Numerical assessment of tidal potential energy in the Brazilian Equatorial Shelf

Alessandro L. Aguiar [a,b,c,j], Martinho Marta-Almeida [g,h], Mauro Cirano [i,j], Janini Pereira [d,f,j], Letícia Cotrim da Cunha [b,c,e]

a *Departamento de Oceanografia Física e Meteorologia, Faculdade de Oceanografia, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil*
b *Programa de Pós-graduação em Oceanografia, Faculdade de Oceanografia, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil*
c *Rede Clima, Sub-rede Oceanos, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil*
d *Programa de Pós-graduação em Geofísica, Instituto de Geociências, Universidade Federal da Bahia, Salvador, Brazil*
e *Rede Brasileira de Pesquisa em Acidificação dos Oceanos (BrOA), Universidade Federal de Rio Grande, Rio Grande, Brazil*
f *Departamento de Física da Terra e do Meio Ambiente, Instituto de Física, Universidade Federal da Bahia, Salvador, Brazil*
g *Centro Oceanográfico de A Coruña, Instituto Español de Oceanografia, A Coruña, Spain*
h *Centro Interdisciplinar de Investigação Marinha e Ambiental, Universidade do Porto, Portugal*
i *Departamento de Meteorologia, Instituto de Geociências, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil*
j *Rede de Modelagem e Observação Oceanográfica (REMO), Brazil*

INTRODUCTION

A numerical assessment study of the tidal potential energy was conducted for Brazilian Equatorial Shelf (BES), one among the macrotidal regions worldwide.

METHODS

This study used a high-resolution (1/24°) numerical configuration of the ocean model ROMS (Regional Ocean Modeling System) forced with realistic surface (CFSR) and lateral forcing (HYCOM/NCODA), as well as with tides (TPXO 7.2) and river discharges.

