



II WORKSHOP DE ENERGIAS OCEÂNICAS E FLUVIAIS



Projetos de energia renovável no oceano

Dr. Milad Shadman
Prof. Segen F. Estefen

Research Areas



Subsea Production
Systems/ Subsea
Pipelines and Risers



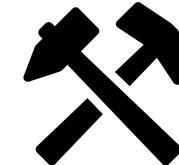
Integrity and Reliability of
Structures and Equipment



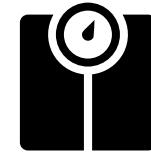
Flow Assurance



Well Drilling and
Completion



Maintenance,
Inspection and Repair



Composite Materials and
Intelligent Materials

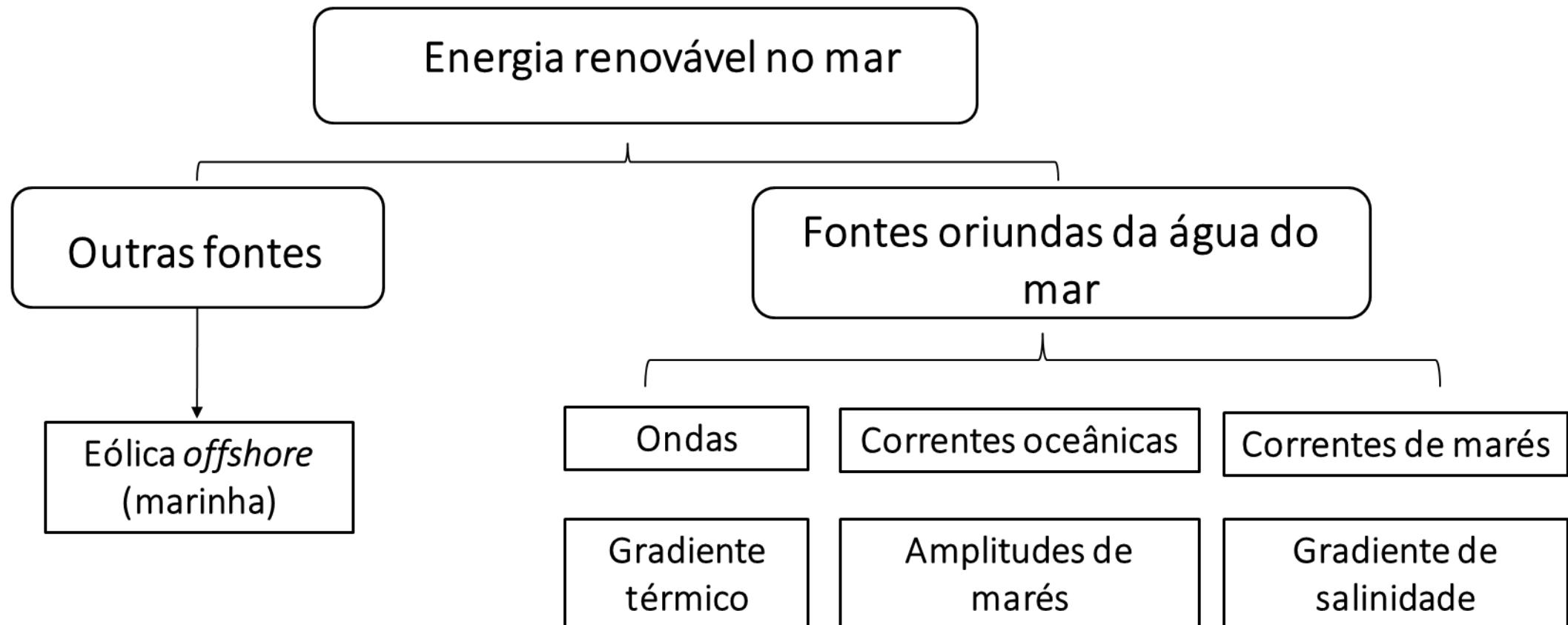


Chemical Phenomena
Study in Subsea
Environments



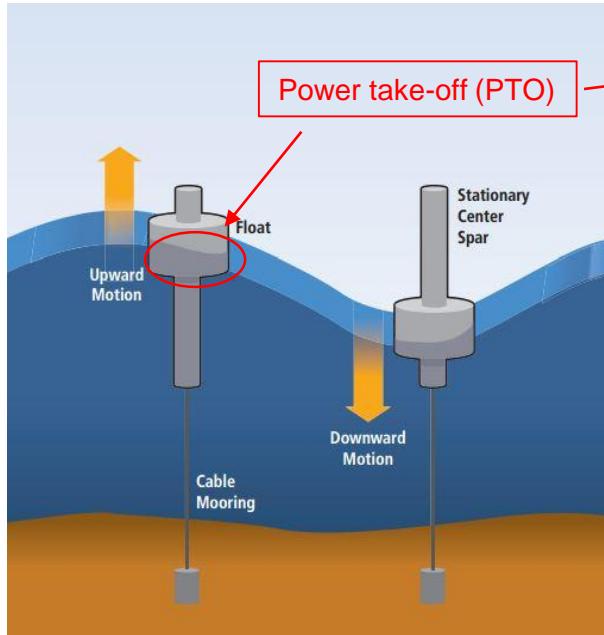
Offshore wind and Ocean
Renewable Energy



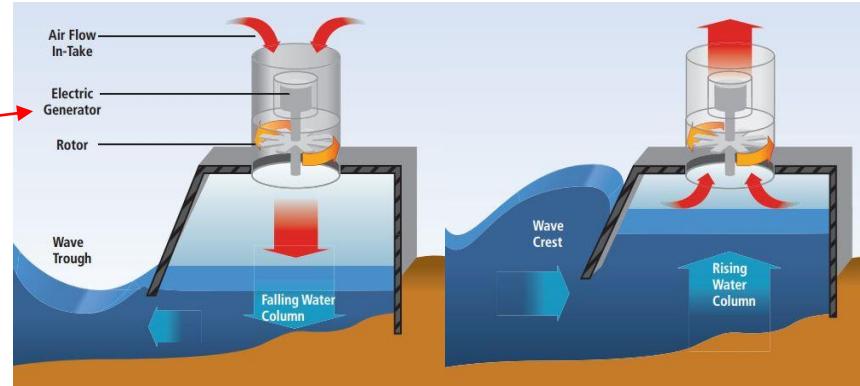


Wave Energy Converter (WEC)

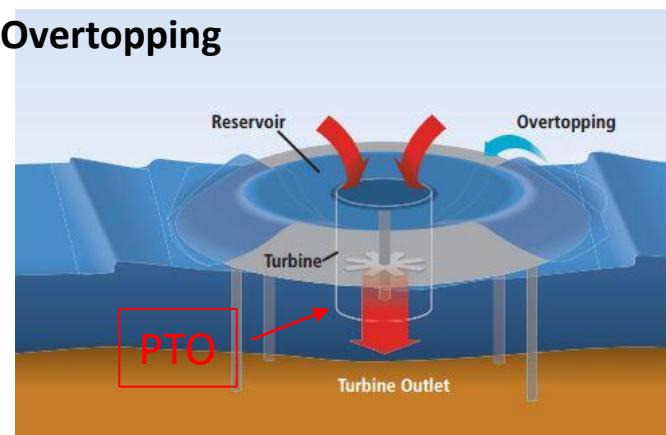
Oscillating body



Oscillating water column (OWC)

