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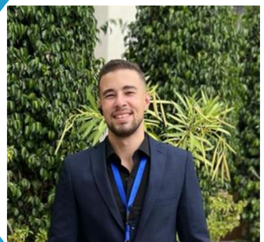

Omar Mahdy

Marine and Offshore Engineering Department, College of Engineering and Technology, AASTMT

GREENING MARITIME ENERGY

A SUSTAINABLE APPROACH TO HYDROPOWER GENERATION THROUGH MATHEMATICAL MODELLING IN GRAVING DOCK FLOODING

Miral Michel, Omar K. Mahdy, Omar M. Alkholy, Kareem M. Yousef, Yousef M. Shaban, Amir M. Abu Bakr and Ahmed S. Shehata

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- Aim and objective
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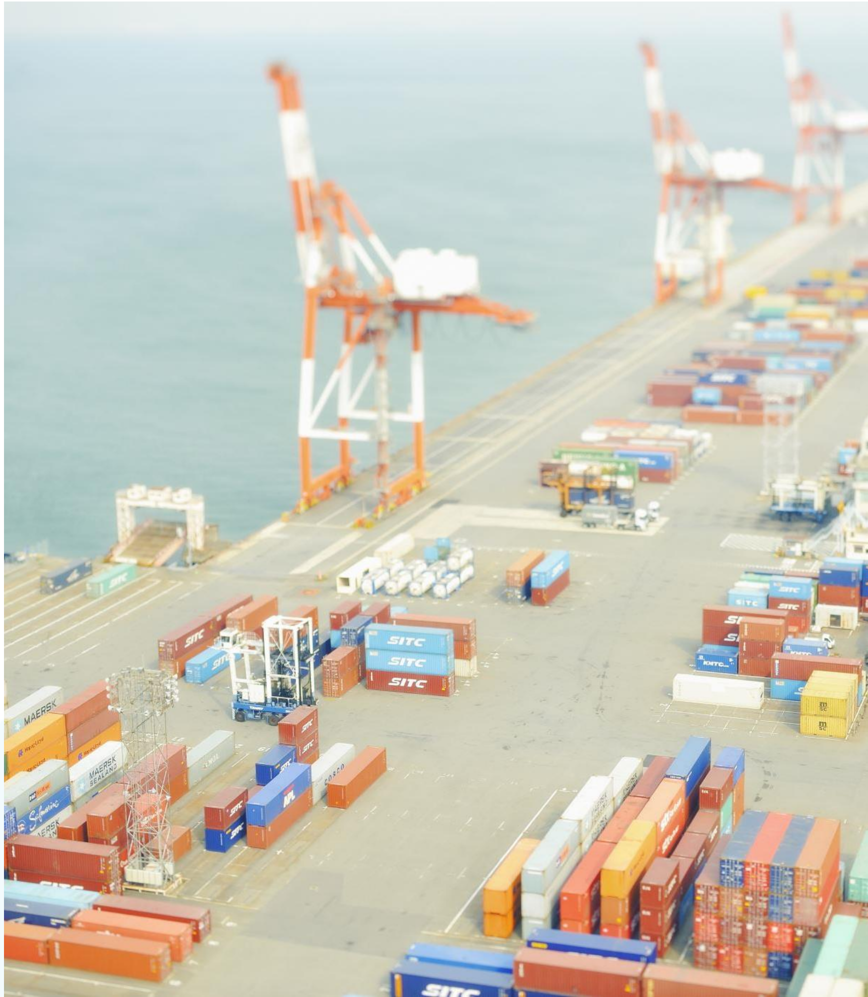
Introduction

The maritime transport industry's attention to safety, cost-effectiveness, and efficiency has driven considerable growth in shipbuilding to meet global trade demands, leading to an increased need for additional docks.