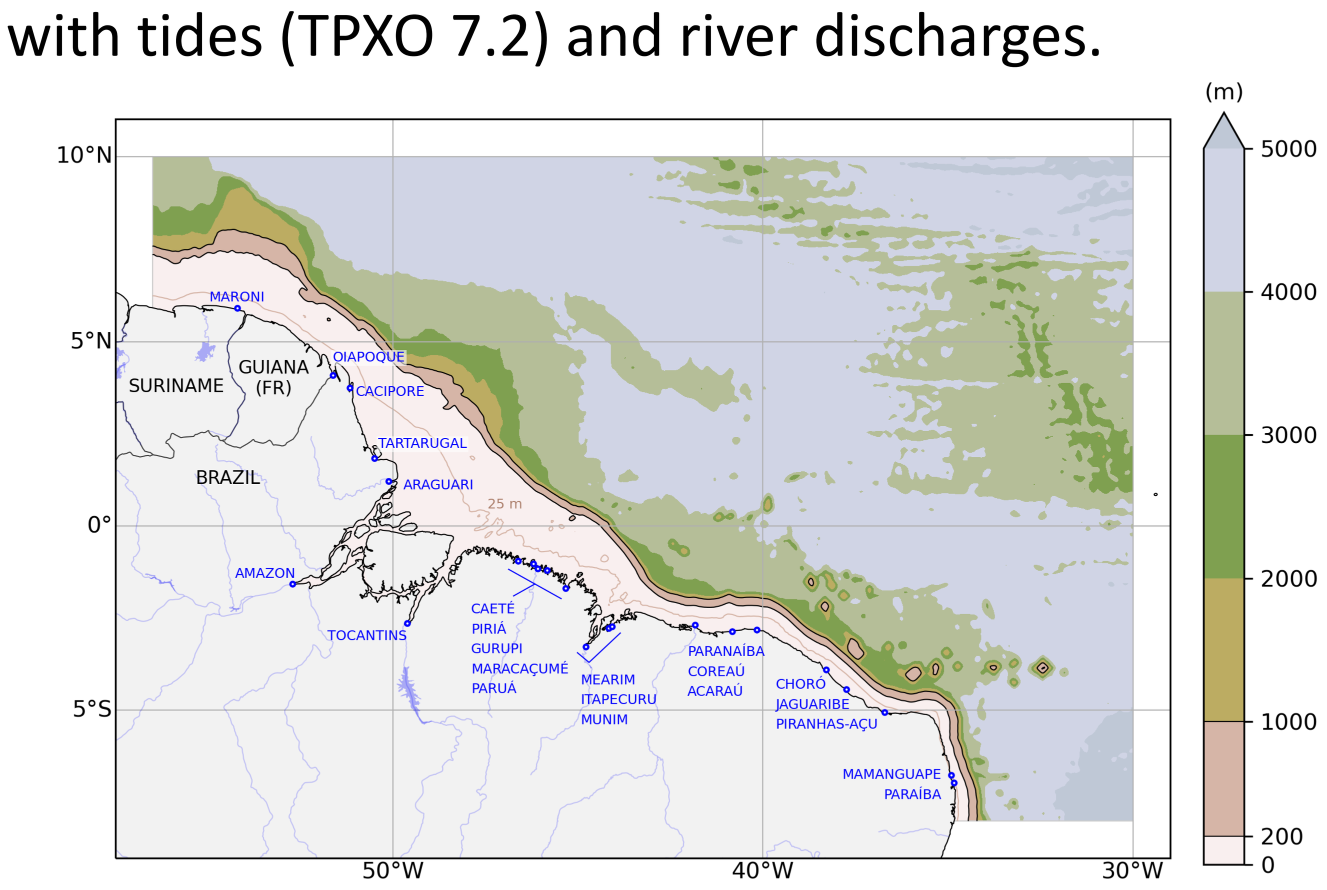

Fig. 1. Bathymetry and model domain. The light brown line indicates the 25 m isobath. The blue circles indicate the location where the discharge of each river was included in the model configuration. The inset world map shows Brazil in green and the model domain in orange.

The time series of modeled tidal heights have hourly time resolution and were used to calculate the tidal energy. The potential energy (J) of a filled tidal barrage is given by E; where ρ is the water density (1024 kg m^{-3}), g is the acceleration of gravity (9.81 m s^{-2}), A is the area of the barrage (m^2) and H is its height (m, the difference between high and low tide). During a period T (s) during which the barrage fills N times, the potential power density (W m^{-2}) is P:

$$E = \frac{1}{2}\rho g A H^2 \qquad P = \frac{1}{T}\sum_{i=1}^{N}\frac{1}{2}\rho g H_i^2 \qquad G = \frac{L}{E10^{-6}/3600}$$

The Gibrat Ratio (G) is the ratio between the length of the dam, L (m), and the amount of stored energy at the dam (MWh):

RESULTS AND DISCUSSION

Tidal heights of more than 2 m were found in three regions in BES due to the large tidal amplification across the estuarine channels inside each region: Amazon, Pará, and Maranhão, and for a considerable time fraction. Heights between 4 and 5 m occurred

