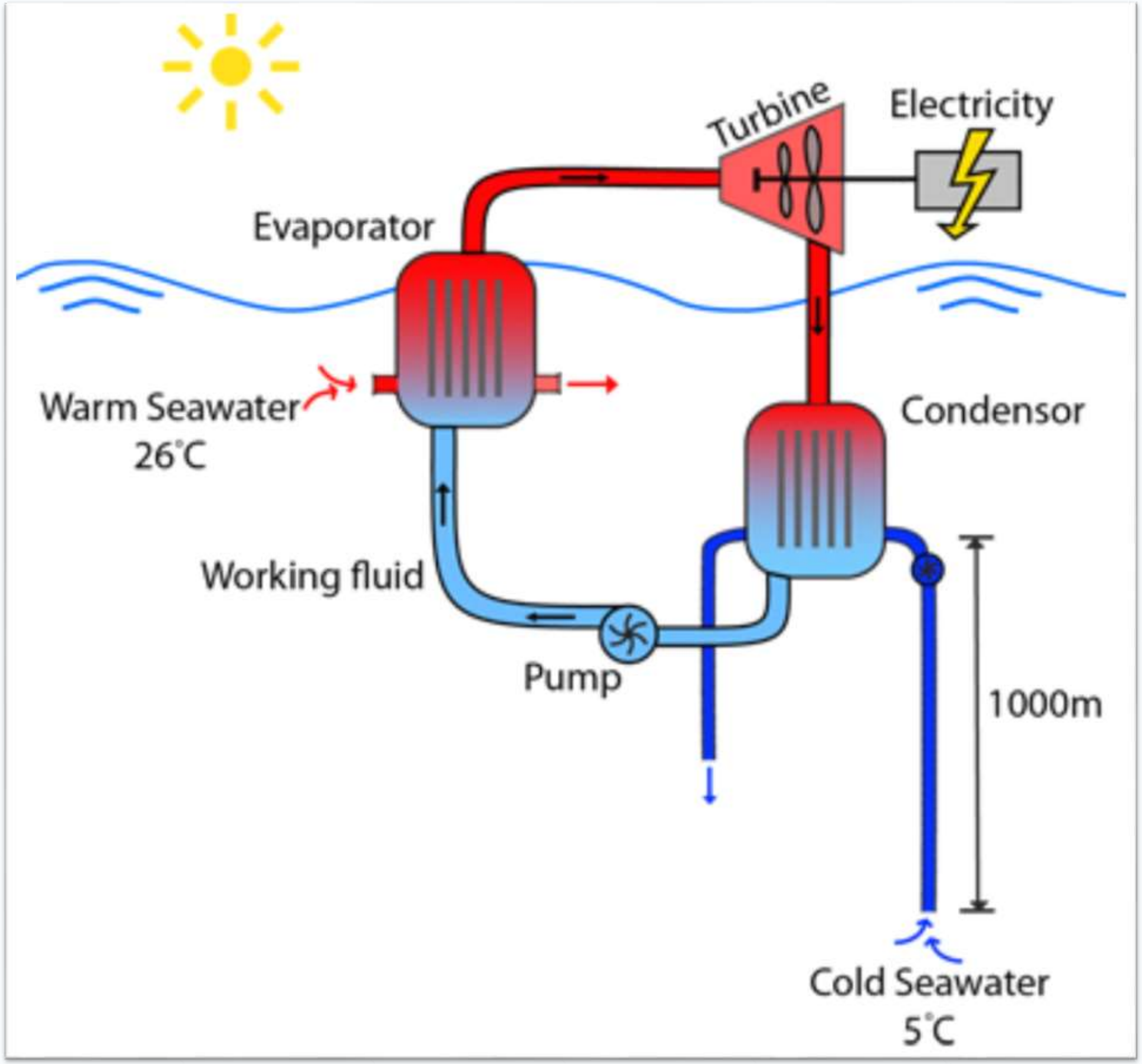


Fig 3. OTEC-CC diagram. Source INDC, 2020

Note the rapid change between 100 and 1000 meters. The temperature is nearly constant after 1500 meters depth.

Classic OTEC features

- Small thermal gradient

- Deep water pumping

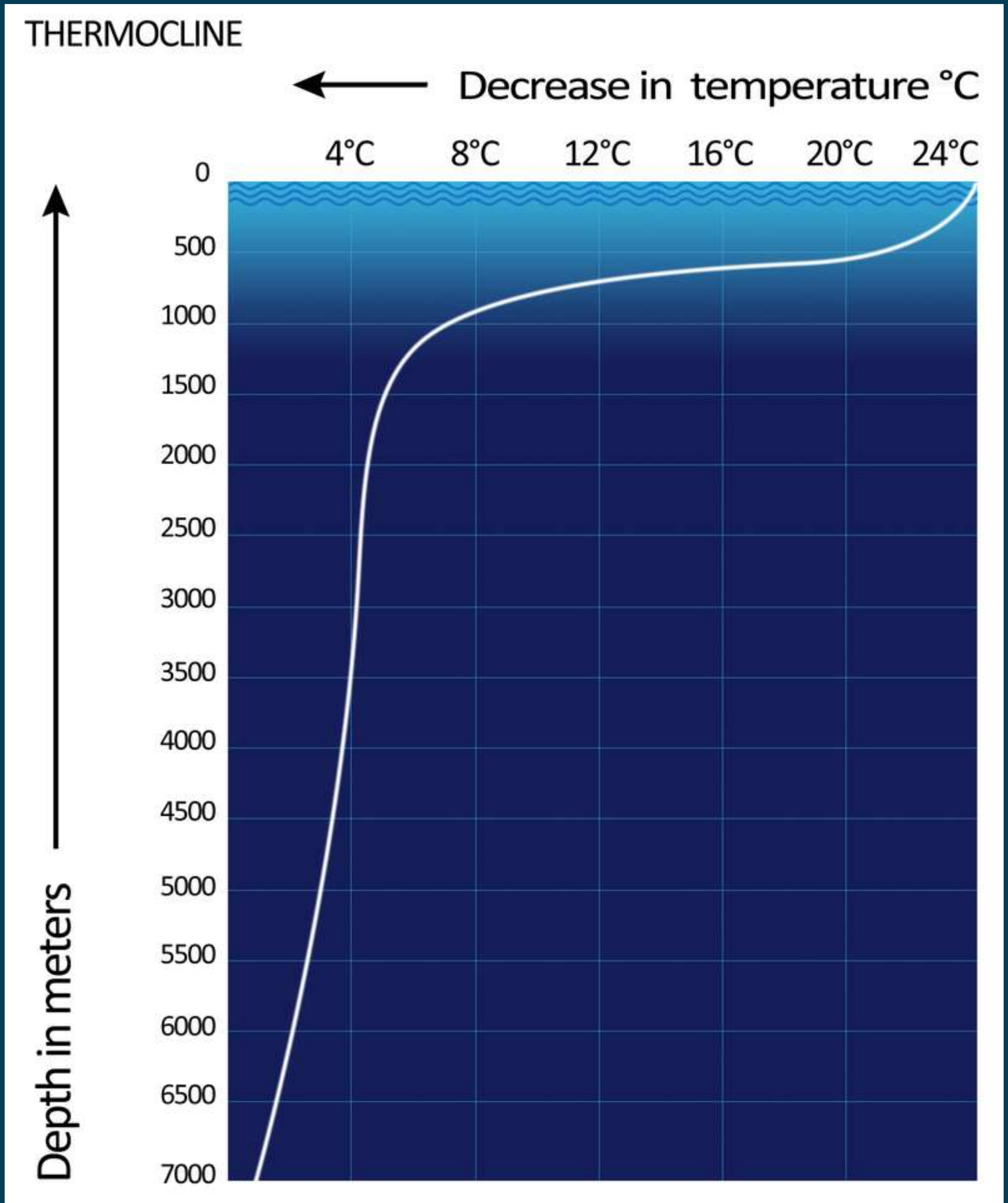


Fig 4. Graph showing a tropical ocean thermocline (depth vs. temperature).

“

Is there another natural resource where OTEC can be applied?