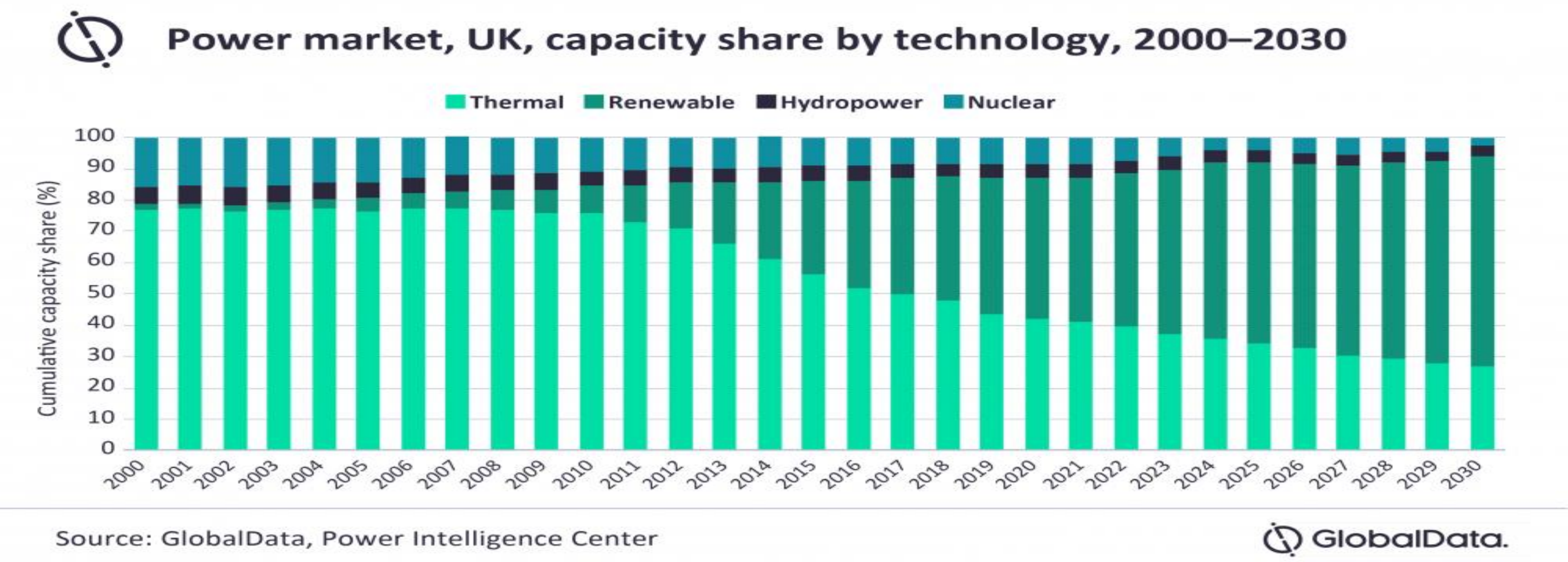


Problem Statement

The escalating demand for additional dock facilities to accommodate ship repairs and other marine operations, coupled with heightened electricity consumption within docks, is contributing to an increase in emissions, posing a pressing environmental and infrastructure challenge.