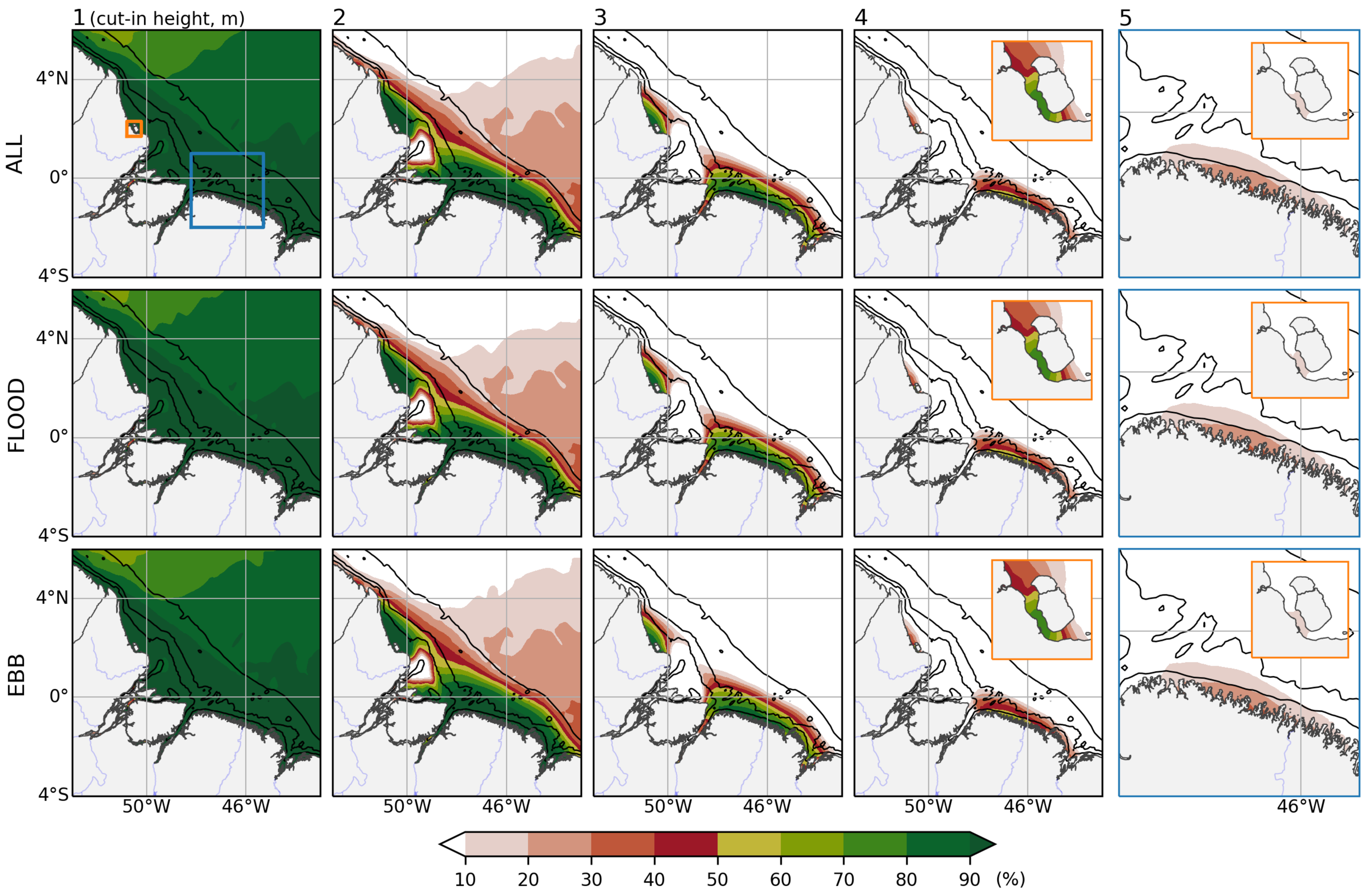

Fig. 2. Spatial distribution of the percentage of tidal heights (semi-cycles) greater than the cut-in values of 1, 2, 3, 4 e 5 m. Results are shown for the whole tidal cycle (ALL), flood, and ebb respectively. The isobaths 10, 25 and 200 m are also illustrated in each panel. The blue rectangle in the first panel (upper left) shows the zoom region depicted in the right panels (cut-in 5) and the small orange rectangle represents the zoom region inset in the two rightmost columns (cut-in 4 and 5).