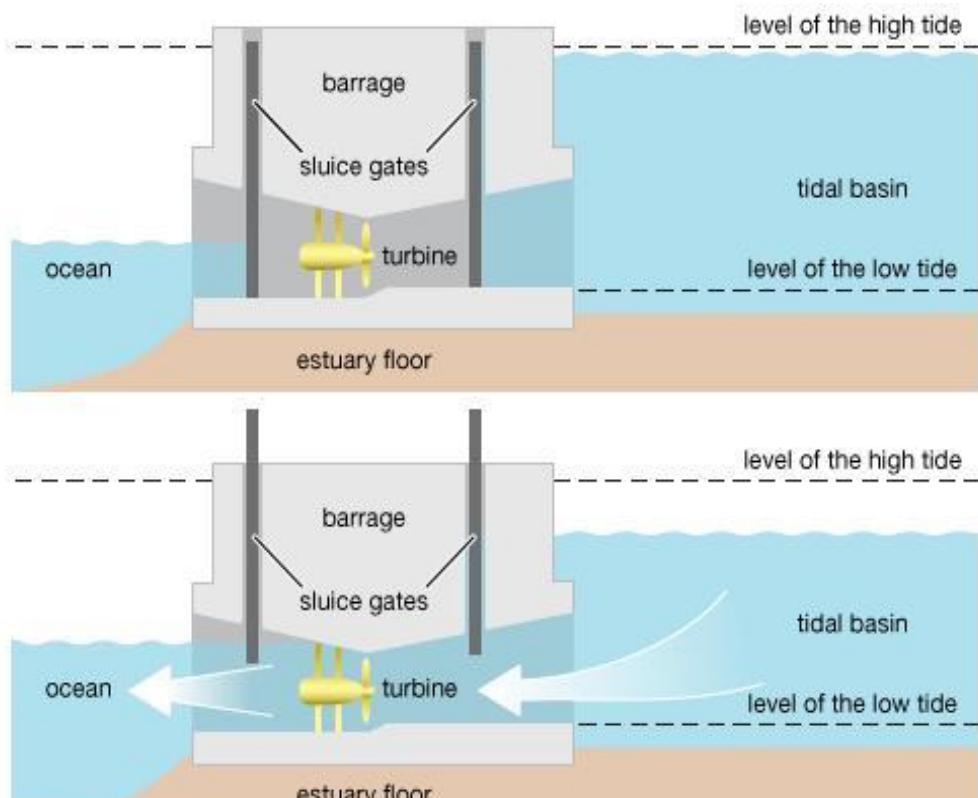


Overtopping



Images: NREL

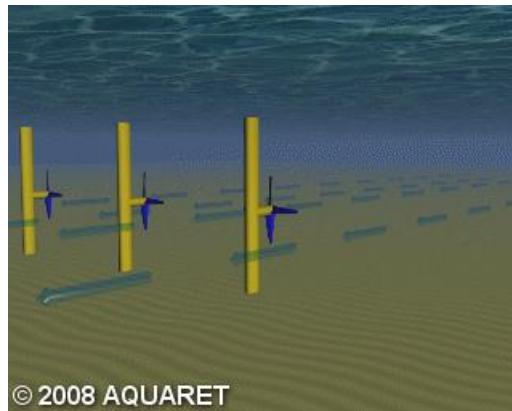
Tidal barrage



Source: <http://global.britannica.com>

Tidal and ocean current

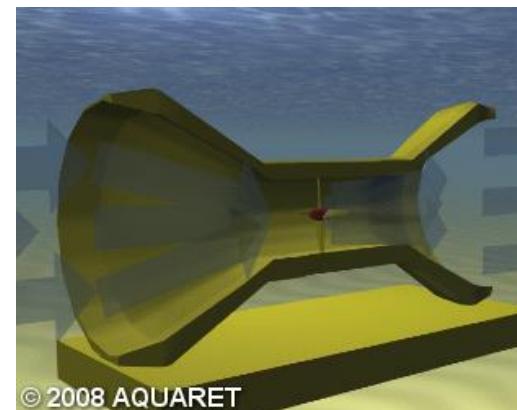
Horizontal-axis



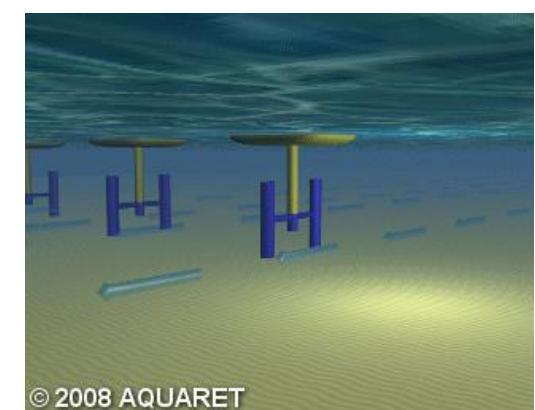
Oscillatory hydrofoil



Venturi-effect

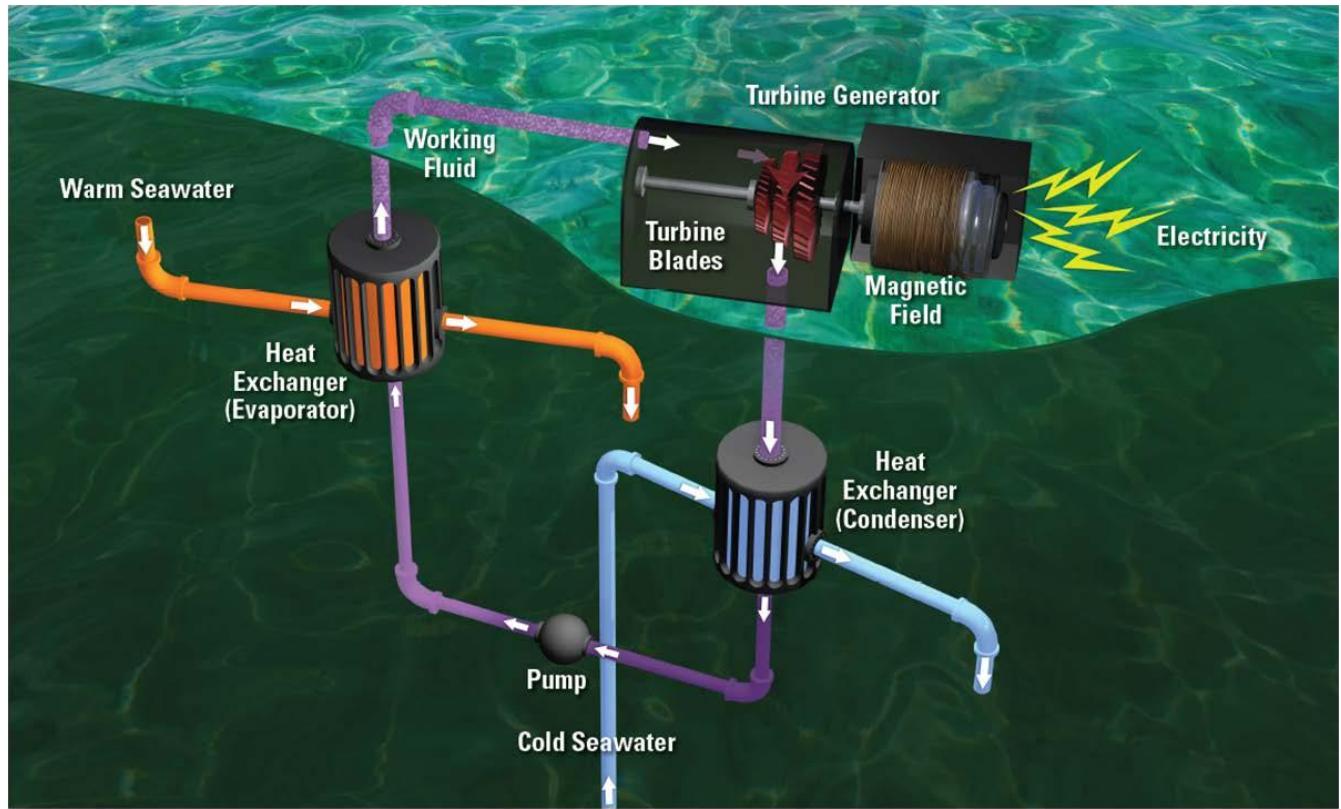
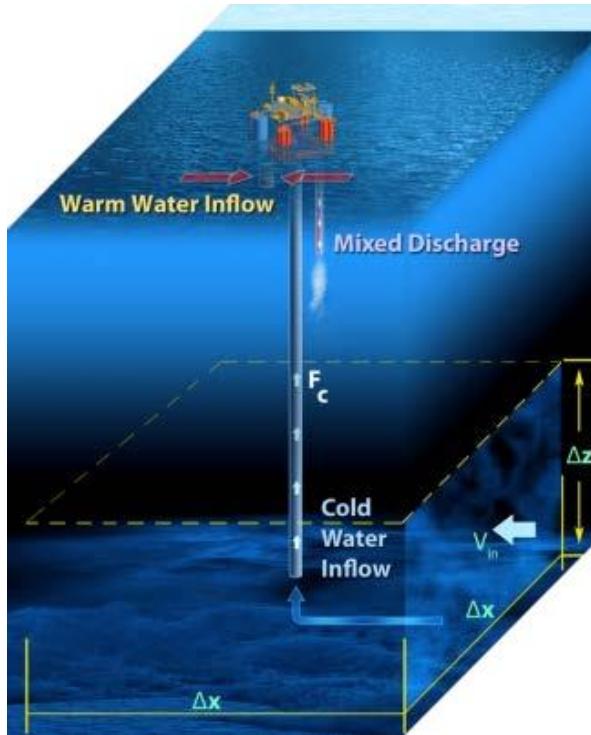