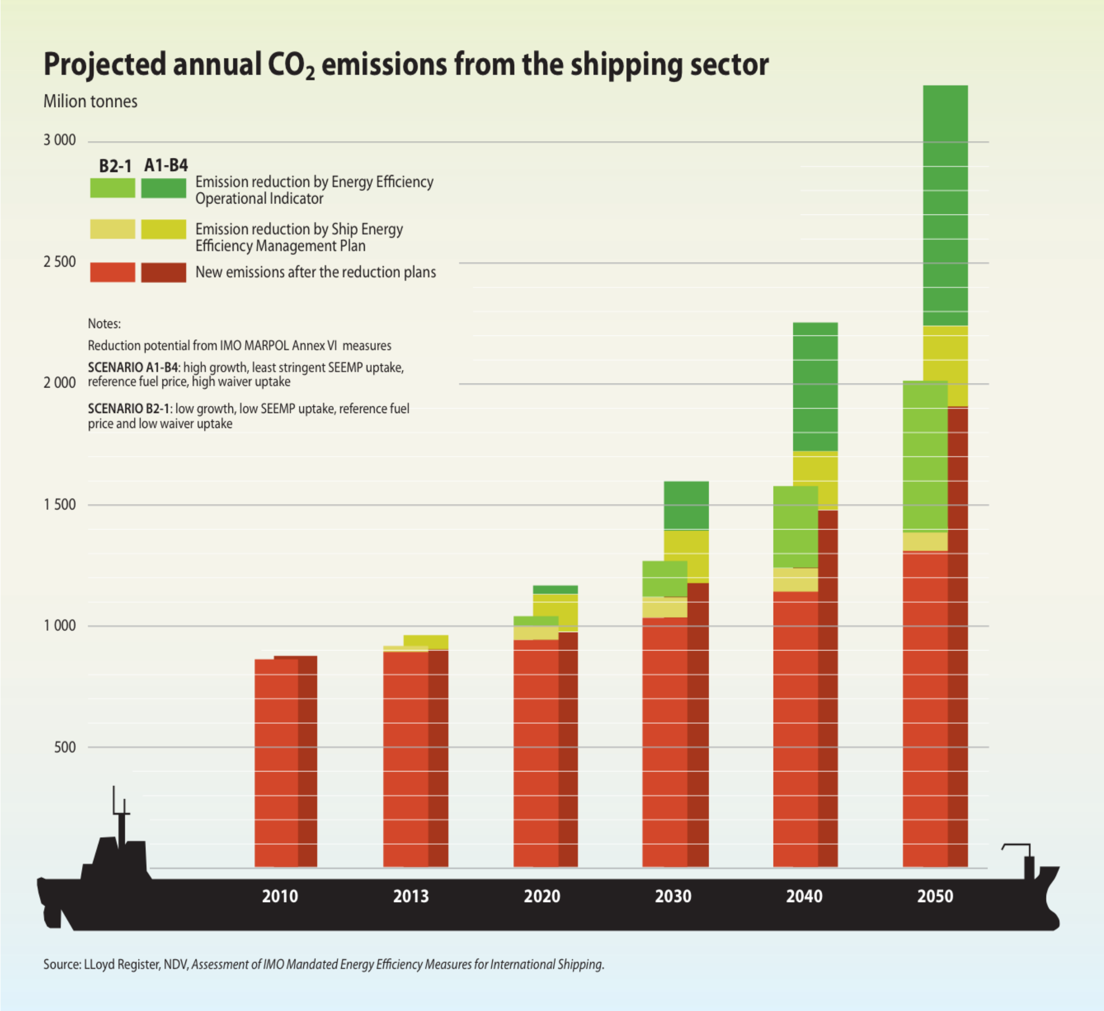
Survey

Renewable energy sources including tidal energy and hydropower, have a crucial role in assisting the United Kingdom to achieve its goal of accomplishing net zero greenhouse gas emissions.



Survey

By 2050, it is anticipated that the industry will emit 50% more greenhouse gases than the 2018 levels, constituting 2.89% of global emissions. Furthermore, the sector is accountable for 5–10% and 17–31% of global emissions of sulfur and nitrogen oxides, respectively.



Survey

Significant progress in wind and solar energy over the last ten years has allowed them to compete with conventional fossil fuels.

Diverse sources of renewable energy include hydroelectric dams, solar, biomass, geothermal, tidal, and offshore wind.

Survey

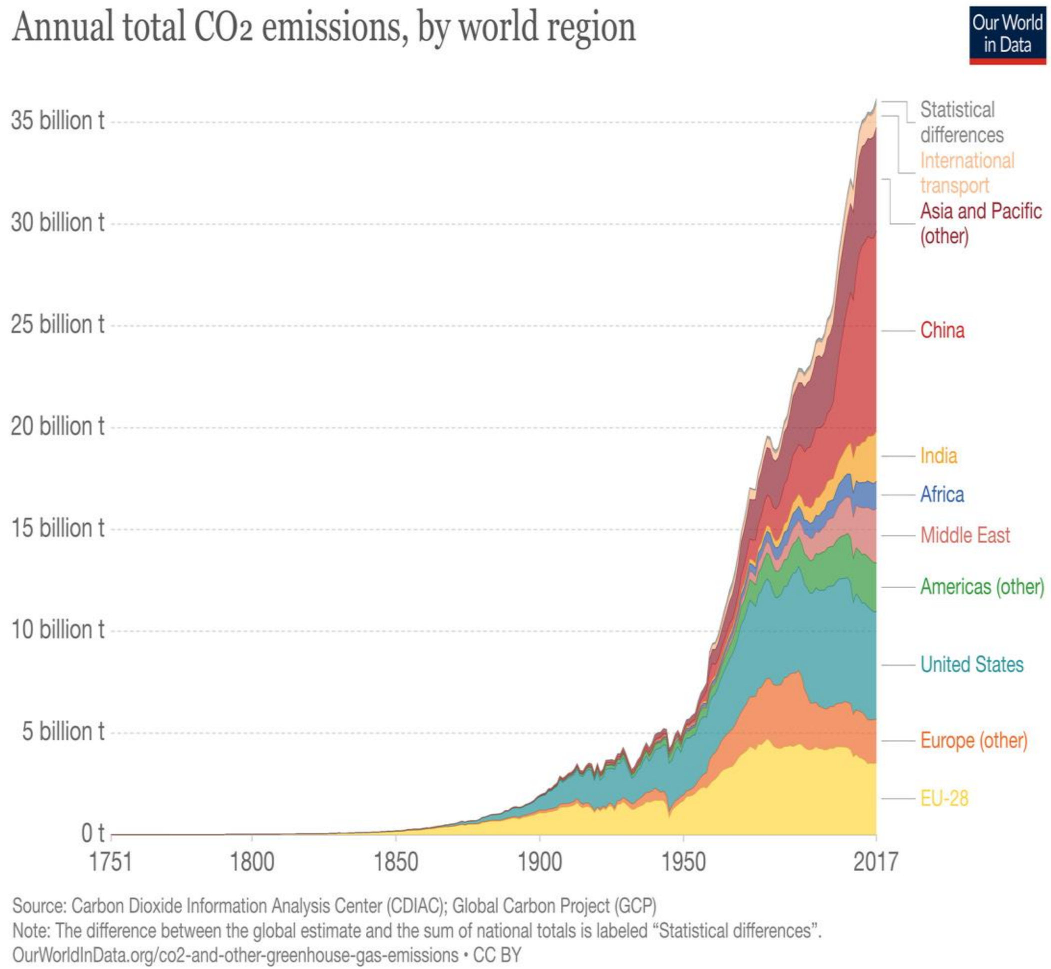
As documented by the 4th International Maritime Organization (IMO) greenhouse gas assessment, there was a discernible rise in the contribution of the shipping industry to air emissions. Specifically, the industry's share increased from 2.76% in 2012 to 2.89% in 2018.