Geothermal manifestations in the Northwest of Mexico

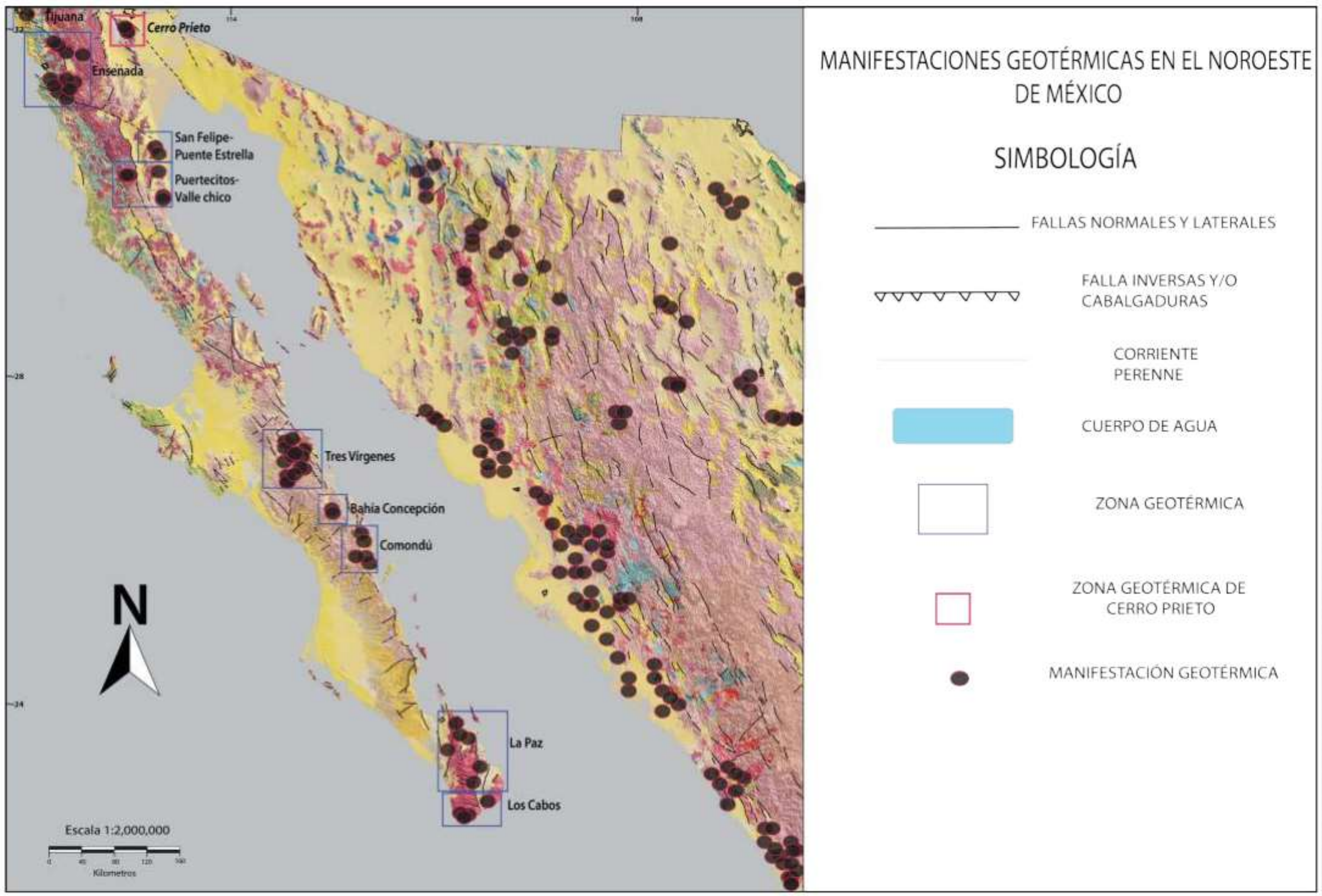


Fig. 5. Geothermal anomalies of North-West Mexico.

Source: Universidad Politécnica de Baja California (2011) and Servicio Geológico Mexicano (2007)

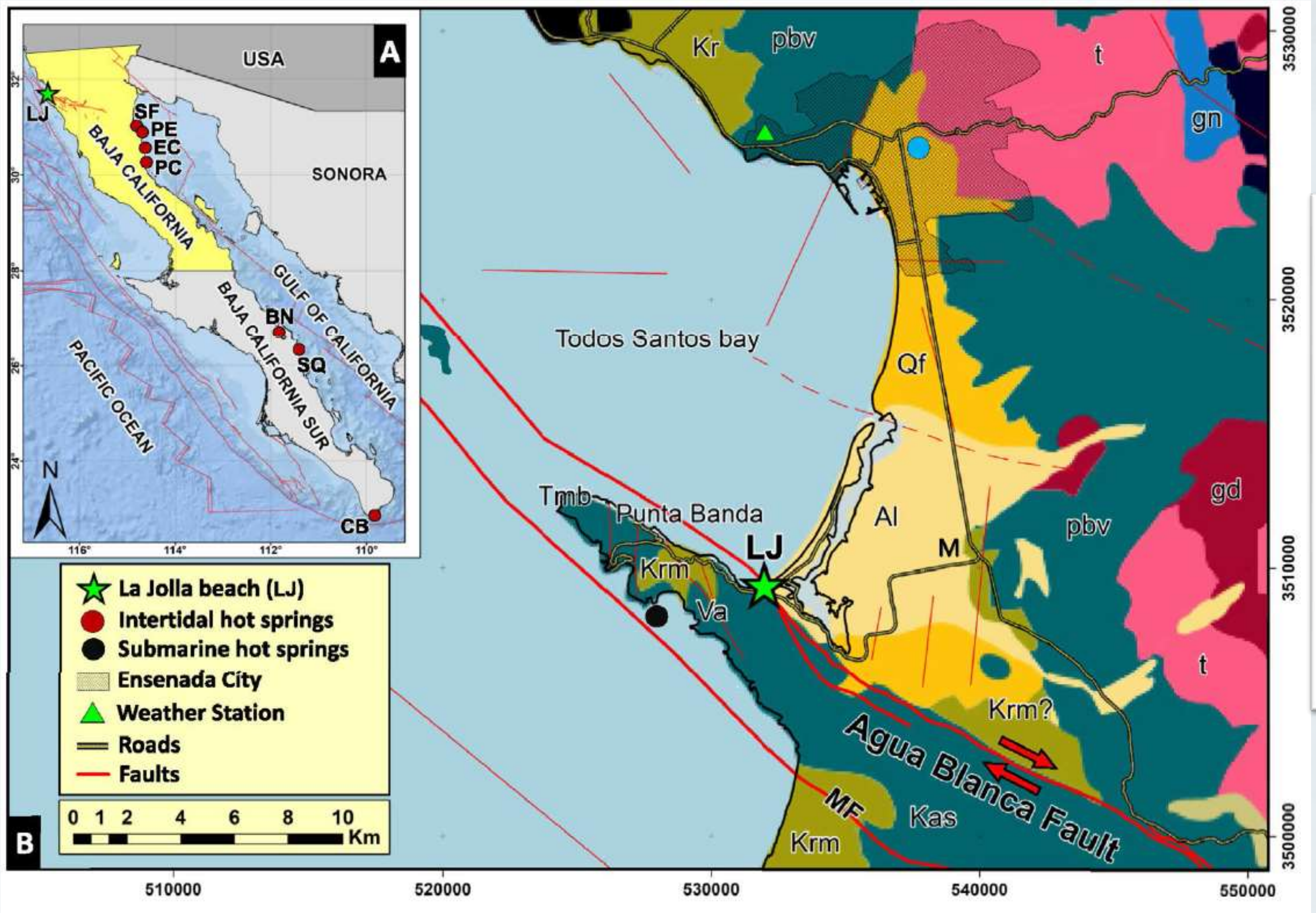


Fig. 6. La Jolla Beach Location. Source: Carbajal et al., 2020.

