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Tidal Energy as a Sustainable Source of Power for Marine Transport Stations in Dubai Creek & Water Canal

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Abstract

This research explores the feasibility and economic viability of generating tidal power from the stations of the Roads and Transport Authority RTA Dubai. The focus of the study is to enhance sustainable mobility and increase the share of renewable energy in Dubai. The station locations were chosen based on resource assessments and calculations of water currents velocity reflecting a deliberate and strategic approach to harnessing the tidal energy potential in the area.

After conducting a resource assessment and financial analysis, the study predicts an annual collective tidal energy output from these stations to be 129.83 megawatts-hours, which translates into a substantial annual economic value of 4,284,680.4 dirhams. This economic feasibility positions the tidal power as a viable and beneficial solution.

The versatility of the identified output is a key highlight, as it proves capable of meeting the energy consumption needs of RTA marine electric vessels and fulfilling the power requirements of the stations themselves by covering 35% of the energy demand of the selected stations and increasing the renewable energy share by more than 20% for all the sta-tions located in Dubai creek and water canal. The option to store tidal energy in batteries or seamlessly connect it to the grid adds a layer of flexibility, enabling efficient energy management.

Dubai is committed to sustainability and integrating renewable energy. This research has provided a practical blueprint for successfully implementing tidal power solutions. This blueprint can empower policymakers and energy professionals to actively contribute to a greener and more resilient energy landscape. As energy storage technologies and grid connectivity continue to advance, the feasibility and impact of tidal power initiatives are expected to significantly improve. These advancements are paving the way for a sustainable and environmentally conscious future in Dubai.

Keywords: Sustainability, Tidal energy, generator, Renewable energy.

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Vol 2 Issue 1 (2024) Pages (4 –11)

1. Introduction

With the global increase in the demand for energy and the demand in the United Arab Emirates which was about 27.6 GW in 2019 in UAE and is expected to in-crease according to Frost and Sullivan up to 67 GW in 2030 [1], the Emirate of Dubai has launched the Dubai Clean Energy Strategy 2050, which aims to transition Dubai towards a sustainable future and more share for clean energy, Dubai has set a renewable energy target of 5 percent by 2030, and a clean energy target of 75 per-cent by 2050 [2].

According to the annual report from the Regulatory & Supervisory Bureau for Electricity & Water in Dubai, by 2030, the aim is to raise energy efficiency by 30% and the electricity generation mix, currently dominated by gas, is to be transformed, particularly by the addition of large- and small-scale renewables [2]. A report by the International Renewable Energy Agency IRENA concluded that an annual saving of USD 1.9 billion could be generated by 2030 from a 10% share of renewable energy in the total energy mix [3].

In 2020, the percentage of electricity generated from non-renewable sources was 96%, and 4% from renewable sources, and more than 90% of the renewable energy generation is from Solar systems according to the UAE energy profile published by the International Renewable Energy Agency IRENA [4].

Solar power has been a focus of renewable energy development in the UAE. large-scale solar projects have been implemented, including the Mohammed bin Rashid Al Maktoum Solar Park in Dubai. This solar park is one of the largest in the world and is expected to contribute significantly to the renewable energy mix. The major renewable power projects in UAE are provided in Table 1. However, to ensure sustainable and eco-friendly electricity generation, exploring alternative sources to diversify renewable energy is necessary.

Project	Capacity	Emirate
Mohammad Bin Rashid Al Maktoum Solar Park	900 megawatts-hours	Dubai
Noor Solar park	1.7 Gigawatts-hours	Abu Dhabi

Table 1. Major renewable power projects in UAE [1]

As per IRENA, one terawatt of energy is available to be extracted worldwide, it is expected that 200 Megawatt to be generated using tidal current technologies by 2020 [5].

This paper focuses on tidal energy that can be extracted from Marine stations in Dubai Creek, as no studies are available on the potential of extracting tidal energy from Marine stations that belong to Roads and Transport Authority RTA in Dubai Creek and Dubai Canal.

1.1. Tidal Energy

The tidal force is caused by the moon's gravitational force which results in a bulge for the earth and its water on the side closest to the moon, another bulge also occurs on the side farthest from the moon caused by inertia, these two bulges out on both sides causes the High tide as illustrated in Figure 1.