Table 1 – *Total shipping and voyage-based and vessel-based international shipping CO_2 emissions 2012-2018 (million tonnes)*

Year	Global anthropogenic CO_2 emissions	Total shipping CO^2	Total shipping as a percentage of global	Voyage-based International shipping CO_2	Voyage-based International shipping as a percentage of global	Vessel-based International shipping CO_2	Vessel-based International shipping as a percentage of global
2012	34,793	962	2.76%	701	2.01%	848	2.44%
2013	34,959	957	2.74%	684	1.96%	837	2.39%
2014	35,225	964	2.74%	681	1.93%	846	2.37%
2015	35,239	991	2.81%	700	1.99%	859	2.44%
2016	35,380	1,026	2.90%	727	2.05%	894	2.53%
2017	35,810	1,064	2.97%	746	2.08%	929	2.59%
2018	36,573	1,056	2.89%	740	2.02%	919	2.51%

Survey

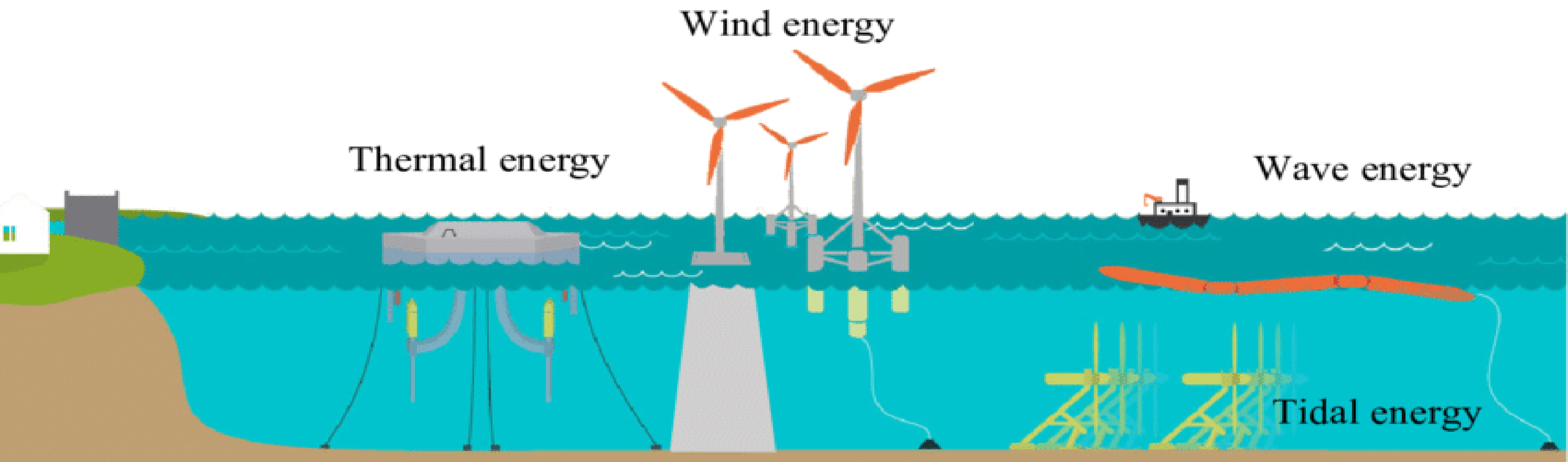
In contrast to the preceding three decades, there was a notable increase in greenhouse gas emissions between 2017 and 2018. The average rise of 2.7% during 2018 equated to around 37.1 gigatons of CO2-equivalents per year.