Vertical-axis



Images: (Augustine et al, 2012)

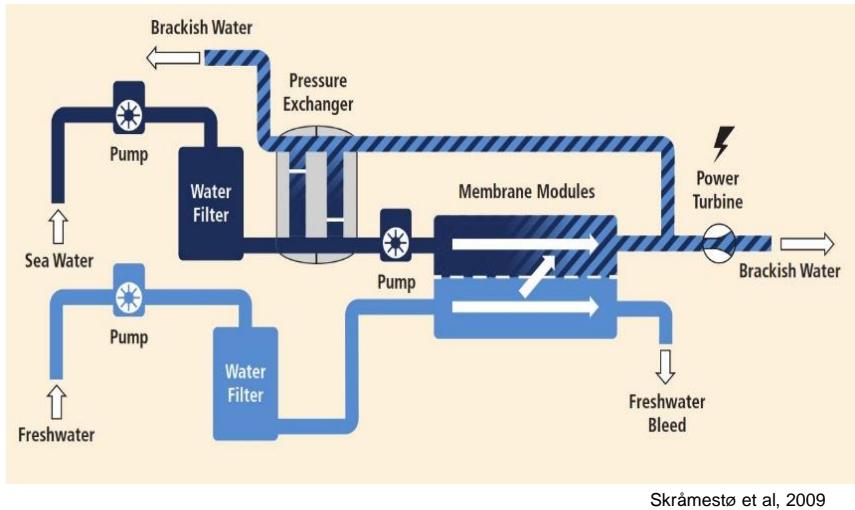
Gradiente térmico (OTEC)



(Fonte: Lockheed Martin Corporation)

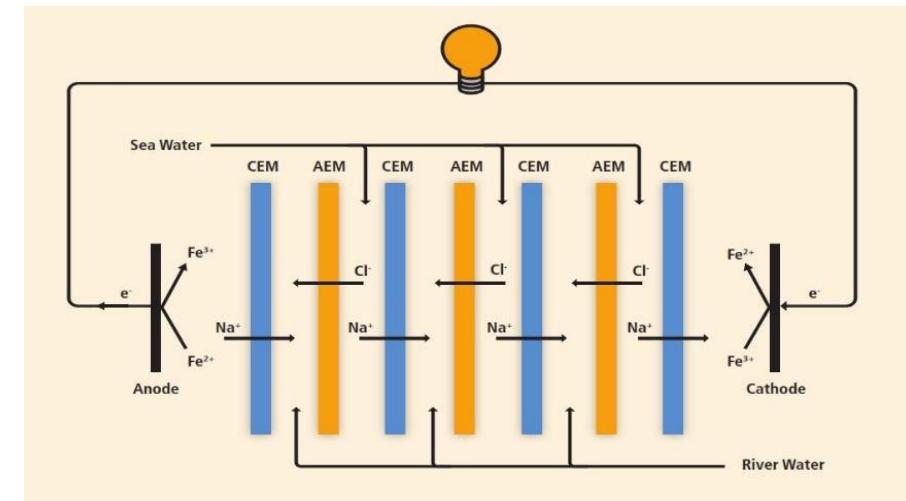
Gradiente de salinidade

Osmose retardada por pressão (ORP)



- Extrair a pressão química devido a mistura de água salobra e água

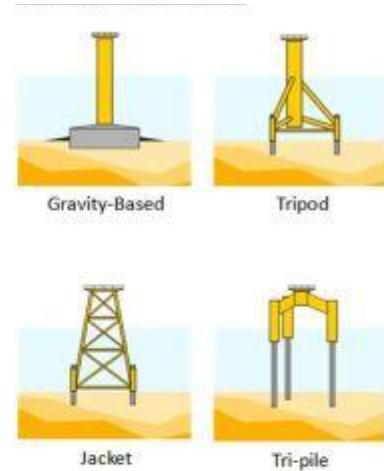
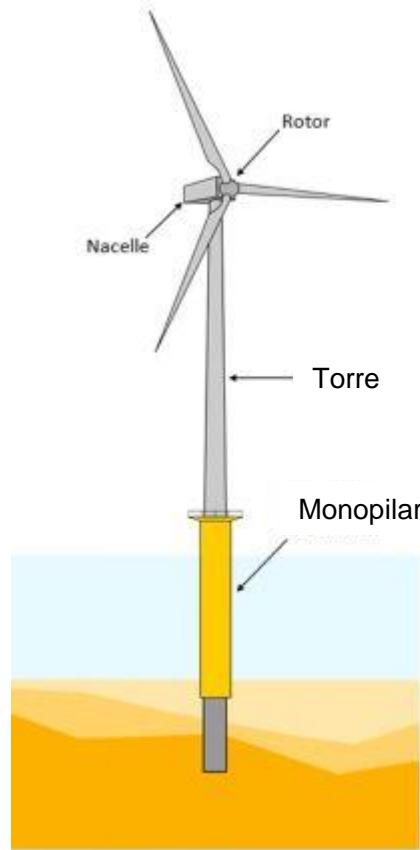
Eletrodiálise reversa (EDR)



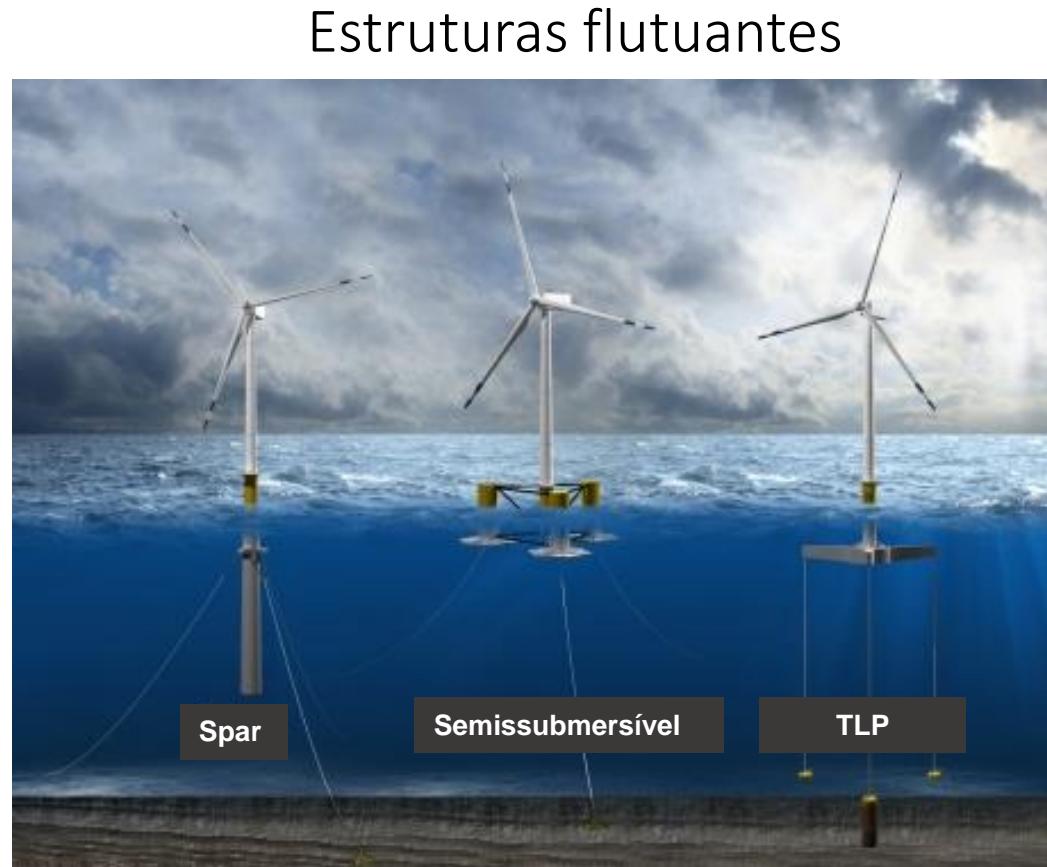
Van den Ende and Groeman, 2007

- Método de EDR baseia-se no transporte de íons (sal) através de membranas
- A diferença do potencial químico entre as membranas resulta em uma tensão elétrica