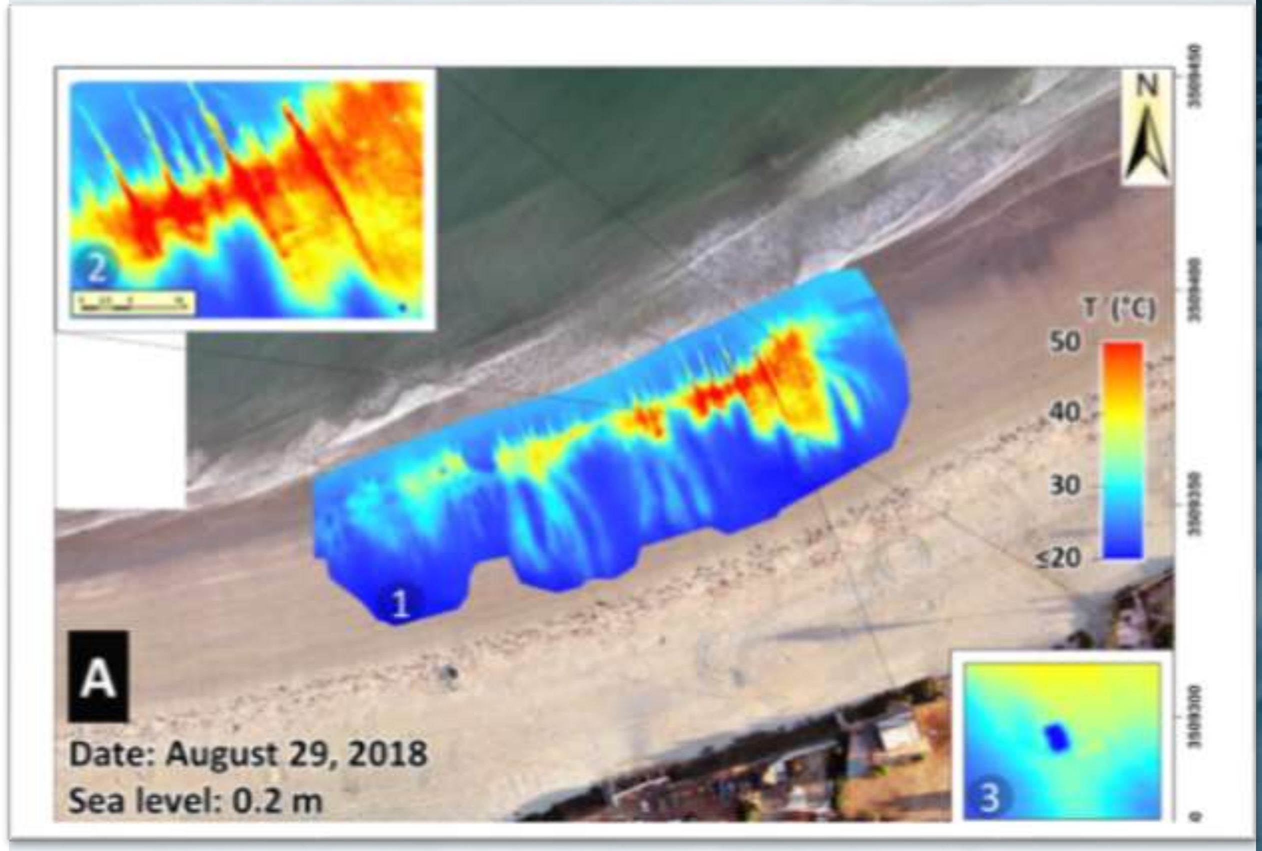
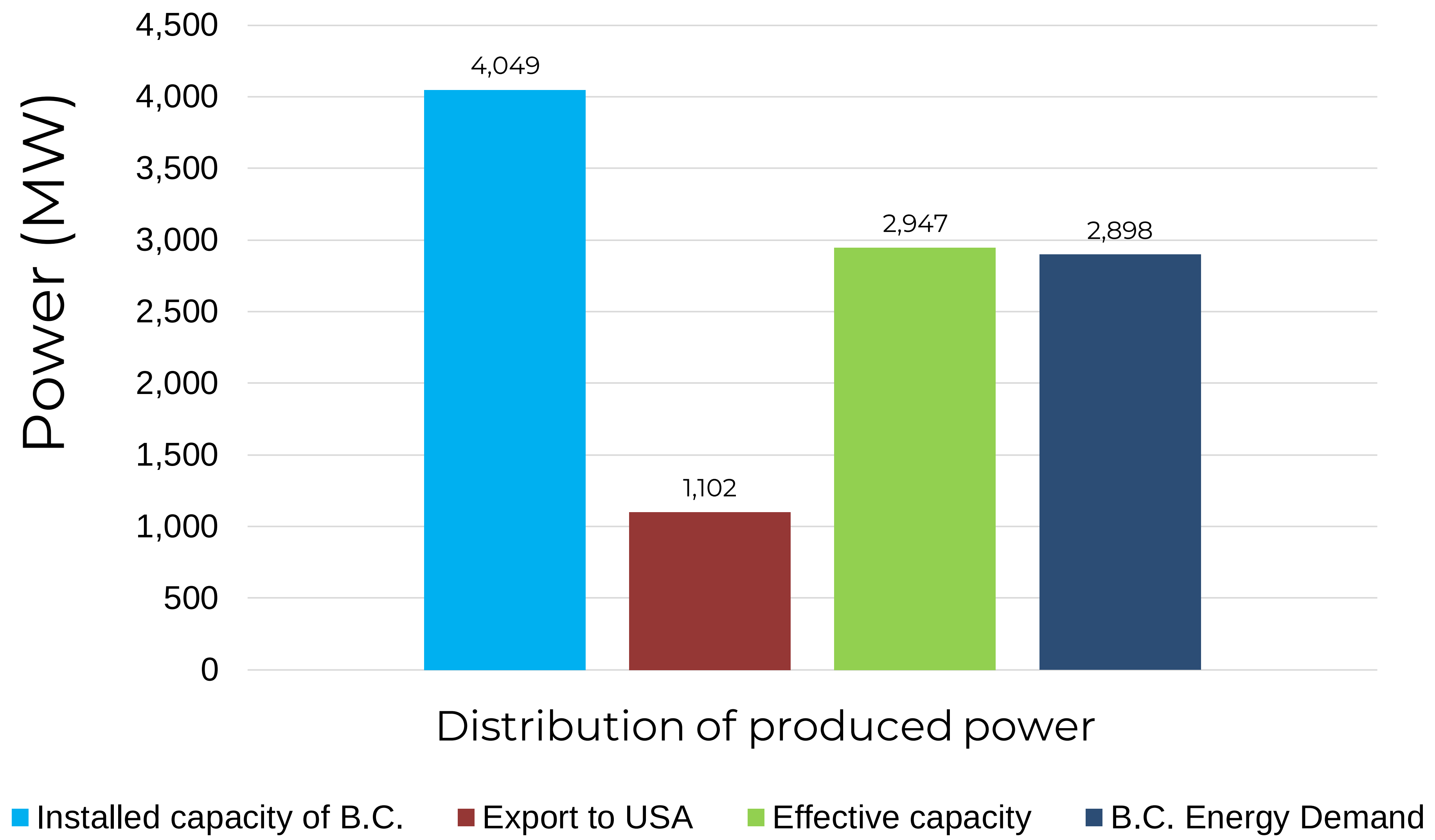


Fig. 7. Orthomosaic TIR of thermal anomaly La Jolla beach, Ensenada, Mexico. Source: Carbajal et al., (2020).

Electrical power of B.C. in 2019



Graph 1. Electrical power generated and distributed in B.C in 2019. Source: Institute of the Americas, 2019.

Considering that not all facilities are fully operational at the same time, actual capacity is insufficient to meet current peak load and the projected increases in demand.

(Institute of the Americas, 2019)