Gap Analysis

Traditionally, marine renewable energy has focused on natural occurrences like waves and currents, neglecting the energy potential in routine port activities.

This paper explores a new approach, tapping into the dock-filling process to generate clean energy. By using the water head created during filling, turbines at seawater inlets can be powered, offering a sustainable solution that integrates port operations into energy production.



Aim & Objective

Harness natural flow during dock-filling for clean energy integration into daily operations.

Estimating power generated and economic and environmental benefits.

Assessing efficiency at 5% intervals

Developing a precise mathematical model for evaluating economic and environmental benefits.

Methodology

❖ **Data Collection**

- Graving Dock No. 1 at ASRY
- Can accommodate ships with 500,000 tons (dwt)
- length of 375 m, width of 75 m and 14 m height
- Usually filled within 1-2 hours
- Flooded by an arrangement of 6 valves each having a diameter of 1.5 m

$$\nabla = L \times W \times D \times \rho$$

Methodology

❖ Mathematical Model

❑ Head Calculation

$$H_n = H_s - H_d$$

H_n : Net head pressure.

H_s: Head of the sea level.

H_d : The head inside the dock.

❑ Velocity Determination

$$V = \sqrt{2 \times g \times H_n}$$

V : Water velocity.

g : Gravitational acceleration.

H_n : Net head pressure.

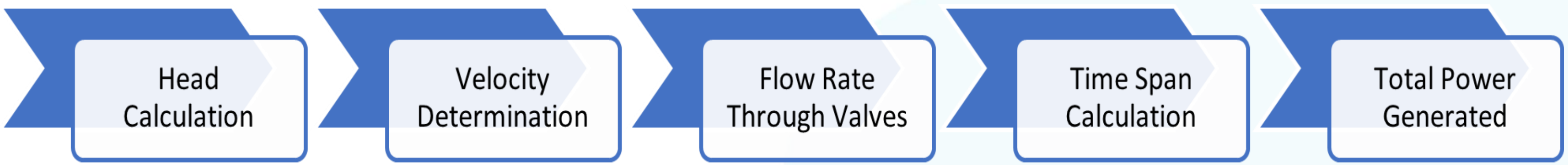
❑ Flow Rate Through Valves

$$Q = V \times A$$

Q : Flowrate.

V : Velocity.

A : Cross Sectional Area.



Methodology

❖ Mathematical Model

❑ Time Span

$$t = \frac{\nabla}{Q}$$

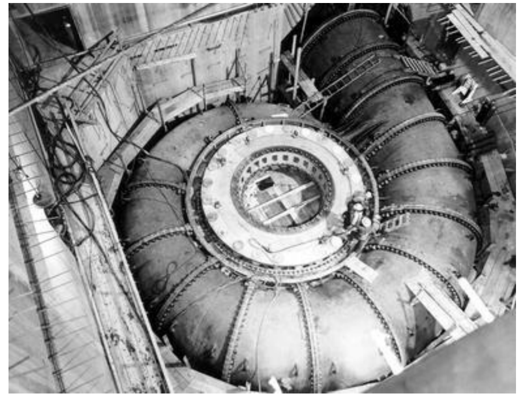
t : Time span for each interval.

∇ : Total volume of water in the dock.

Q : Flowrate.

❑ Turbine selection

❖ Francis-Type turbine



➢ Efficiency is considered to be 85%

Head Calculation → Velocity Determination → Flow Rate Through Valves → Time Span Calculation → Total Power Generated

Methodology

❖ Mathematical Model

❑ Power Calculation

$$P = \mu \times \rho \times g \times H_n \times Q$$

P : Power generated

μ : Turbine efficiency

ρ : Water Density

g : Gravitational acceleration.

H_n : The net head

Q : Flowrate

❑ Energy Calculation

$$P_i = P \times T$$

P_i: total energy produced for each interval in kWh.

P : power generated.