Fundações das turbinas eólicas



Estruturas fixas



Estruturas flutuantes

Nível de maturidade da tecnologia (TRL)

TRL	Atividades	Estágio atual de desenvolvimento tecnológico				
1	Princípios básicos observados e reportados					
2	Conceito tecnológico e/ou aplicação formulada	Gradiente de salinidade	Gradiente térmico (OTEC)	Correntes oceânicas	Energia de ondas	Amplitudes de marés
3	Função crítica analítica e experimental e/ou característica de prova de conceito					
4	Validação de componente e/ou sistema parcial em ambiente laboratorial					
5	Validação de componente e/ou sistema parcial em um ambiente relevante					
6	Validação de modelo de sistema/subsistema em um ambiente relevante					
7	Demonstração de protótipo em um ambiente operacional					
8	Sistema completo em escala real e serviço qualificado por teste e demonstração					
9	Sistema completo em escala real testado por missão operacional bem sucedida					

Research activities

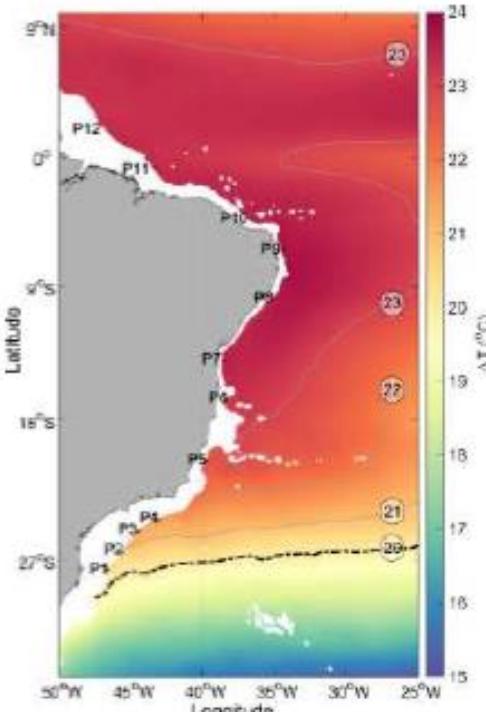
Mestrado
(5)

Doutorado
(2)

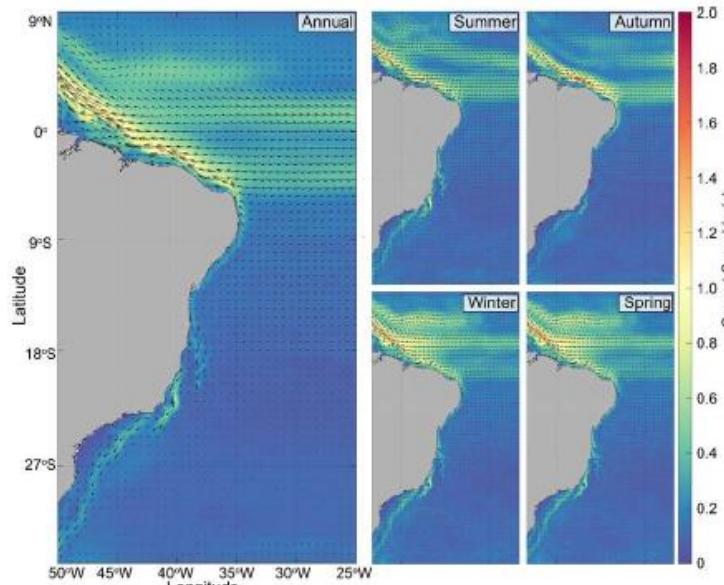
Pós doutorado
(4)

- Assessment of marine renewable energy resources
- Wave energy converters
- Offshore wind turbines
- Hybrid wind-wave systems

Assessment of marine renewable energy resources



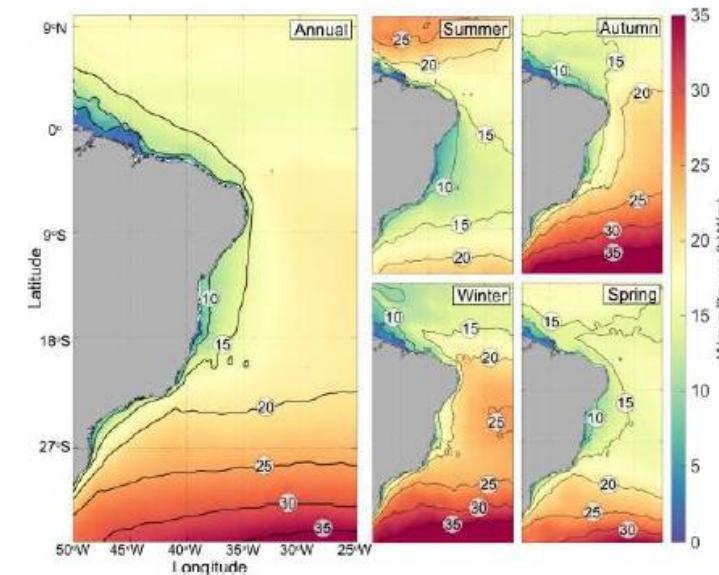
OTEC



Ocean current

10 MW OTEC plants

20 OTEC plants → **10% of the residential electricity consumption of the Northeast which was 27 TWh in 2017 (EPE)**



Wave



Article

Ocean renewable energy potential, technology and deployments: a case study of Brazil

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^a Ocean Engineering Department, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

^b Civil Engineering Program, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

^c Center for Global Sea Level Chance (CSLC), New York University Abu Dhabi (NYUAD), Abu Dhabi, United Arab Emirates

^d China Sup Scientific Research Centre (CSSRC), Wuxi, Jiangsu 214082, China

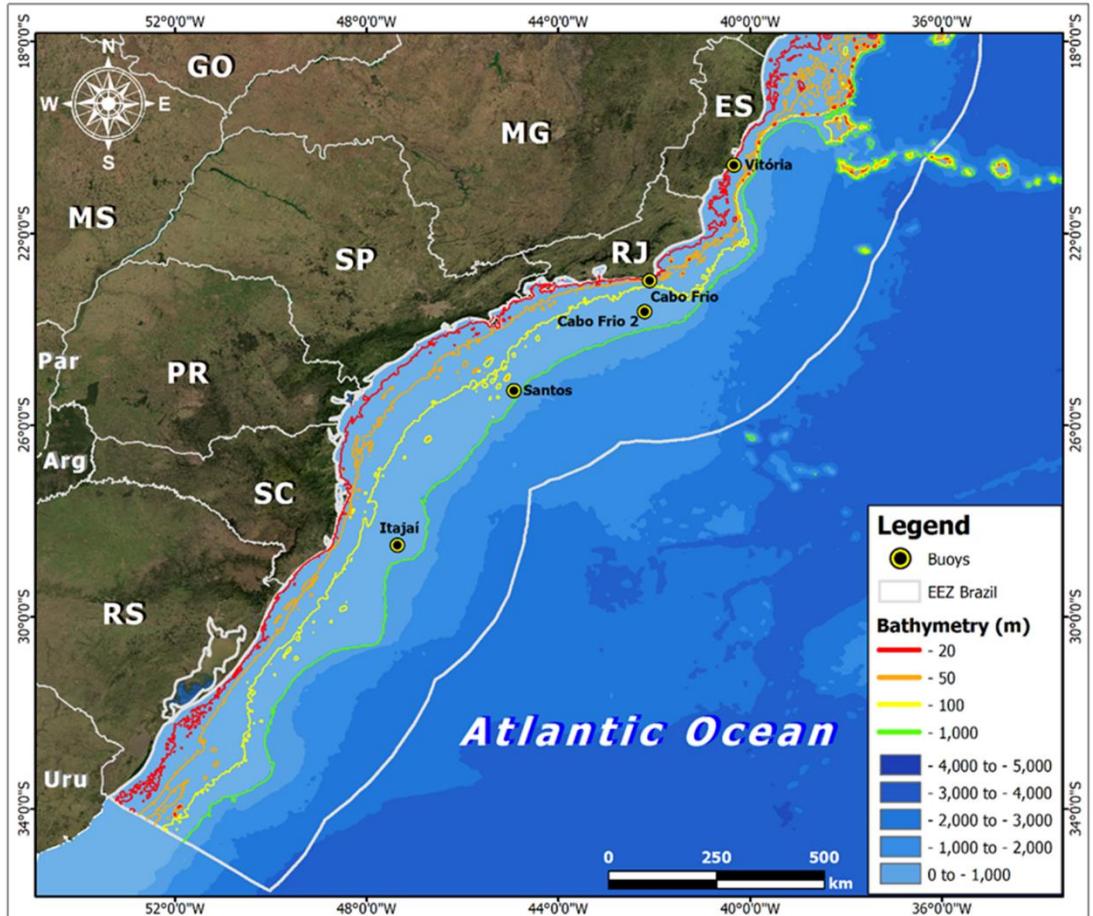
^e Meteorology Department, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