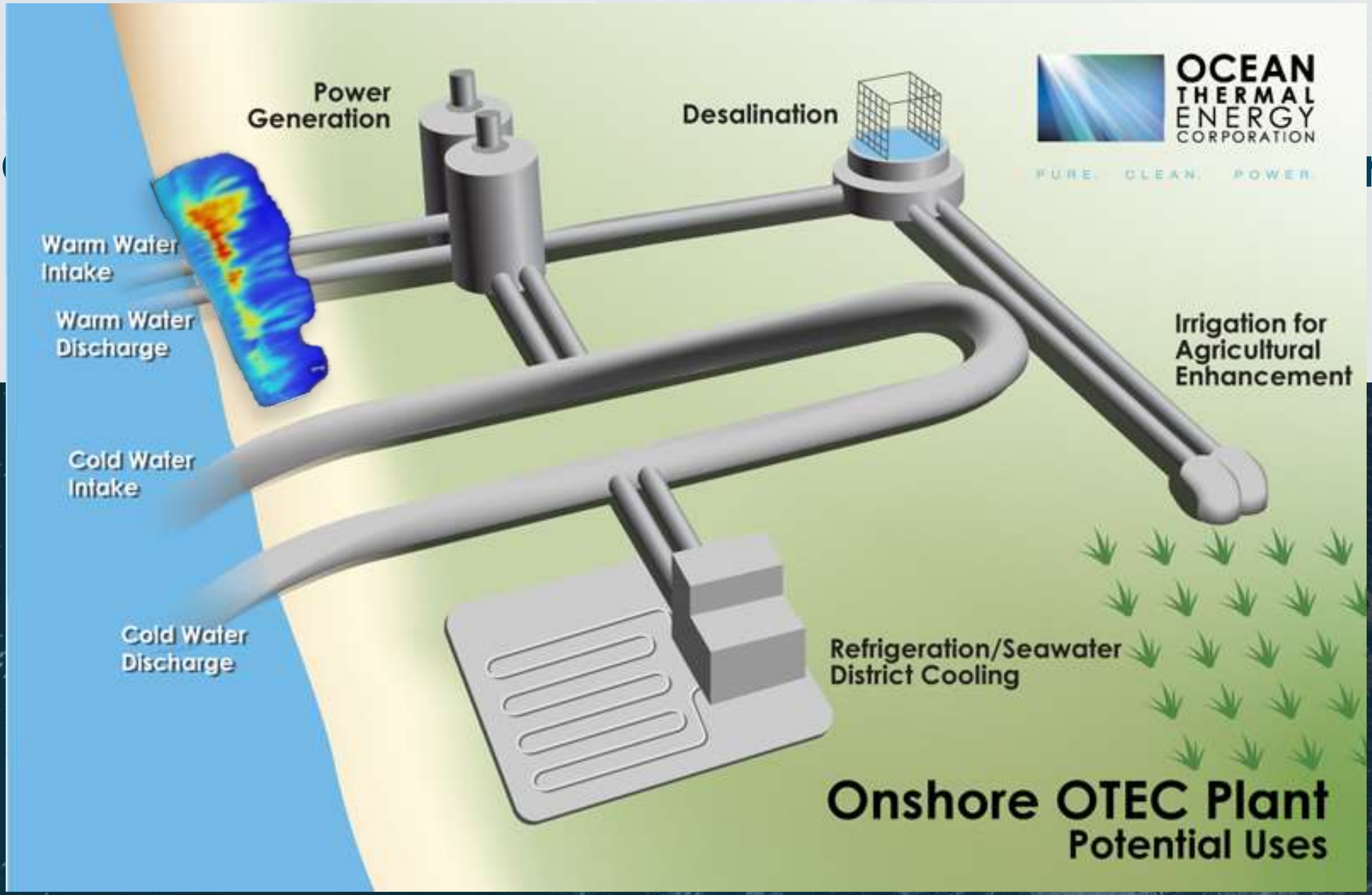
During 2022, in Ensenada

84.96%

of the population has frequent water cuts

(Secretaría para el Manejo, Saneamiento y Protección del Agua, 2022)

OTWEC


Power Generation
Desalination
OCEAN THERMAL ENERGY CORPORATION
PURE. CLEAN. POWER.
Warm Water Intake
Warm Water Discharge
Irrigation for Agricultural Enhancement
Cold Water Intake
Cold Water Discharge
Refrigeration/Seawater District Cooling
Onshore OTEC Plant
Potential Uses

Objectives

General

Develop the basic engineering of an open cycle OTWEC plant for the production of electrical energy and desalinated water from the thermal gradient of the hot springs on La Jolla Beach and the surface seawater of the Pacific Ocean in Ensenada, Baja California, Mexico.

Specific

- Determine the amount of electrical energy and desalinated water produced by natural flow.
- Sizing a plant to cover the water deficit of Ensenada, B. C. until 2030.
- Evaluate greenhouse gas emissions
- Identify the main environmental impacts

Front End Loading

VISUALIZATION PHASE

Documentary research

CONCEPTUAL ENGINEERING

Evaluation of 2 scenarios: considering the natural mass flow of the source and the mass flow of the source to cover the deficit until 2030

BASIC ENGINEERING

Mass and energy balances and effects on population

ENVIRONMENTAL EVALUATION

CO_2
Identification of environmental impacts

OTWEC Diagram

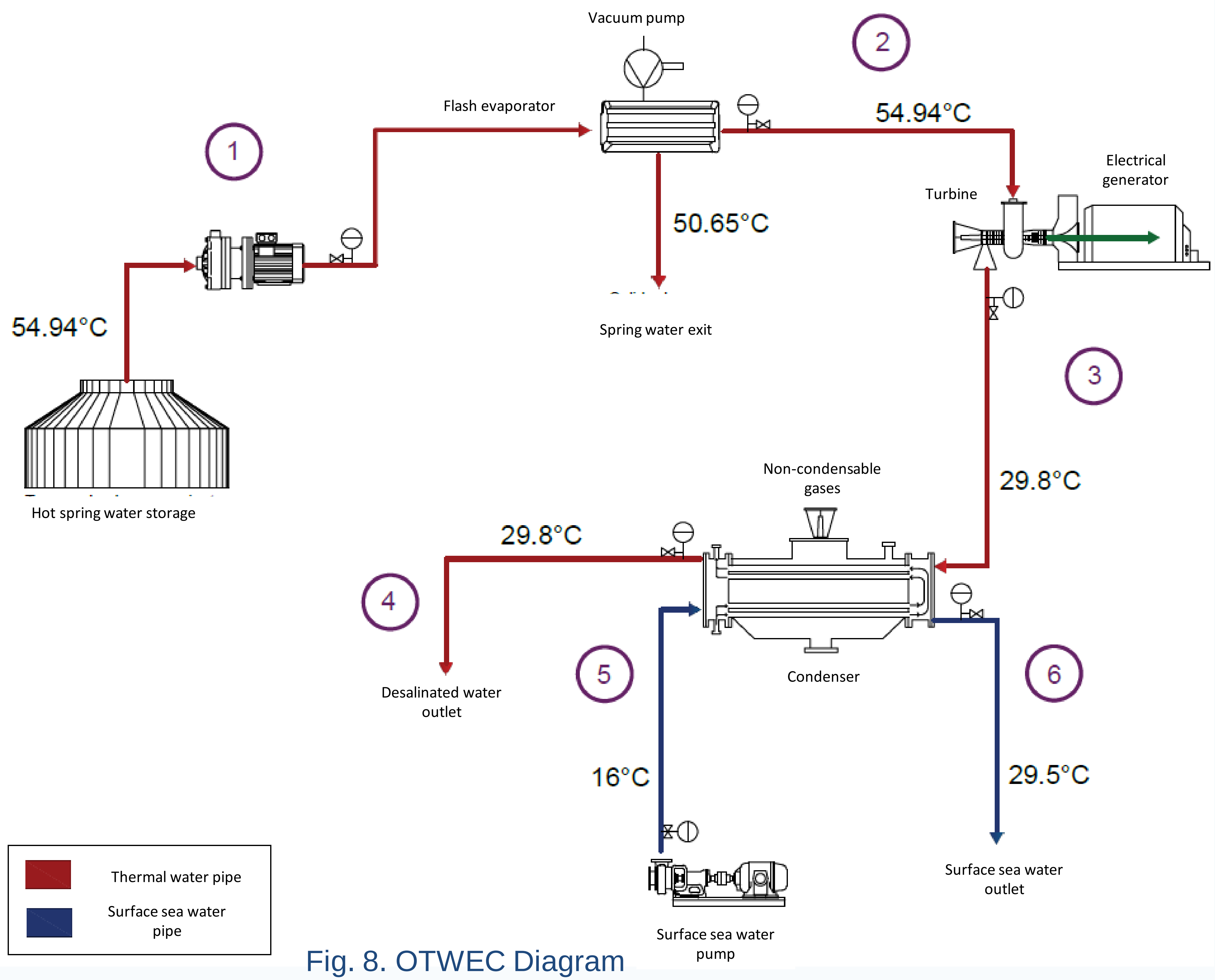
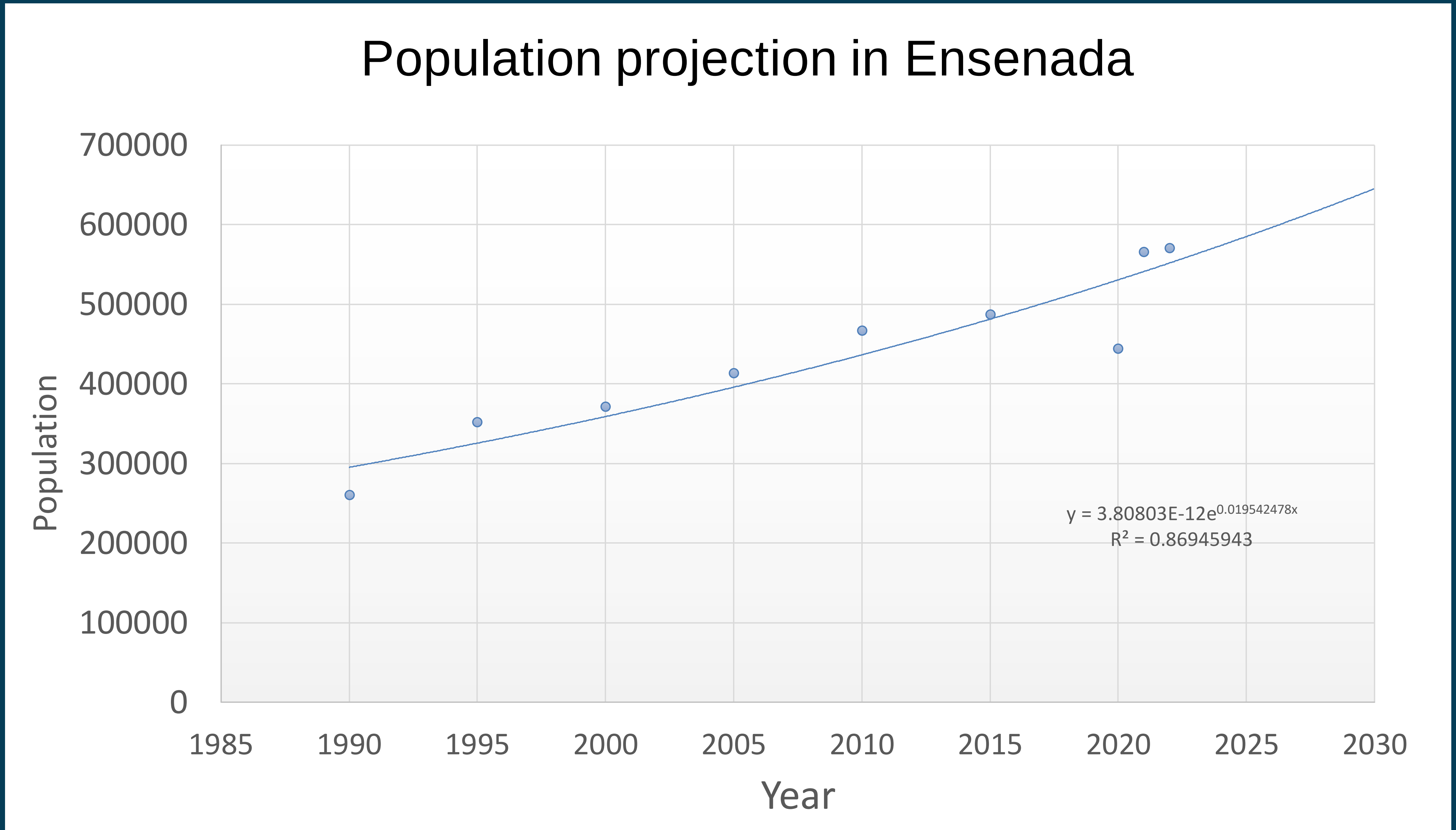