T : time in hours.

$$P_t = \sum P_i$$

P_t : The total energy produced

Results & Discussion

Water level	Net head (m)	Velocity (m/s)	Flowrate (m^3/s)
0%	12.6	15.7	27.8
25%	9.5	13.6	24.1
50%	6.3	11.1	19.6
75%	3.2	7.9	13.9
100%	0.0	0.0	0.0

❖ **Initial Conditions: -**

- Net head: 12.6 m
- Velocity: 15.7 m/s
- Flowrate: 27.8 m3 /s

❖ **Midpoint (50%) of Filling Process: -**

- Velocity: 11.1 m/s (slight reduction from initial value)
- Flowrate: 19.6 m3/s (decrease from initial value)

❖ **Overall Trend: -**

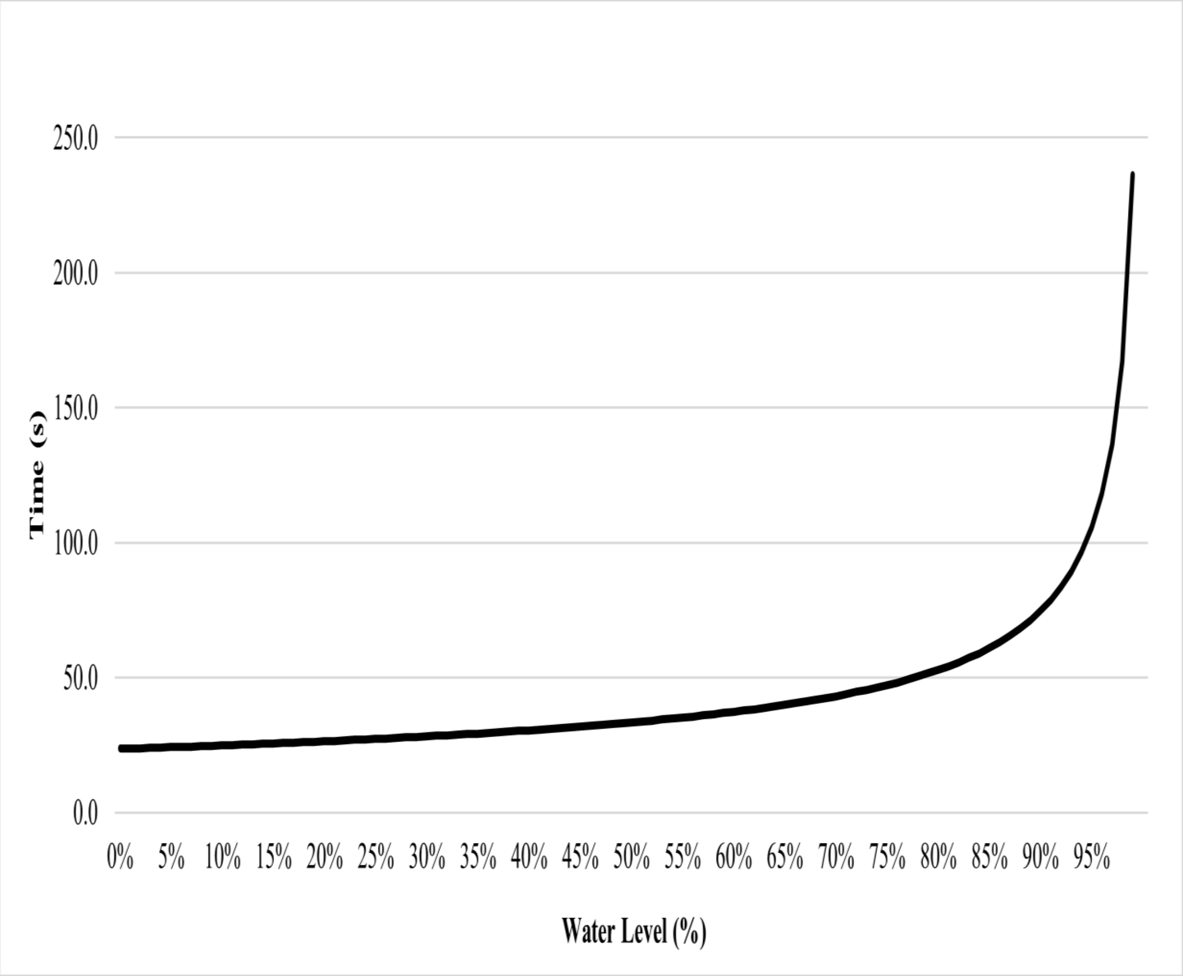
- Increase in water level corresponds with a decrease in net head, velocity, and flowrate.
- Consistent relationship between rising water level and decreasing values of net head, velocity, and flowrate throughout the filling process.