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Abstract: This study, firstly, provides an up to date global review of the potential, technologies, prototypes, installed capacities, and projects of ocean renewable energy including wave, tidal, and thermal and salinity gradients. Secondly, as a case study, it presents a preliminary assessment of the wave, ocean current, and thermal gradient sources along the Brazilian coastline. Global status of technological maturity of the projects, their different stages of development and the current global installed capacity for different sources indicate the most promising technologies considering the



Theoretical and technical offshore wind potential

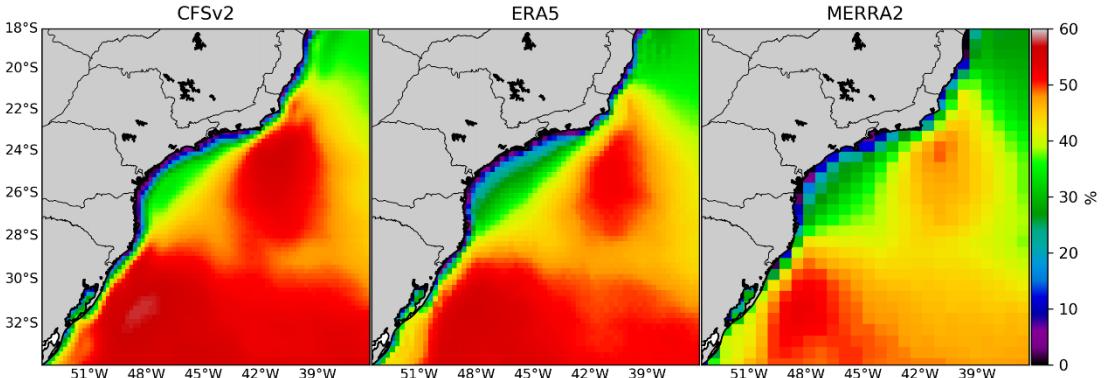


Three scenarios for 6 and 10 MW:

- Exclusive Economic Zone (EEZ)
- Between 18 km of coastline and 1000 m depth
- 0-25-50-75-100-500-1000

Reanálise atmosférica – 3 bases de dados

	Area [km ²]	Number of turbines	Total annual energy production [TWh]
South	190279.99	161254	ERA5 3569
			CFSv2 3857
			MERRA2 3486
Southeast	149137.18	126387	ERA5 2151
			CFSv2 2365
			MERRA2 1759
TOTAL	339417.17	287642	ERA5 5720
			CFSv2 6222
			MERRA2 5246



Wave energy converters

COPPE hyperbaric wave converter

- 100kW capacidade instalada
- Ceará, Pecém (2012)

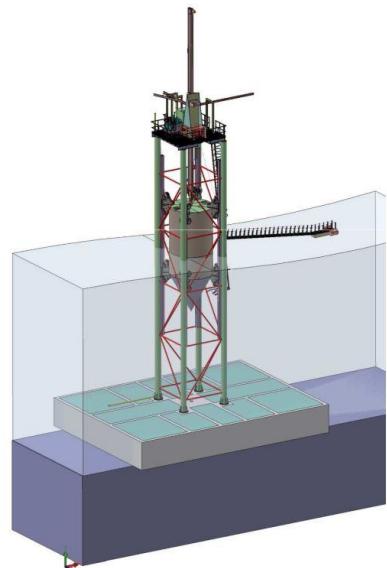


References:

- Estefen, S.F et al. (2007, 2012)
Shadman, M et al. (2015)

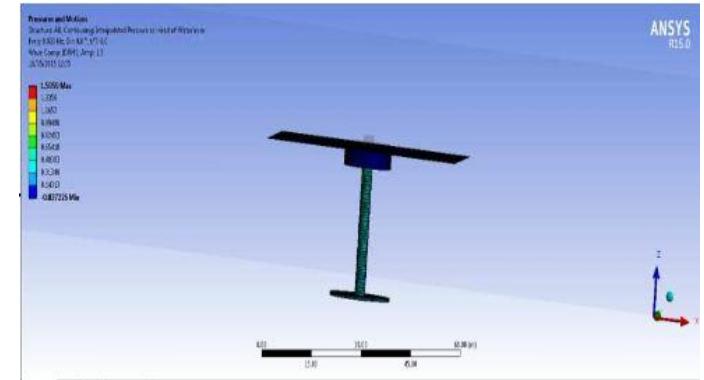
COPPE nearshore wave converter

- 50kW capacidade instalada
- Ilha Rasa, Rio de Janeiro

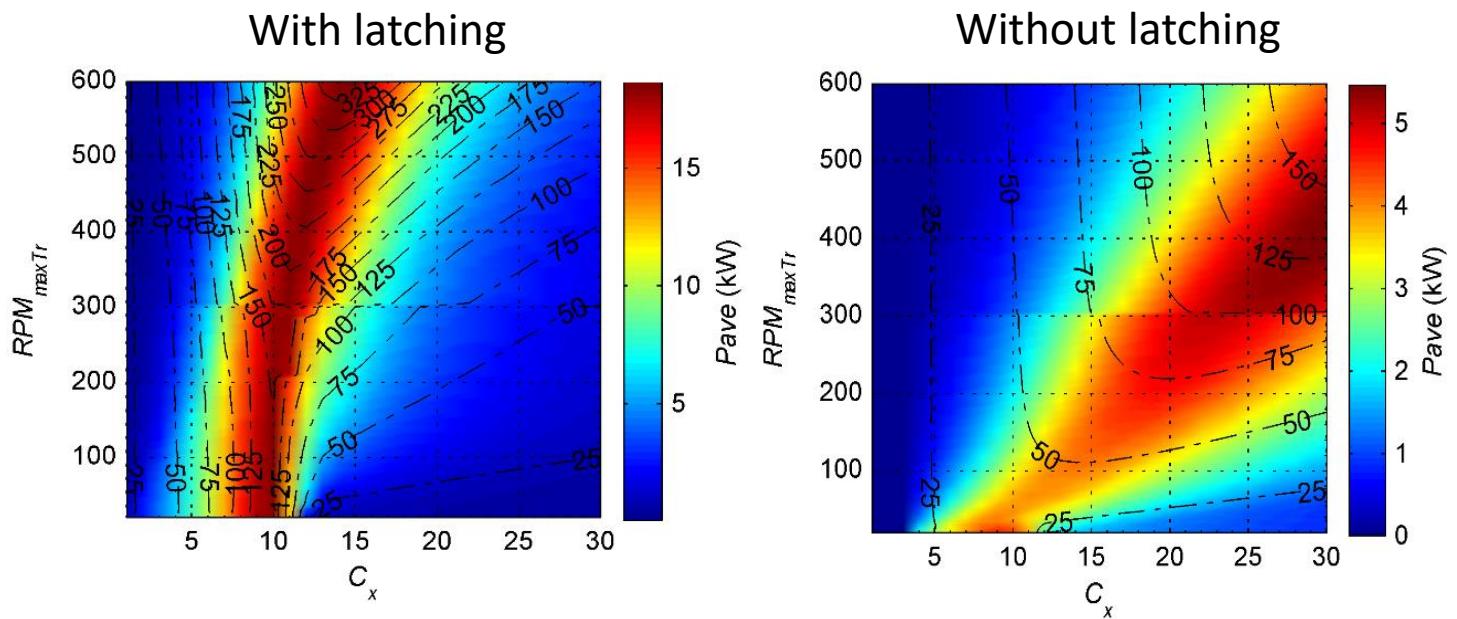
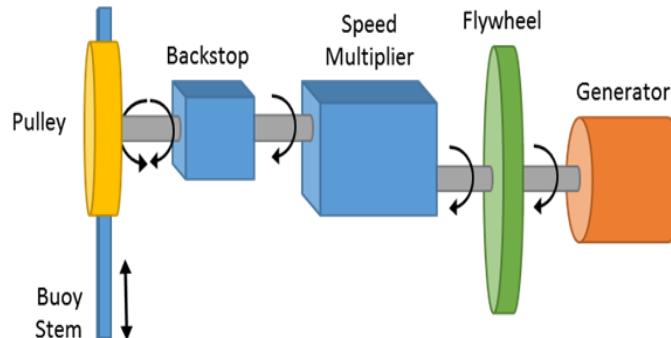
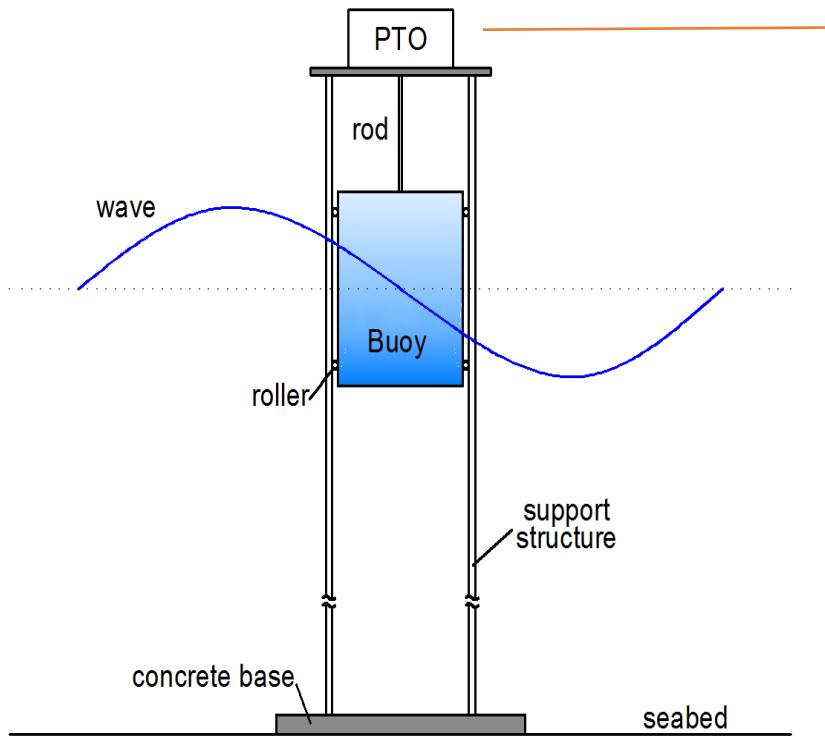