Fig. 8. OTWEC Diagram

- Stationary conditions.
- There are no energy losses due to friction, heat exchange with the environment.
- The system reaches thermodynamic equilibrium

Projection of water deficit and energy demand for 2030

The percentage of the population that does not have water service, according to SEPROA (2022), is 15.04%, and with the historical censuses of the INEGI (2021) and data from SEPROA (2022), an estimate of the population in the Municipality of Ensenada for the year 2030.



Graph 2. Population projection in Ensenada

Year	Maximum energy demand (MW)
2018	2800
2019	2898
2020	3016
2021	3108
2022	3205
2023	3300
2024	3429
2025	3530
2028	3839
2030	4046

Table 1 . Maximum energy demand projection in Ensenada

Projection of water deficit and energy demand for 2030

In 2030, the projected population in the Municipality of Ensenada is **645,204 people**, so if the **15.04%** deficit were to remain, there would be 97,039 people who do not have a water supply. According to SECTUR (2018), the average water use per average person in the Municipality is 140.2 L/habitant/day

$$\text{Water deficit} = 97{,}039 \text{ people}\left(140.2\,\frac{\text{L}}{\text{person} * \text{day}}\right)\left(365\,\frac{\text{days}}{\text{year}}\right) = 4{,}965{,}776{,}747\ \text{L/year}$$

$$\text{Desalination} = 4{,}965{,}776{,}747\ \frac{\text{L}}{\text{year}}\left(\frac{1\ \text{year}}{365\ \text{days}}\right)\left(\frac{1\ \text{day}}{24\ \text{hours}}\right)\left(\frac{1\ \text{hour}}{3600\ \text{s}}\right) = 157.4637\,\frac{\text{L}}{\text{s}}$$

Greenhouse gases

In this section, CO_2 emissions from various energy generation sources are evaluated during their operational phase, using the following formula:

$$\mathrm{CO_2\ Generation}\left(\frac{\mathrm{Ton}}{\mathrm{year}}\right) = \mathrm{Nominal\ capacity} * 8760\ \mathrm{h} * \mathrm{Plant\ factor}\ (\%) * \mathrm{Generation}\ \frac{\mathrm{CO_2}}{\mathrm{kWh}}$$

It is compared against other sources of electrical energy generation installed in Baja California. In the case of OTWEC-OC, the measurements made by Green and Guenther (1990) in their experimental work with OTEC-OC are taken.

Leopold matrix

These show the relationship between the actions of a project on one axis and the environmental factors on the other axis of the matrix.