Results & Discussion

- ➢ Total time to fill the dock is approximately 1 hour and 17 minutes.
- ➢ Exponential Increase After 90% Filling
- ➢ Attributed to a decrease in flow rate throughout the filling process, linked to the reduction in net head.

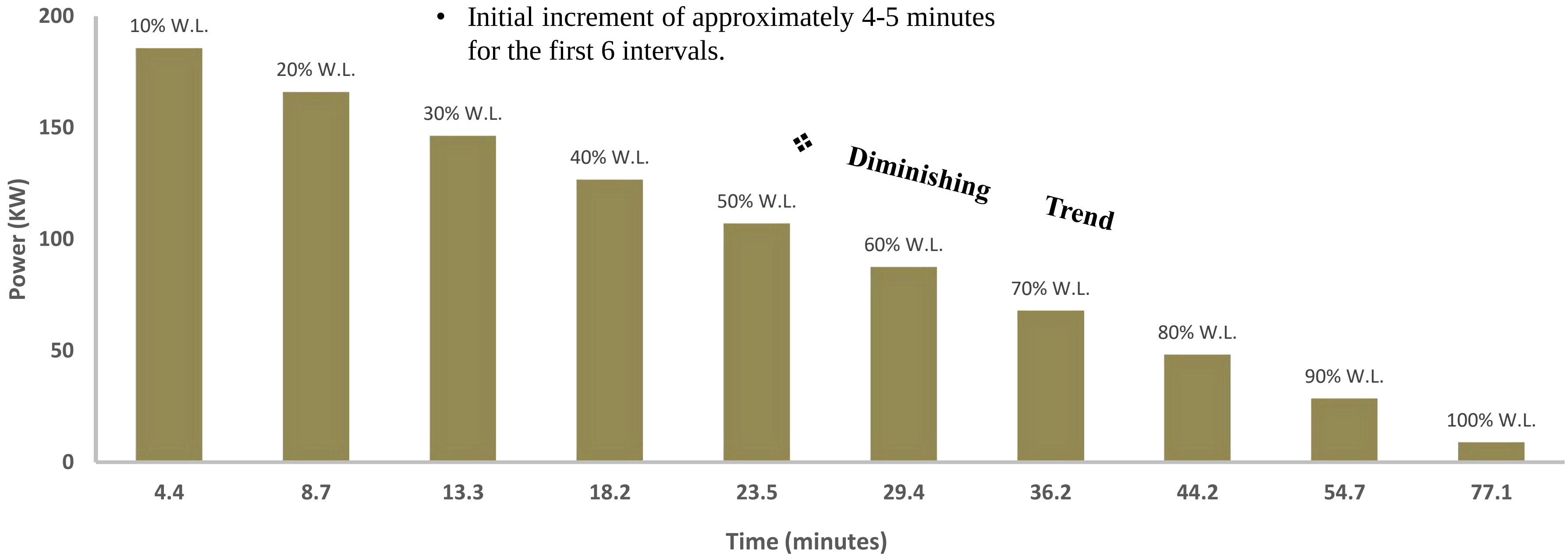
❖ **<u>Time Span Variation: -</u>**

- Initial 5%: 118 seconds.
- 25% to 30%: 136 seconds.
- 45% to 50%: 159 seconds.
- 70% to 75%: 236 seconds.
- 95% to 100%: 528 seconds.



Results & Discussion

- ❖ Initial 10% (4.4 minutes): 185.5 KW.
- ❖ 40% to 50% (5.3 minutes): 107 KW.
- ❖ 90% to 100% (22.3 minutes): 8.8 KW.