COPPE offshore wave converter

- 50kW capacidade instalada
- CEO flutuante
- Analise numérica



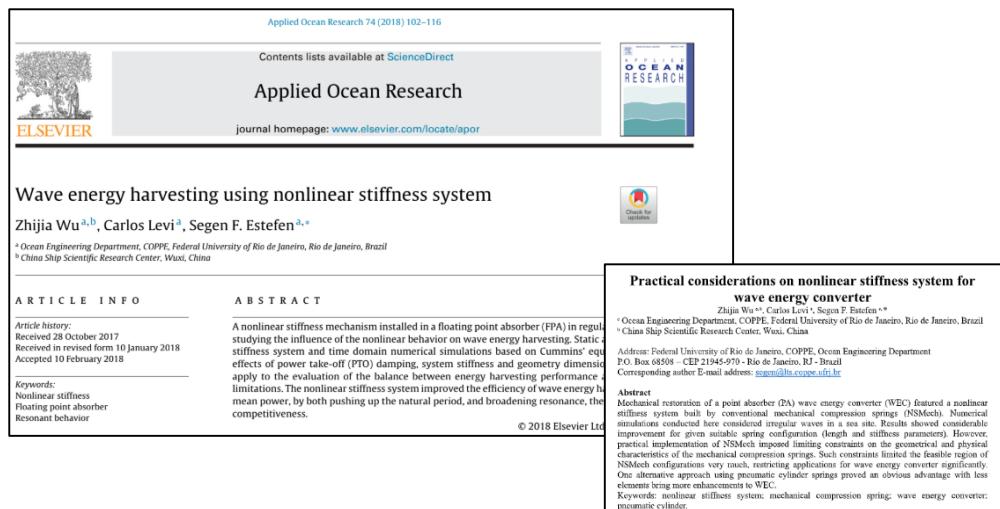
Latching control



Nonlinear stiffness control system (NSS)

Objective: Investigate the influence of NSS on improving WEC performance.

- Increasing the resonance period and broaden the response bandwidth theoretically;
- Indicating that the constraints of mechanical characteristics weaken the performance of NSMech drastically;
- Propose an alternative NSPneu and verify its performance.



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Wave energy harvesting using nonlinear stiffness system
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^a Ocean Engineering Department, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
^b China Ship Scientific Research Center, Wuxi, China

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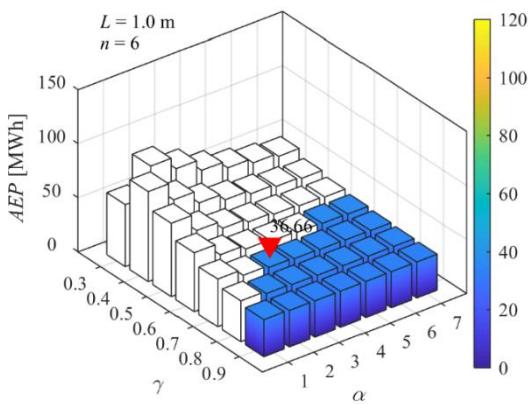
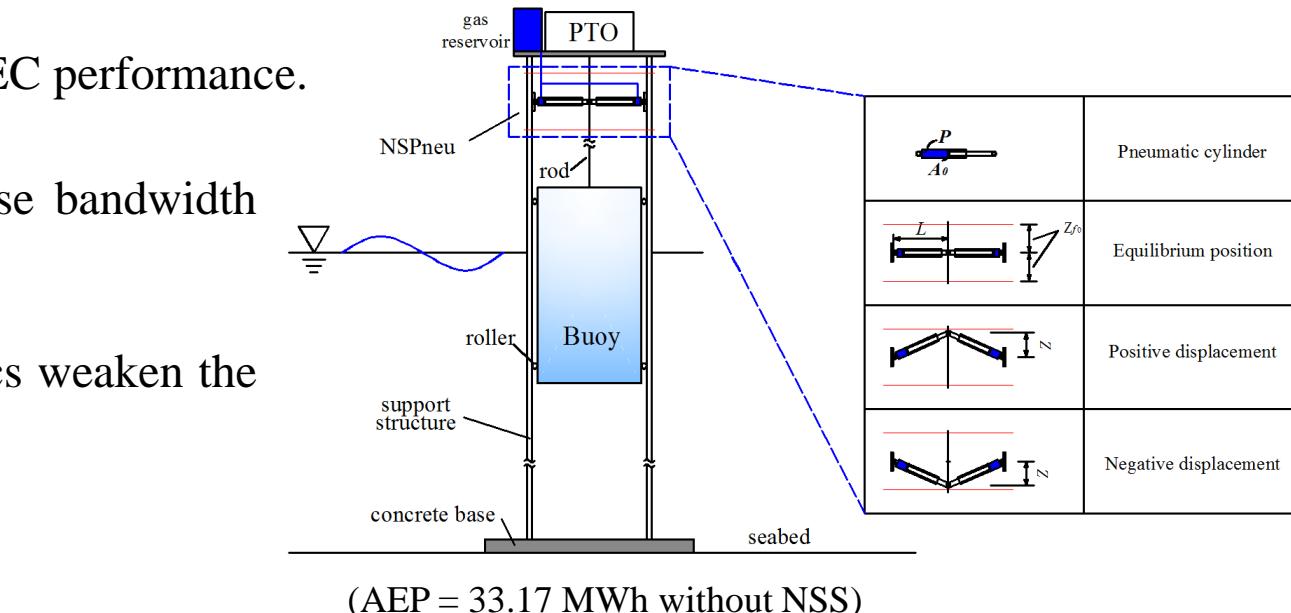
Keywords:
Nonlinear stiffness
Floating point absorber
Resonant behavior

ABSTRACT
A nonlinear stiffness mechanism installed in a floating point absorber (FPA) is regularized to study the influence of the nonlinear behavior on wave energy harvesting. Static stiffness system and time domain numerical simulations based on Cummins' effects of power take-off (PTO) damping, system stiffness and geometry dimensions apply to the evaluation of the balance between energy harvesting performance and limitations. The nonlinear stiffness system improved the efficiency of wave energy harvesting power, by both pushing up the natural period, and broadening resonance, the competitiveness.