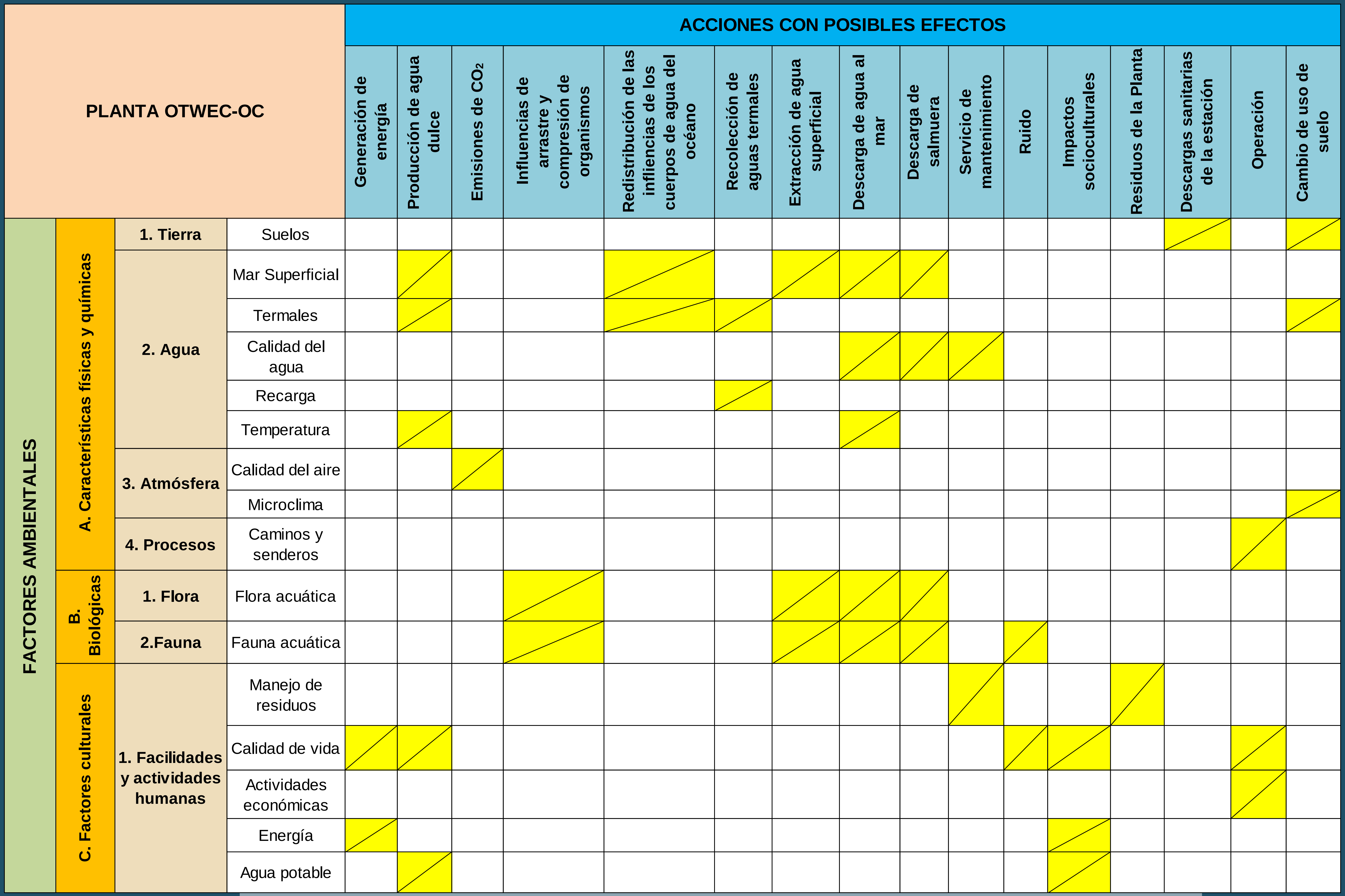


Fig. 9. Leopold matrix for OWTEC-OC

Results

OTWEC-OC plant natural mass flow

Net power: 281.6 kW

Desalination: 2.41 kg/s

OTWEC-OC plant with mass flow to cover the 2030 deficit

Net power: 18.4 MW

Desalination: 157.46 kg/s

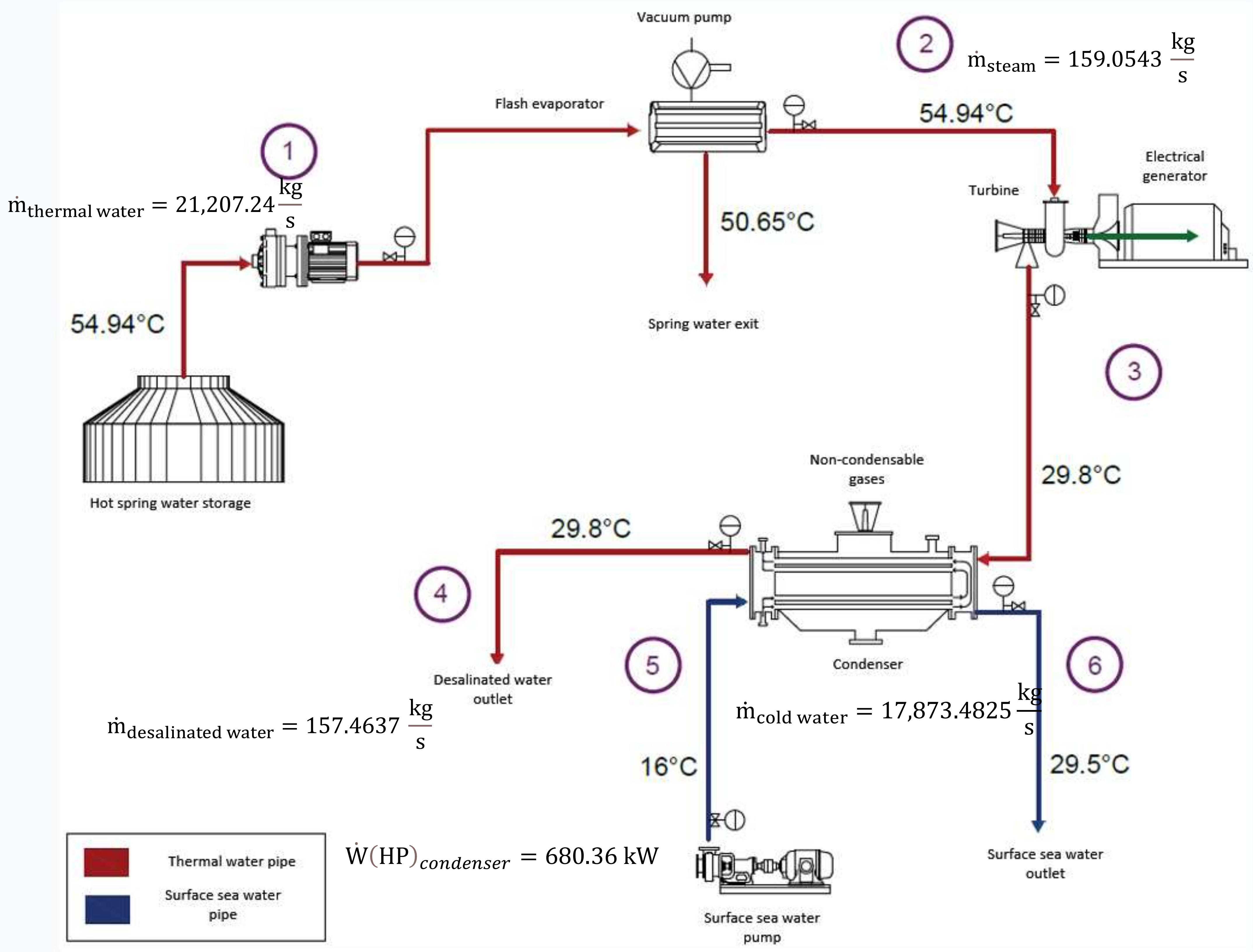


Fig. 10. OTWEC-OC plant diagraman with results.

Variables	Description	Natural Flow	Deficit Flow	Units
η_{carnot}	Carnot efficiency	11.87	11.87	
η_{OTWEC}	Cycle efficiency	4.9	4.9	
$x_{2,3r}$	Steam quality at the turbine outlet	0.96	0.96	
$\dot{m}_H$	Mass flow entering the evaporator	325	21,207.24	kg/s
$\dot{m}_{exit}$	Mass flow leaving the brine	322.56	21,048.19	kg/s
$\dot{m}_{evap}$	Mass flow that continues in the cycle	2.44	101.43	kg/s
$\dot{m}_6$	Mass flow entering and leaving the condenser	273.91	21,048.19	kg/s
$\dot{m}_{desalinated}$	Desalinated water mass flow	2.41	157.46	kg/s
$\dot{Q}_{evaporator}$	Evaporator input heat	5756.69	375,641.47	kW
$\dot{Q}_{condenser}$	Heat output in the condenser	5729.49	373,866.88	kJ/s
$\dot{W}_{turbine}$	Turbine power	357.31	23,315.63	kW
$\dot{W}_{generator}$	Generator power	321.58	20,984.07	kW
$\dot{W}_{pumpev}$	Pump power for warm water	29.6	1903.72	kW
$\dot{W}_{bombacond}$	Pump power for cold water	10.42	680.36	kW
$\dot{W}_{netpower}$	Net power	281.56	18,4000	kW

Table 2. Main results of the OTWEC-OC plant with natural mass flow and to cover the deficit