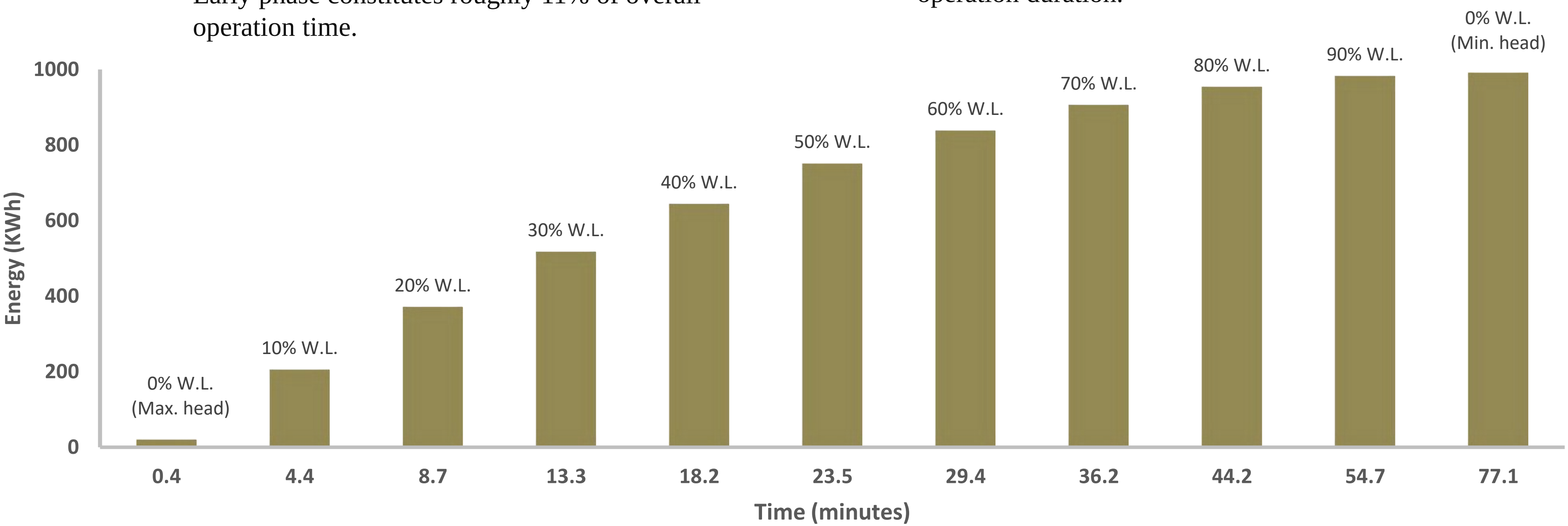
Results & Discussion

❖ Initial Surge in Energy Production:

- 37% of total energy generated within initial 20% of filling process
- Early phase constitutes roughly 11% of overall operation time.

❖ Significant Milestone at 60% :

- More than 80% of total energy generated at 60% mark.
- Occurs within a time span of 29.4 minutes.
- Represents approximately 38% of entire operation duration.



Results & Discussion

❖ **Electricity Generation Estimate:**

- Operation of six intake lines estimated to generate a total of 6 megawatt-hours (MWh).

❖ **Financial Savings:**

- Prospective electricity generation expected to result in financial savings of approximately $445.

❖ **Environmental Impact:**

- Anticipated to avert the emission of 4572 kilograms of carbon dioxide into the environment.

❖ **Dual Benefit:**

- Serves as a proactive measure for both financial savings and environmental impact mitigation.

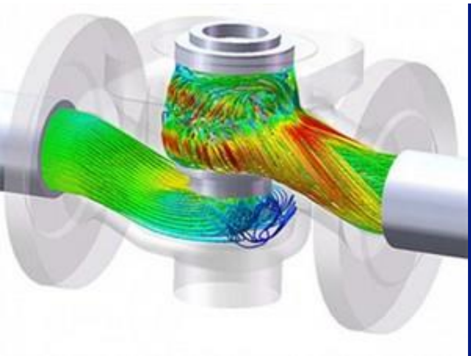
Conclusion

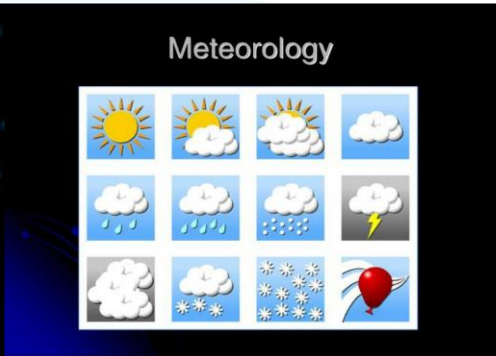
- Each intake line within the dock contributes an estimated 1 megawatt-hour (MWh) of power.
- Total of nearly 6 MWh per fill.
- Projected cost savings approximately $445 per fill.
- Beyond 60% of the filling process system's efficiency diminishes
- To generate an equivalent amount of energy using natural gas, approximately 4572 kg of CO_2 would be emitted into the environment.

Future Work

❖ **Future work: -**

- Employing advanced computational fluid dynamics (CFD) simulations to analyze the water movement within the dock, taking into account factors such as tides and weather
- leveraging cutting-edge software tools to delve deeper into the flow behavior within graving docks
- Integrate a broader array of influencing factors, including tidal fluctuations and meteorological parameters, into its analytical framework.
- Advanced AI algorithms and experimental models
- Using smart computer programs and doing experiments to understand how hydropower works in docks even better.





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