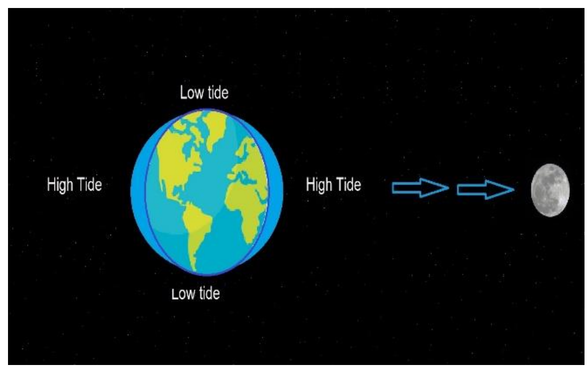


Figure 1. Water bulges result from the moon's gravity on Earth

The movement of the sun also has an impact on the tide. When the sun aligns with the moon twice a month, it results in an extremely high tide. This happens during the new moon and full moon phases when the gravitational forces of the sun and moon work together. This phenomenon is known as Spring tide. Conversely, when the sun and moon's gravitational forces work against each other, it results in a weaker tide. This is known as neap tide. [6]. Figure 2. Illustrates the influence of both the sun and the moon on the water of the Earth.

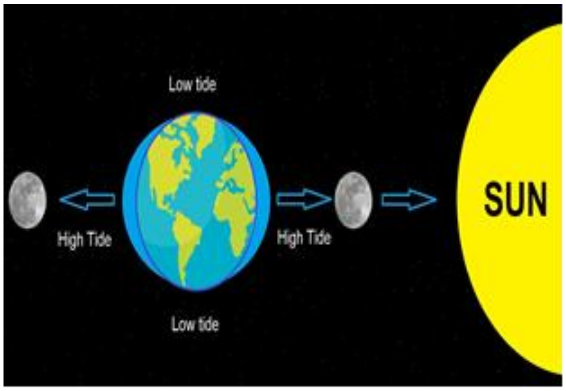


Figure 2. Water bulge resulted from the moon and sun's gravity on Earth

To harness the tidal force, the kinetic or potential energy resulting from the movement of water caused by the moon's gravitational force is converted into electricity using electrical generators. The regular and consistent nature of Tide encourages the use of this type of renew-able energy. Tidal energy can be extracted using two methods [5]:

1. Tidal currents: In this method, a turbine is placed under water and the current caused by the tide pushes the turbine blades and generates a spin force, the turbine is connected to an electric generator, which converts the kinetic energy into electric energy. This method requires finding a location where currents are strong enough to produce the required energy; also, the maintenance of this type of system is difficult due to the harsh marine environment. However, this method has a low impact on the environment.
2. Tidal Range: This method is similar to water dams where the potential energy is used utilizing the difference in water levels between high and low tides. The system captures water behind a dam during high tide and releases it through turbines to generate electricity during low tide. This method is more efficient compared to tidal streams but more costly and has more impact on the environment.

In certain scenarios, it may be beneficial to use a combined approach that utilizes both tidal currents and tidal ranges to optimize energy production. The decision to use either tidal currents or tidal ranges should be based on a thorough evaluation of the specific conditions, and site-specific studies and resource assessments to deter-mine the most suitable tidal energy solution.

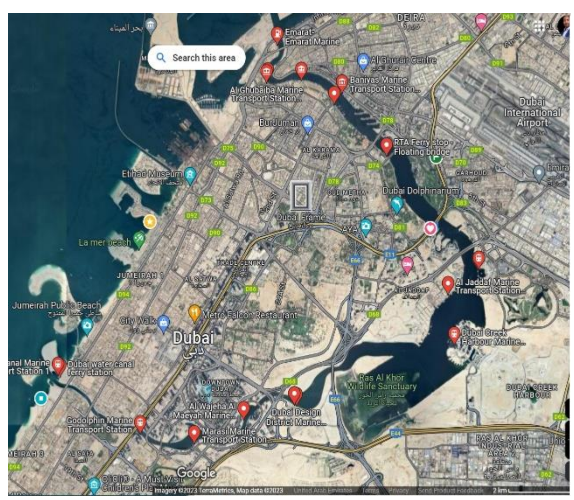
1.2. Layout of Dubai Creek and Water Canal