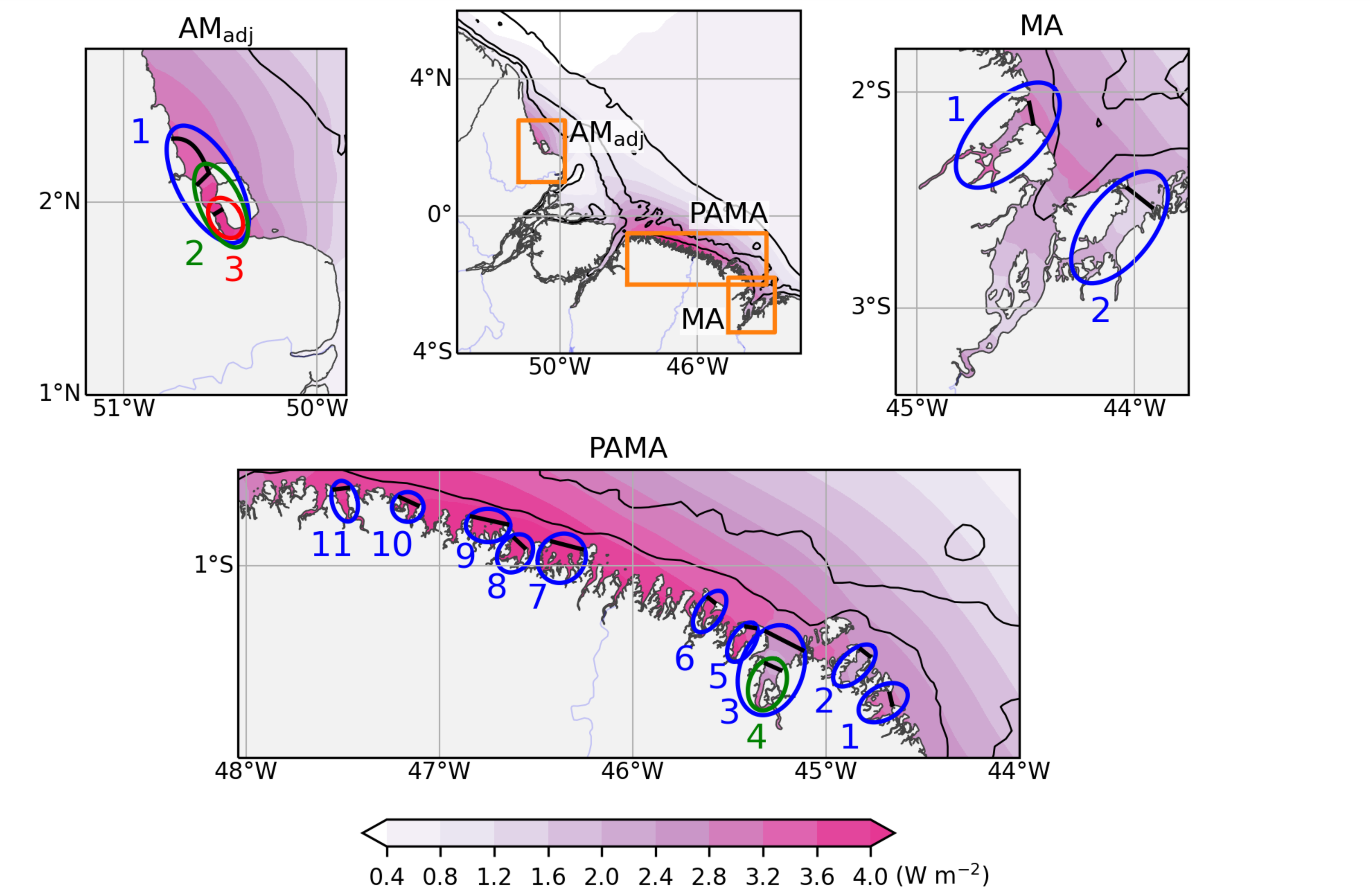

Fig. 3. Time averaged power density of tidal heights (10³ W m²) calculated considering the whole tidal cycle. The proposed tidal barrages are indicated by the ellipses in their respective region. The black contours shown indicate the isobaths 10, 25 and 200 m.

All hypothetical barrages proposed in this study (Fig. 3) were capable of an annual power production, in two-way mode, higher than La Rance (533 GWh year−1, two-way operation, France) and Sihwa (553 GWh year−1, flood-only operation, South Korea), except one with the same production as Sihwa barrage (Fig. 4).