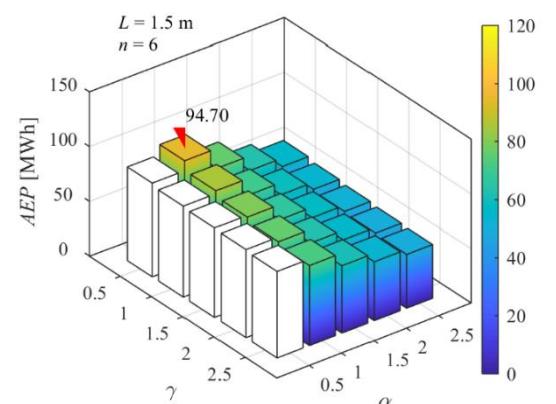
Practical considerations on nonlinear stiffness system for wave energy converter
Zhijia Wu^{a,*}, Carlos Levi^a, Segean F. Esteften^{a,*}
^a Ocean Engineering Department, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
^b China Ship Scientific Research Center, Wuxi, China
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Abstract
Mechanical resonance of a point absorber (DA) wave energy converter (WEC) featured a nonlinear stiffness system built by conventional mechanical compression springs (NSMech). Numerical simulations conducted here considered irregular waves in a sea site. Results showed considerable improvement for given suitable spring configurations (length and stiffness parameters). However, several limitations of NSMech were observed, mainly on the mechanical constraints and physical characteristics of the mechanical compression springs. Such constraints limited the feasible region of NSMech configurations very much, restricting applications for wave energy converter significantly. One alternative approach using pneumatic cylinder springs proved an obvious advantage with less mechanical constraints and better performance for WEC.

Keywords: nonlinear stiffness system; mechanical compression spring; wave energy converter; pneumatic cylinder.

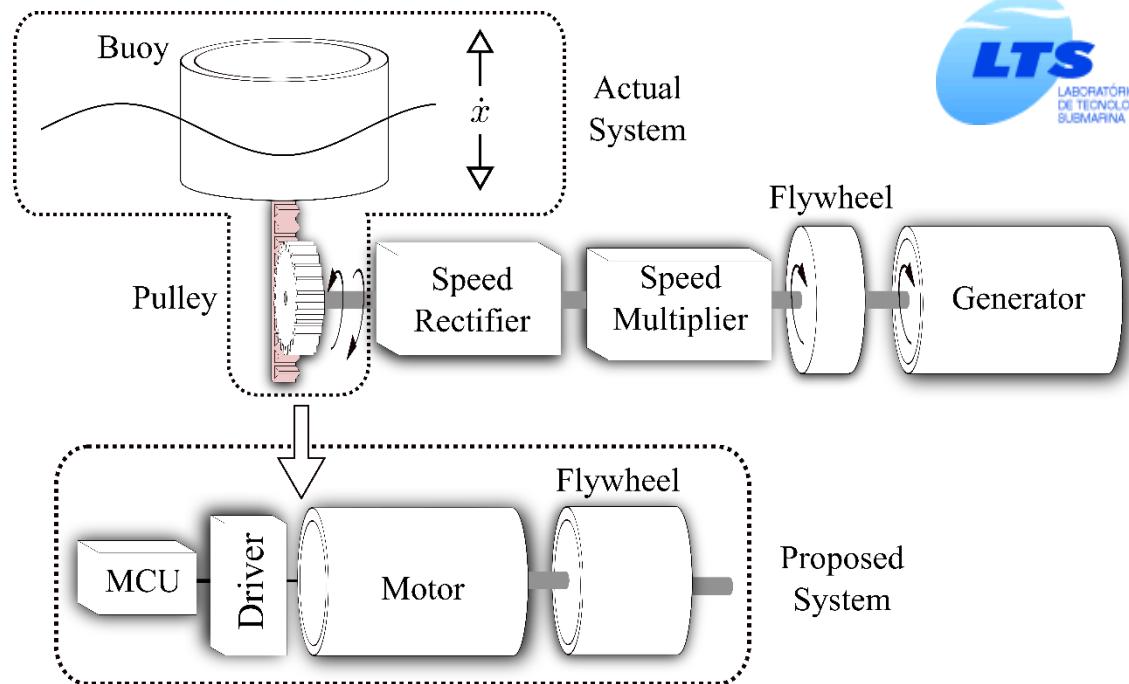


with NSMech (36.66 MWh)



with NSPneu (94.70 MWh)

PTO dry-test equipment



MANUSCRIPT

Dry Test Setup Development of a Heaving Point Absorber Wave Energy Converter

Ryan O. Berriel, Milad Shadman, Zhiqia Wu, Robson F. S. Dias, *Senior Member, IEEE*,
Richard M. Stephan, *Senior Member, IEEE*, and Segean F. Esteven

Abstract—This paper presents the development of a down-scaled dry test set-up for a heaving point absorber wave energy converter (WEC) with a mechanical power take-off (PTO) system. The dynamic model of the heave motion is first demonstrated and compared with the experimental results. The main objective is the reproduction of resultant torque due to the heave motion of WEC using an electric machine is presented. The technique is developed for real-time implementation and allows the reproduction of different wave conditions which enables a wide-ranging dynamic analysis of the PTO system. The Froudes law is used in this paper to determine the scale down factor considering the machine limitations and the desired wave conditions. Experimental results are presented to validate the methodology.

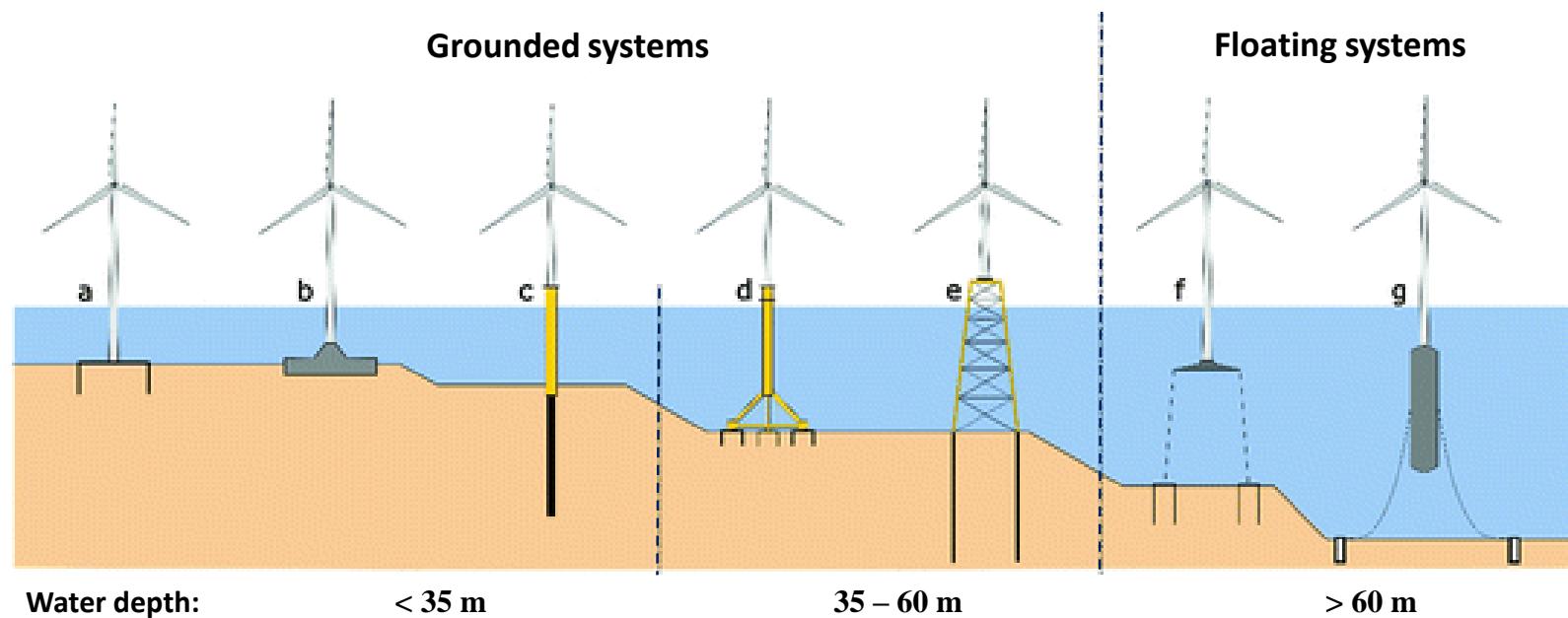
Index Terms—Wave energy converter, dynamic emulation, heaving point absorber.