Dubai Creek is a 6.5 to 7 m deep waterway located in the Emirate of Dubai that extends approximately 14 km. The creek's entrance starts near Port Rashid with a width of 200m and this width varies in width but in-creases up to 1200 m towards Ras Al Khor Wildlife Sanctuary. In November 2016, the Water Canal project was completed, and the waterway extended for the length of 24 km approximately [7]. Figure 3. Illustrates the Layout of Dubai Creek and Water Canal

Figure 3. Layout of Dubai Creek and Water Canal

1.3. Locations of marine stations

There are 23 Marine transport stations located on both sides of Dubai Creek and the water canal as shown in figure 4. They serve RTA marine transport vessels which are operated in Dubai creek and canal and other areas as well.



Emirati Journal of Environment, Sustainability, and Climate Change
Vol 2 Issue 1 (2024) Pages (4 –11)

Figure 3. Layout of Dubai Creek and Water Canal

2. Methodologies of Research

The methodology employed in this study is quantitative, relying on observations, theoretical analyses, and the assessment of resources from both technical and financial perspectives.

To evaluate tidal energy resources, it is crucial to consider-er the water velocity in various areas of Dubai Creek and the water canal. In this investigation, the behaviour of tides was examined in November 2022, utilizing data obtained from the National Centre of Meteorology (NCM) in the United Arab Emirates. The velocities of the water stream were analysed based on a study that employed a two-dimensional hydrodynamic model to assess their behaviour in Dubai Creek and the canal [8]. Additionally, water velocities were measured at different locations in Dubai Creek and the water canal using a water speed probe. The recorded data identified locations with high-velocity water streams. The potential power was then calculated using the velocity data and other assumptions.

In the financial analysis, the energy calculation resulting from the resources assessment is translated into a monetary value, taking into account the energy tariff set by the Dubai Electricity and Water Authority (DEWA). A comparison is made between the annual energy production and the consumption of electric vessels, considering the maximum output power of the engines during operational hours. Additionally, the annual consumption of the selected stations, based on the resources assessment, is calculated and compared with the tidal energy output from the turbines. Given the absence of prior cases related to this study, the capital costs (Capex) and operating expenditures (Opex) are assessed in terms of cost per unit of energy, with data sourced from the International Renewable Energy Agency (IRENA) [5]

2.1. Resources assessment

Assessing tidal energy resources in Dubai Creek involves evaluating tidal movements, the resulting water currents, and their speed. To analyze tidal data in Dubai Creek, the pattern of tide and variations in water levels are examined for a period during November 2022. The height of low and high tide data for one week are pro-vided in Table 2. The data source is the National Centre of Meteorology (NCM), United Arab Emirates.

Tide		Low Tide		High Tide		Time of water movement
Date	Tide set	Time	Height	Time	Height	
Fri, Nov 19	Tide Set One	00:18:00	1.34	05:43:00	0.56	05:25:00
	Tide Set Two	12:00:00	1.65	18:38:00	0.17	06:38:00
Sat, Nov 20	Tide Set One	00:56:00	1.34	06:08:00	0.62	05:12:00
	Tide Set Two	12:27:00	1.67	19:07:00	0.12	06:40:00
Sun, Nov 21	Tide Set One	01:34:00	1.33	06:31:00	0.67	04:57:00
	Tide Set Two	12:55:00	1.67	19:37:00	0.1	06:42:00
Mon, Nov 22	Tide Set One	02:12:00	1.29	06:54:00	0.72	04:42:00
	Tide Set Two	13:24:00	1.66	20:09:00	0.11	06:45:00
Tue, Nov 23	Tide Set One	02:52:00	1.24	07:18:00	0.77	04:26:00
	Tide Set Two	13:54:00	1.63	20:43:00	0.15	06:49:00
Wed, Nov 24	Tide Set One	03:33:00	1.17	07:44:00	0.81	04:11:00
	Tide Set Two	14:25:00	1.58	21:22:00	0.22	06:57:00
Thu, Nov 25	Tide Set One	04:20:00	1.12	08:14:00	0.85	03:54:00
	Tide Set Two	15:01:00	1.51	22:07:00	0.29	07:06:00

Table 2. Tide heights in November 2022

Two sets of tides occur daily, high tide and low tide, tidal currents are produced by the rising and falling of the tide. These currents are water motions that are horizontal and related to tidal changes. As a result of the movement of water resulting from the tide occurrence, the speed of the water current is increasing between the high and low tide due to the current movement. This movement occurs every 5.7 hours on average as in table no.2 and the data is predictable as low and high tides can be forecasted daily.