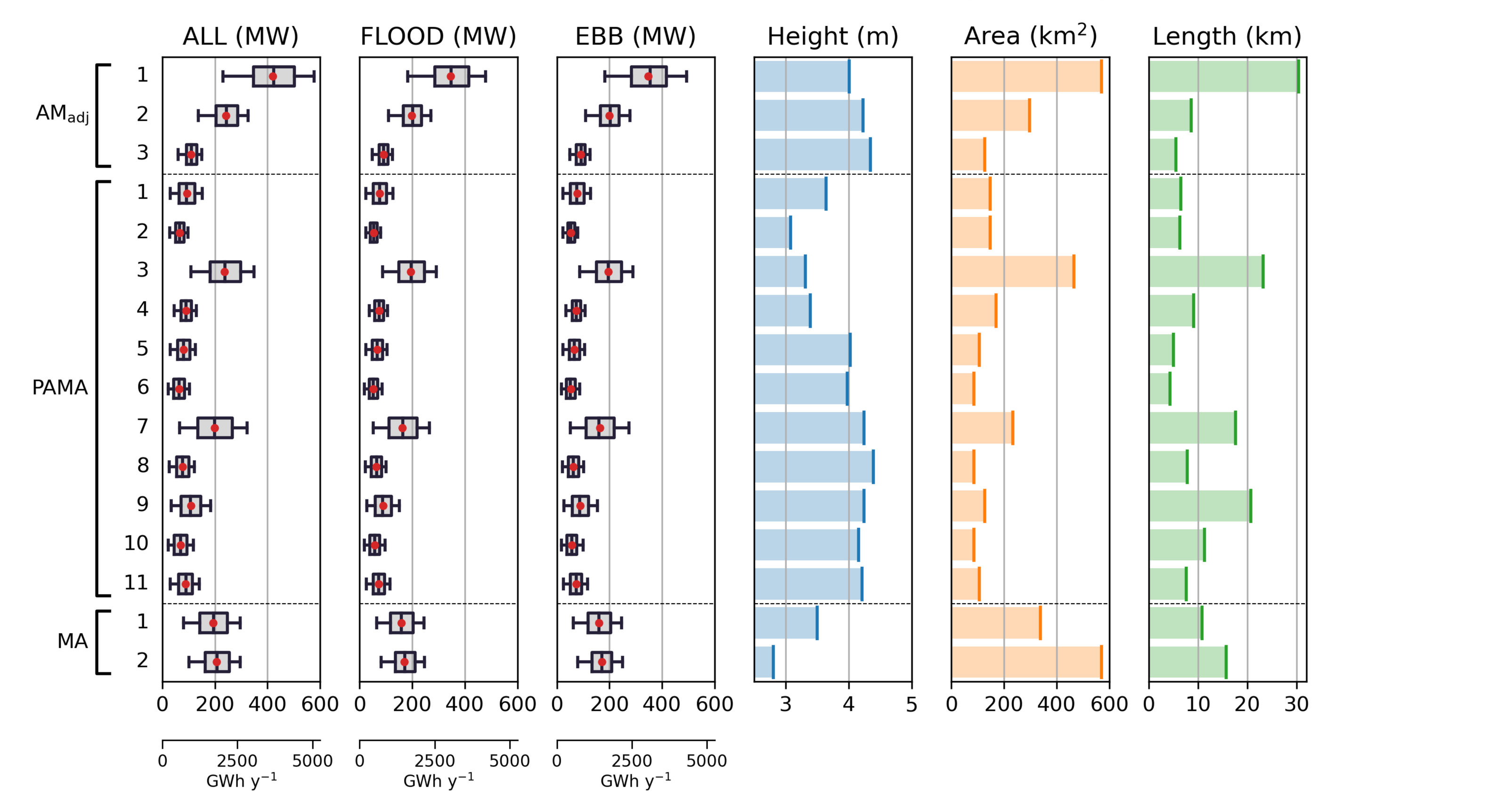

Fig. 4. Boxplots of energy production (GWh) of the proposed tidal barrages in the study area. Results are shown for the whole tidal cycle (ALL), flood, and ebb respectively. The lower and upper limits of the box plots are the percentiles 5 and 95%. The red dot inside the interquartile range rectangle indicates the mean and the vertical line represents the median. Also shown the average tidal height (of both flood and ebb), area and length of the barrages in the three rightmost panels.

The installation effort was evaluated using the Gibrat ratio. Among the proposed barrages, the most efficient ones have an annual power generation greater than 1500 GWh year−1 and a Gibrat ratios between 1.17 and 3.26, much lower than the Gibrat ratio of Sihwa tidal barrage (Table 1).

	H (m)	A (km^2)	L (km)	Gibrat ratio	E (GWh year^{-1})		
					All	Flood	Ebb
$AM_{adj}1$	4.0	571	30.4	2.37	3677	3034	3041
$AM_{adj}2$	4.2	296	8.6	1.17	2113	1742	1745
$AM_{adj}3$	4.3	127	5.5	1.65	959	791	792
PAMA1	3.6	148	6.5	2.39	814	671	672
PAMA2	3.1	148	6.3	3.25	569	470	469
PAMA3	3.3	466	23.2	3.26	2068	1708	1705
PAMA4	3.4	169	9.1	3.36	784	646	647
PAMA5	4.0	106	5.0	2.10	701	579	579
PAMA6	4.0	85	4.3	2.32	553	456	457
PAMA7	4.2	233	17.6	3.01	1733	1429	1431
PAMA8	4.4	85	7.8	3.43	670	553	553
PAMA9	4.2	127	20.7	6.50	950	783	784
PAMA10	4.2	85	11.3	5.55	608	502	502
PAMA11	4.2	106	7.6	2.92	772	637	637
MA1	3.5	339	10.8	1.87	1690	1395	1393
MA2	2.8	571	15.7	2.51	1810	1493	1495
La Rance	8.5	22.5	0.7	0.36	533.0	–	–
Sihwa	5.6	30.0	12.7	9.64	–	553.0	–
Severn	7.5	570.0	16.1	0.92	–	–	15600

Table 1. Annual energy production obtained through the potential energy of tidal heights. H indicates the average height in the simulation period inside the barrage, L the barrage length and A the barrage area. Values related to La Rance, Sihwa and Severn were obtained in literature (e.g., [55,56]).

CONCLUSION

The BES is a source of clean energy to be explored. Considering the extraction of energy from tidal heights, it is possible to produce renewables along the entire extension of BES.

References

Aguiar, A.L., Marta-Almeida, M., Cirano, M., Pereira, J., Cunha, L.C. Numerical assessment of tidal potential energy in the Brazilian Equatorial Shelf. Renewable Energy 220 (2024) 119684. https://doi.org/10.1016/j.renene.2023.119684

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