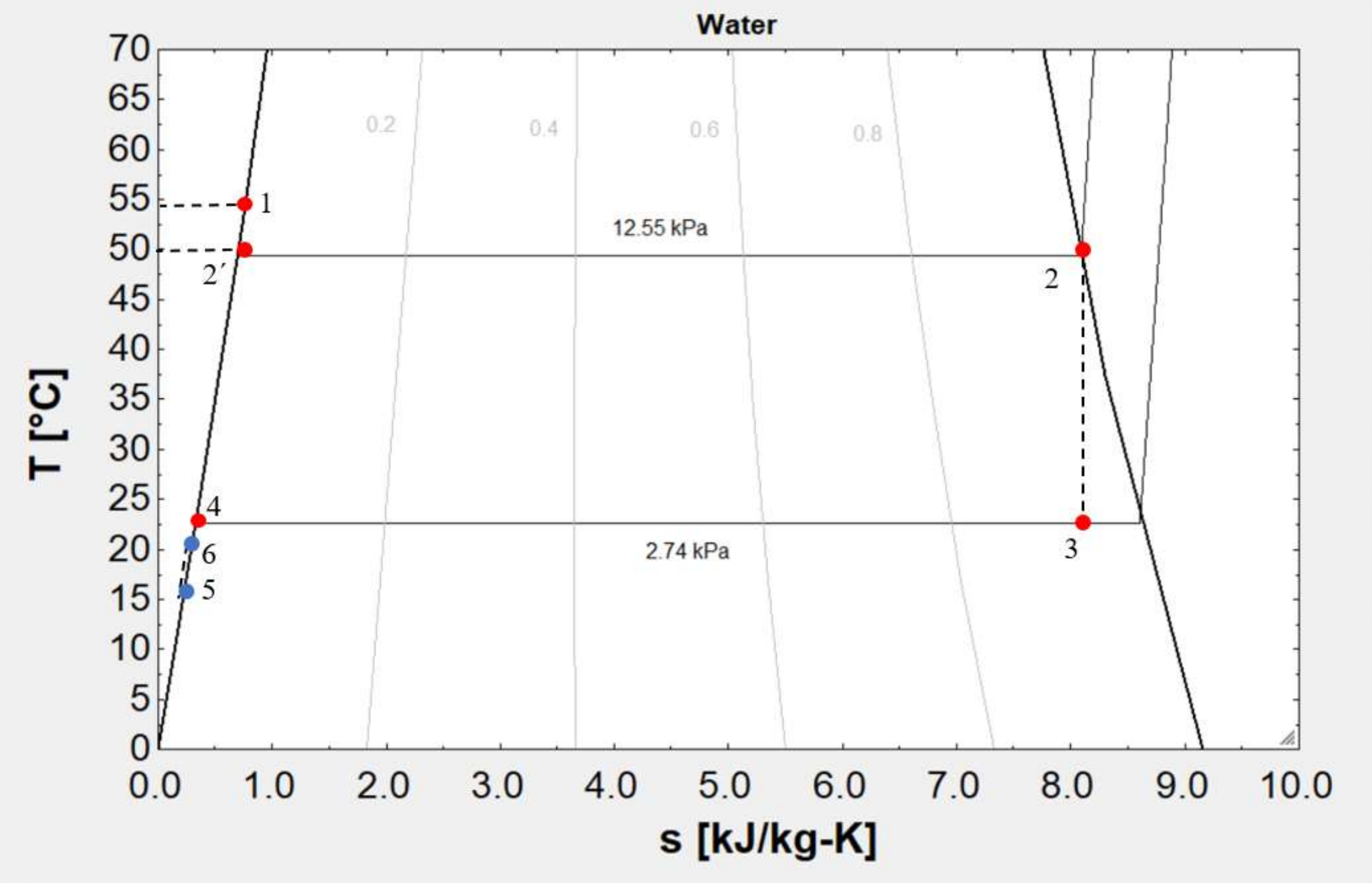
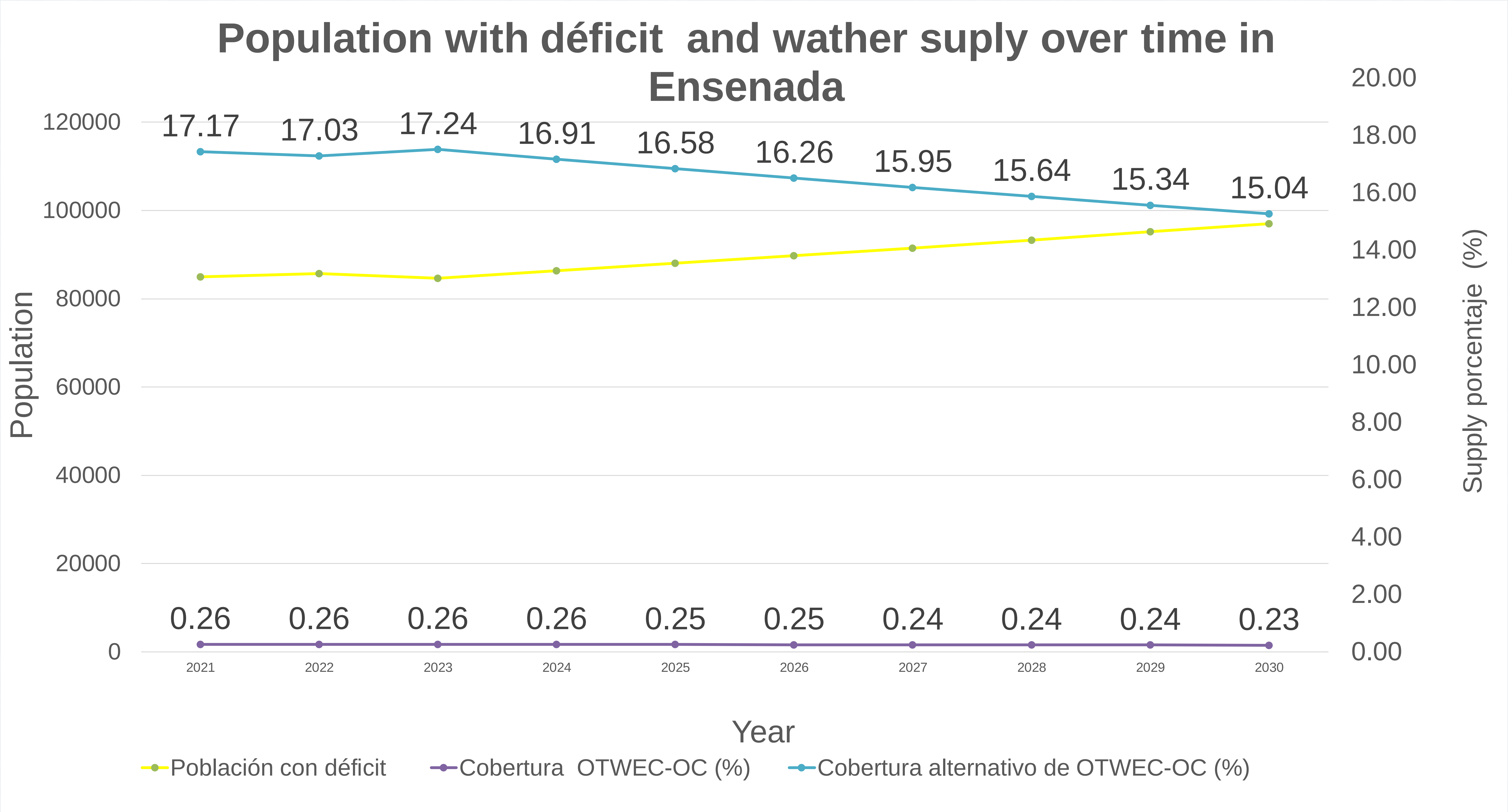
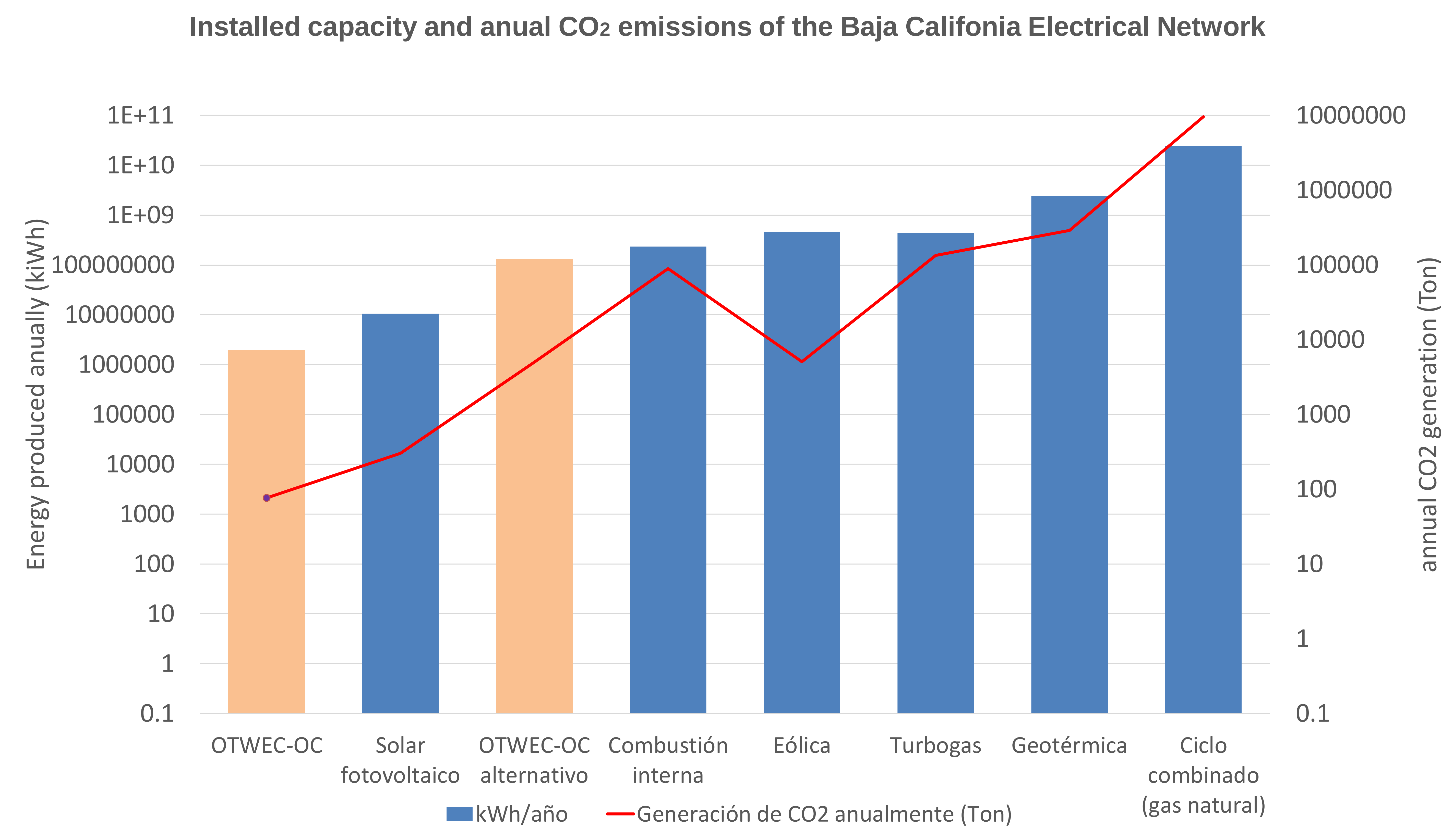


Fig. 11. Thermodynamic states in temperature-entropy diagram of the OTWEC-OC plant.