Measuring the current speed is vital to determine the potential energy that can be extracted. A study carried out by Mohamed El Amrousi1, Mohamed El Hakeem 1, Evan Paleologos, and Maria Alessandra Misuri from Abu Dhabi University in September 2018 assessed the velocities behavior in Dubai Creek and canal using a two-dimensional hydrodynamic model, the study showed that velocities are higher in creek and canal mouth and gradually decreases from both

Emirati Journal of Environment, Sustainability, and Climate Change
Vol 2 Issue 1 (2024) Pages (4 –11)

canal and creek mouth towards Ras Al Khor Wildlife Sanctuary [8]. this is illustrated in Figure No. 4

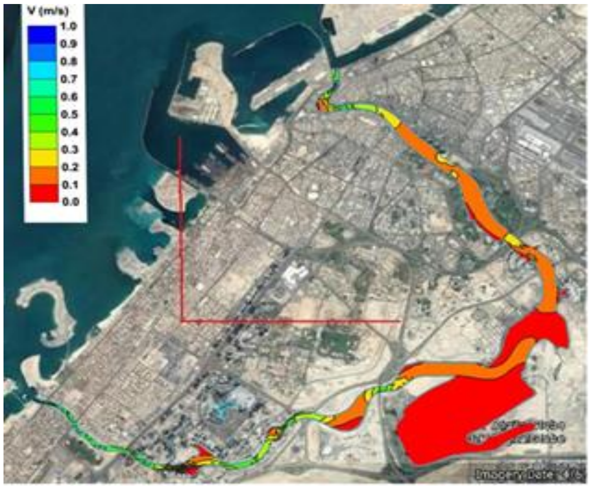


figure 4. Water velocity behavior in Dubai Creek and Canal [8]

To get accurate data and verify the velocity of the water, the speed probe shown in Figure 5. is used to measure the water velocity, this probe is equipped with a shielded water turbo prop plus a digital data display.

Figure 5. Water speed probe

The readings collected from various stations revealed a notable consistency, with the highest water speed recorded at 1.99 m/s observed at the creek mouth. This reading emphasizes a noteworthy and consistent parallel with the previously referenced study within this research [8]. The readings of water speed at these locations pro-vide valuable insights and offer a foundation for under-standing and harnessing tidal energy potential in Dubai Creek and the water canal.

The water speed readings at various stations are visually depicted in Figure 6, highlighting variations in speed through the use of color codes to distinguish between slow and high speeds.

Figure 6. Water speed velocity variation

Based on the velocity behavior illustrated in Figure 5, the research shall focus on the stations where high-velocity water currents occur, these stations are listed in Table 3.

SN	Station name	Location
1	Al Shindagha Marine Transport Station	Dubai Creek
2	Al Ghubaiba Marine Transport Station	Dubai Creek
3	Bur Dubai Marine Transport Station	Dubai Creek
4	Dubai Old Souq Marine Transport Station	Dubai Creek
5	Alfahidi Souq Marine Transport Station	Dubai Creek
6	Deira Old Souq Marine Transport Station	Dubai Creek
7	Al Sabkha Marine Transport Station	Dubai Creek
8	Baniyas Marine Transport Station	Dubai Creek
9	Alseef Souq Marine Transport Station	Dubai Creek
10	Dubai Water Canal Marine Transport Station	Water Canal
11	Jumeirah Marine Transport Station	Water Canal
12	Al Wasl Marine Transport Station	Water Canal
13	Sheikh Zayed Road Marine Transport Station	Water Canal
14	Godolphin Marine Transport Station	Water Canal
15	Business Bay Marine Transport Station	Water Canal

Table 3. Observed high-velocity water current locations

These fifteen stations have the potential to generate tidal energy based on the water speed current available.

To harness the kinetic energy of the water current movement, the utilization of a turbine is essential. The power output of a turbine, measured in watts (W), can be determined through the following equation [9]:

Power = Cp x 0.5 x ρ x A x V^3

Cp = the turbine power coefficient

ρ = the density of the water (seawater is 1025 kg/m^3)

A = the swept area of the turbine (m^2)

V = the velocity of the flow (m/s)

Using the formula and assuming a turbine with 30% efficiency [33], and a 1 square meter swept area, the out-put power curve shall be represented in Figure 7

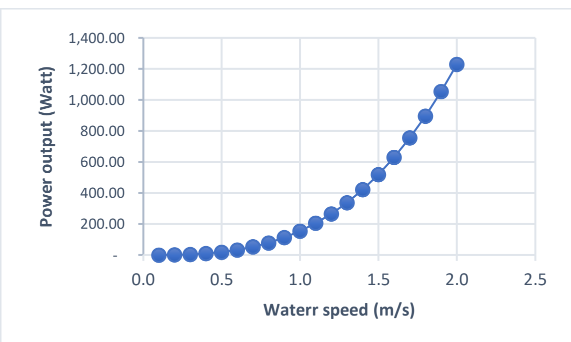


Figure 7. Water speed velocity variation

The maximum power for each turbine shall be 1,054.57 Watt approximately based on the assumption’s mentioned above and the maximum water speed measured in the creek mouth and water canal.

Assuming each station is equipped with two turbines, and considering fifteen stations have the potential for tidal energy generation, with tide current movement for 5.7 hours in each tide set with two sets of tides a day, the total energy that could be harnessed daily shall be 360.663 kilowatts-hour per day or 10,819.9 kilo-watts-hour monthly or 129,838.8 kilowatts-hour annual power generation as in table 4.

Assumptions	Value
Maximum turbine power in Watt	1054.57125
Number of turbines on each station	2
Number of stations	15
Total hours of current movement in each tide	5.7
Number of tidal sets	2
Power generation in kilowatts-hour	Value
Daily Power generation	360.66
Monthly Power generation	10,819.9
Annual Power Generation	129,838.8

Table 4. Energy consumption for RTA electric marine vessels

2.2. Financial analysis

As per the evaluation of resources outlined in section 2.1, the turbines are expected to produce an annual power output of 129.83 megawatts-hours, corresponding to a monetary value of AED 4,284,680.4. This calculation is based on a tariff of 0.33 AED per kilowatts-hour, consistent with the rate set by the Dubai Electricity and Water Authority (DEWA).

The expenses associated with establishing a station equipped with two turbines will be distributed among two crucial elements, namely capital costs (Capex) and operating expenditures (Opex). Capex encompasses initial costs such as turbine procurement and installation, grid connection infrastructure, site preparation, and construction. On the other hand, Opex includes operational and maintenance costs, covering routine maintenance expenses, monitoring and control system costs, personnel, and training.

Estimating the cost of CAPEX and OPEX for tidal energy generation in Dubai proves challenging due to the insufficient research and studies on tidal power generation in the region. However, according to the Internation-al Renewable Energy Agency IRENA, Tidal energy has estimates ranging from AED 0.67 to AED 0.91 per kilo-watt hour for currently used marine technologies, the figures obtained from several studies conducted throughout Europe in 2020 [5].

Nevertheless, the expenses can vary based on the size and location of the turbines. Opting for sites with pre-existing structures significantly lowers the cost, given that installation constitutes the most substantial portion, accounting for approximately 35% of the total cost [5]. In the specific scenario under investigation, the turbines shall be deployed at RTA marine transport stations, chosen for their structures that facilitate straightforward installation and optimal positioning, as outlined in the resource assessment detailed in section 2.1.

3. Results

According to the resource assessment and financial analysis, the yearly power generation is 129.83 mega-watts-hours, equivalent to a monetary value of AED 4,284,680.4. This sum has the potential to support sustainable mobility in two key areas: the first is the consumption of electric marine vessels operated by the RTA, and the second is the consumption of the stations hosting the turbines.

The annual energy consumption of all RTA operational electric marine transport vessels i.e. 112.32 mega-watts-hours. RTA has 17 Electric vessels (Abra), 10 vessels are operated in the Dubai Mall/Burj Khalifa fountain area, 3 are operated in Global Village, and the remaining are on standby or on demand.

The power consumption of RTA marine electric vessels is approximately 112.32 megawatts-hours which is less than the tidal generated power of 129.83 mega-watts-hours as per the resources assessment in point 2.1, the maximum power consumption of RTA marine electric vessels is calculated based on the data in table 5.