Graph 3: Population and water supply in Ensenada.



Graph 4. Production capacity vs CO_2 emissions

Leopold matrix for an OTWEC-OC plant

Negative impacts

CO_2 emissions

Redistribution of influences of ocean water bodies.

Water discharges into the sea in brine

Sociocultural impacts (landscape)

Positive impacts

Energy generation

Production of desalinated water

Sociocultural impacts (quality of life)

Conclusions

The design of an **OTWEC-OC** plant was carried out for the production of energy and desalinated water, taking advantage of the thermal gradient between the thermal waters of Playa La Jolla and the surface seawater of the Pacific Ocean. The **positive** impact is in the **production of water** and **energy**, which improves **people's quality** of life.

Conclusions

The OTWEC-OC plant (**281.56 kW**, 2.41 L/s), would have a daily generation of **208,224 m^3** of desalinated water, would be self-sufficient in energy for its operation, in addition to emitting 75.96 tons of CO_2 yearly, it is one of the least polluting technologies in the region during operation.

Conclusions

Among the most relevant problems in the region, the **need for water** for the municipality was identified, a projection of the deficit was made for **2030** and the OTWEC-OC plant was resized to cover the lack of the resource by 100%. It would have a **daily production of 13,604.87 m³** of desalinated water, it would send 4,964.47 tons of CO_2 into the atmosphere, being 65.35 times more than the first, which has **a net production of 18.4 MW.**

Conclusions

41 interactions **were identified** with possible positive and negative impacts on environmental factors, among the highest negative impacts is **the discharge of brine** due to its **temperature** and **salinity**, as well as the redistribution of the water body of the hot spring in the ocean. The positive impact is in the production of **water** and **energy**, which improves people's quality of life.

More studies are needed to quantitatively determine environmental impacts.

Conclusions

This study is a **great tool for decision-making** in the energy industry, since it opens the panorama on the behavior of electricity generation and opens **new lines of research.**

References

Carbajal-Martínez, D., Peiffer, L., Hinojosa-Corona, A., Trasviña-Castro, A., Arregui-Ojeda, S. M., Carranza-Chávez, F. J., Flores-Luna, C., ..., Casallas-Moreno, K. L. (2020). UAV-based thermal imaging and heat output estimation of a coastal geothermal resource: La Jolla beach, Baja California, Mexico. Renewable Energy, 168: 1364-1376.

García, A. (2018). Determination of the Potential Thermal Gradient for the Mexican Pacific Ocean. MDPI. https://www.mdpi.com/2077-1312/6/1/20

National Institute of Ocean Technology (NIOT). (2018). Ministry of Earth Science, Govt. of India. Annual Report (2017-18). Recuperado de https://www.niot.res.in/documents/admin_annual_report/Annual_report-2017-18.pdf

National Institute of Ocean Technology (NIOT). (2019). Ministry of Earth Science, Govt. of India. Annual Report (2018-19). Recuperado de https://www.niot.res.in/documents/admin_annual_report/Annul_report_2018-2019.pdf

National Institute of Ocean Technology (NIOT). (2021). Ministry of Earth Science, Govt. of India. Annual Report (2019-20). Recuperado de https://www.niot.res.in/documents/admin_annual_report/NIOT%20Annual%20Report%202019-2020.pdf

Universidad Autónoma de Baja California. (2017). Foro Universitario. Obtenido de https://centrosconacyt.mx/objeto/agua-en-ensenada/

Universidad del Caribe. (2021). Prototipo de una Planta OTEC. Obtenido de https://www.unicaribe.mx/noticias/instalan-en-unicaribe-el-primer-prototipo-de-una-planta-otec-en-latinoamerica#:~:text=%2D%20La%20Universidad%20del%20Caribe%20cuenta,t%C3%A9rmico%20de%20los%20mares%20mexicanos.

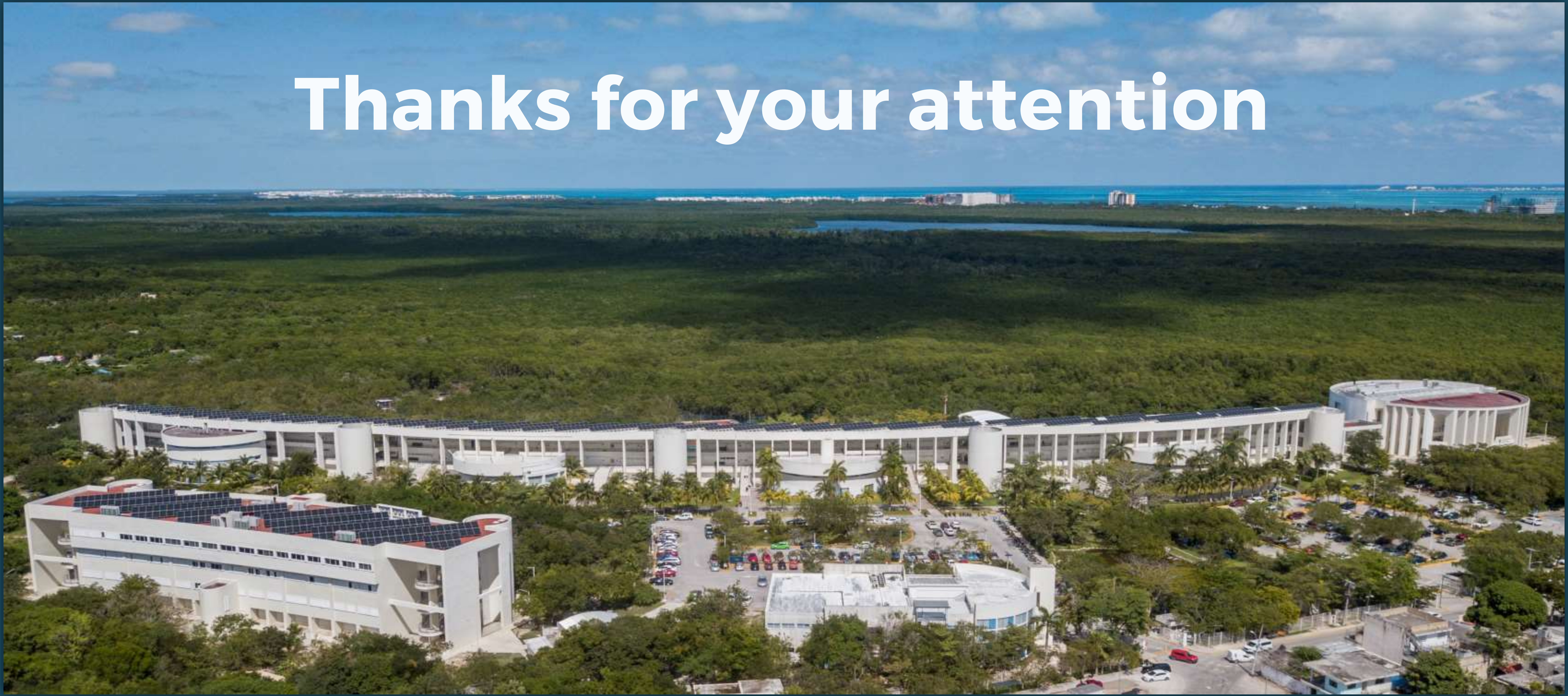
Tobal-Cupul, J.G.; Garduño-Ruiz, E.P.; Gorr-Pozzi, E.; Olmedo-González, J.; Martínez, E.D.; Rosales, A.; Navarro-Moreno, D.D.; Benítez-Gallardo, J.E.; García-Vega, F.; Wang, M.; An Assessment of the Financial Feasibility of an OTEC Ecopark: A Case Study at Cozumel Island. Sustainability 2022, 14, 4654. https://doi.org/10.3390/su14084654

PAMEC.Energy Association

CEMIE-Océano Asociación Civil

Universidad del Caribe
2000 CANCUN, QUINTANA ROO, MÉXICO
CONOCIMIENTO Y CULTURA PARA EL DESARROLLO HUMANO

Thanks for your attention



Contact: 180300399@ucaribe.edu.mx