Electric vessels data	
Number of operational Electric vessels	13
Number of Electric Motor	2
Maximum Motor Power in kilowatt	2
daily operational hours	6 Hours
Power consumption in kilowatts-hour	
Daily power consumption	312
Monthly power consumption	9,360
Annual power consumption	112,320

Table 5. Maximum power consumption of RTA marine electric vessels

Furthermore, the expected output from the turbines is capable of contributing to around 35% of the total energy needs of the selected Marine transport stations. Assuming an average consumption of approximately 2.07 megawatts-hours per station as detailed in Table 6, the monthly energy usage for one station equals 2.07 megawatts-hours, corresponding to an annual consumption of 24.84 megawatts-hours. Taking into account the installation of turbines in 15 stations, the cumulative annual energy consumption for all 15 stations would be 372.6 megawatts-hours. Meanwhile, the tidal-generated power, assessed at 129.83 megawatts-hours in section 2.1, constitutes 35% of the overall consumption.

Item	Kilo watt ratin g	Quantity	Peak load in watts	Hour's item is used in 24 hrs	Energy used in 24hrs
LED Lights	5	10	50	12	600
Standard Lights	60	4	240	12	2880
Floodlight	500	4	2000	12	24000
Radio	50	1	50	12	600
Display screen	250	1	250	24	6000
Wi-Fi System	250	1	250	24	6000
Computer	250	1	250	16	4000
Network Router	15	1	15	24	360
Small Fridge	110	1	110	6	660
Kettle	2000	1	2000	2	4000
Coffee Machine	1200	1	1200	2	2400
Others	1000	1	1000	6	6000
Daily Peak power in watts =					57,500
Plus 20% losses					69,000
Monthly consumption in Watts					2,070,000
Annual consumption in Watts					24,840,000

Table 6. Energy consumption per station

The output energy could be utilized in two ways, either by grid connection or to be stored in batteries and consumed later. The energy output could be connected to the DEWA electricity grid where DEWA computes the difference between the electricity brought into the system and what is exported. According to DEWA [42] If the imported amount surpasses the exported quantity, DEWA will generate an invoice for the discrepancy. Conversely, if the exported electricity exceeds the imported amount, no charges will be applied, and the excess will be carried over to the next billing cycle.

4. Discussion and Conclusions

In conclusion, the research on generating Tidal Energy as a Sustainable Source of Power for Marine Transport Stations in Dubai Creek & and the Water Canal has pro-vided valuable insights into enhancing sustainable mobility and bolstering the share of renewable energy in Dubai and the region. The careful selection of station locations, guided by rigorous resource assessment and water currents velocity calculations, underscores a strategic approach to harnessing tidal energy potential. The subsequent financial analysis has revealed that the expected cumulative output from RTA Marine transport stations, amounting to 129.83 megawatts-hours, trans-lates to a significant economic annual value of 4,284,680.4 dirhams. This economic value positions the tidal power initiative as a viable and economically beneficial solution that constitutes 35% of the overall power consumption of the stations under study. Based on the data provided in Table 6 and taking into account the energy consumption of 23 stations located in Dubai Creek and the water canal, it has been estimated that the total annual energy demand is 571.32 megawatt-hours. With the implementation of renewable energy sources such as turbines, the share of renewable energy can be increased by more than 20%, resulting in 22.7% of the energy demand being met by sustainable energy sources.

In addition, the output that was identified has proven to be versatile and capable of meeting the energy consumption requirements of RTA marine electric vessels and the power needs of RTA Marine transport stations. The ability to store tidal power in batteries or connect it seamlessly to the grid enhances the system's flexibility, facilitating efficient energy management.

Dubai has shown its commitment to sustainable practices and renewable energy integration. The research results offer a practical roadmap for the successful implementation of tidal power generation from RTA marine transport stations. By utilizing these insights, policymakers, stakeholders, and energy enthusiasts can work together to achieve a more sustainable and resilient energy landscape for Dubai and the UAE as a whole.

Continuous developments in energy storage technologies and grid connectivity will additionally improve the practicality and effectiveness of tidal power initiatives, paving the way for a more sustainable and environmentally conscious future in Dubai. It’s recommended to install a prototype on one of the marine stations in Dubai Creek and carry out a comprehensive study accordingly.

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