Country / Region	% of resource in deep water locations (> 60 m)	Potential floating wind capacity
Europe	80%	4,000 GW
USA	60%	2,450 GW
Japan	80%	500 GW
Brazil (no technical/environmental restriction)	86%	6,013 GW

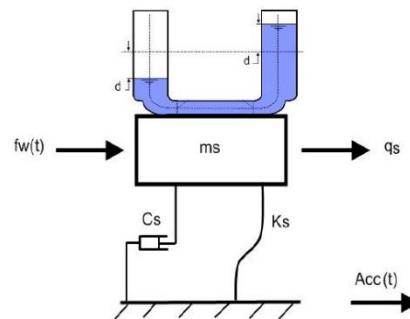
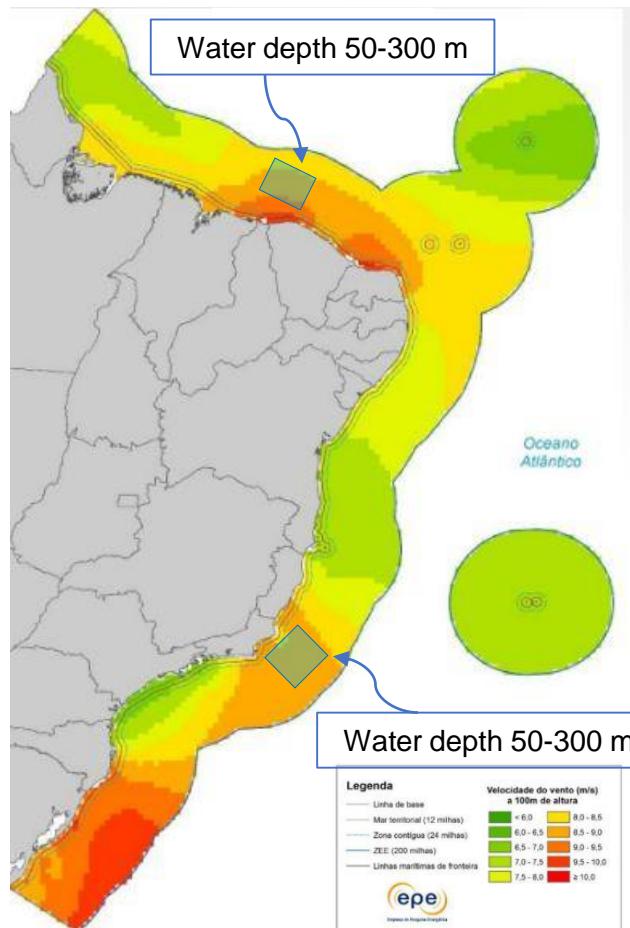
[Carbon Trust. 2015]

[Pimenta et al. 2018]

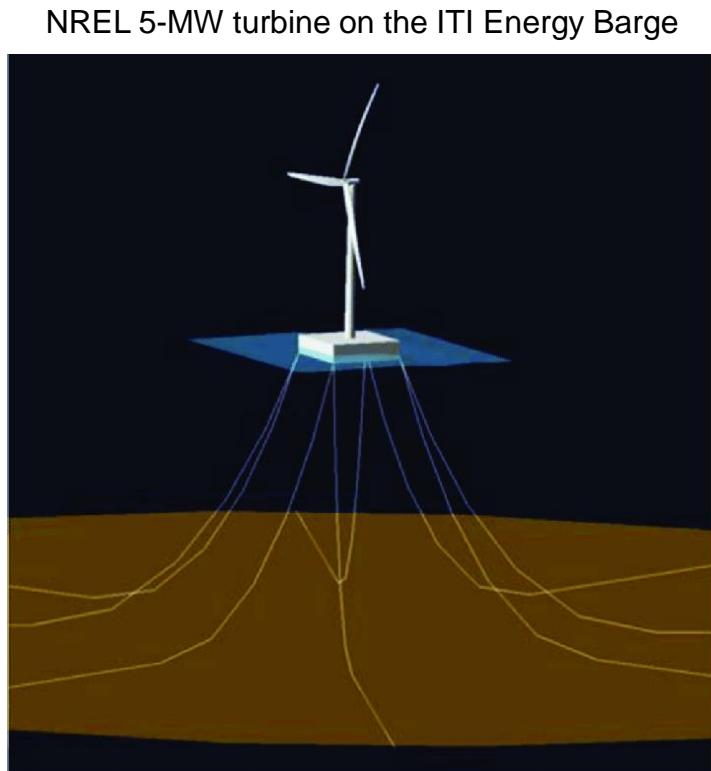
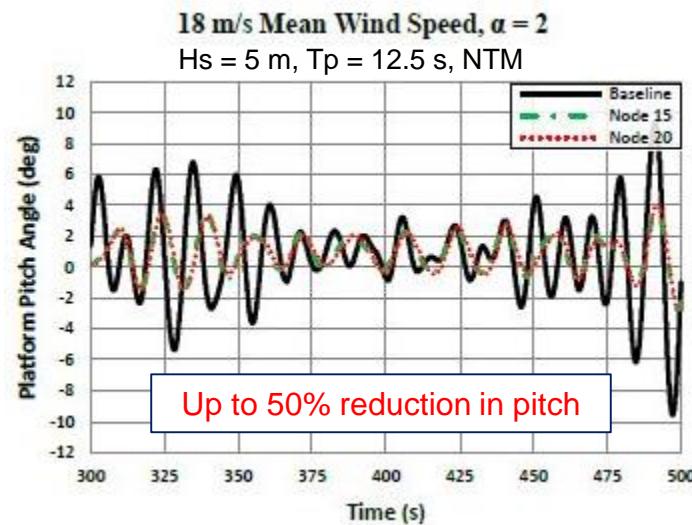


Chno-economical study of the floating offshore wind

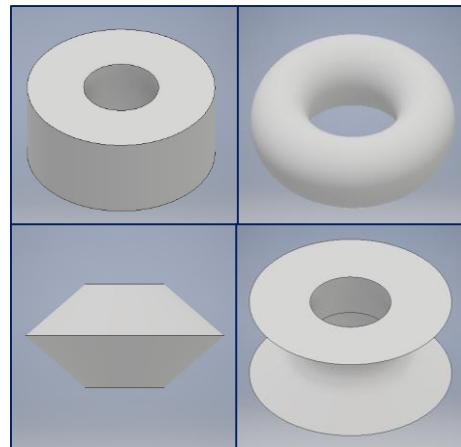
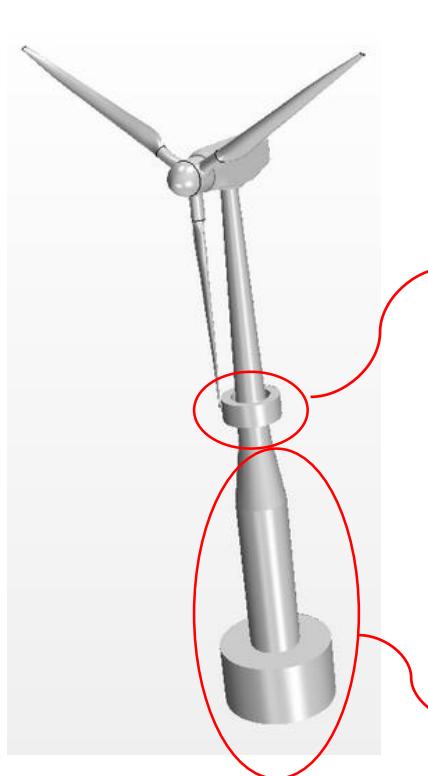
Offshore wind
[Pimenta et al. 2018]



Tuned Liquid Column Damper (TLCD)



Floating hybrid wind-wave system

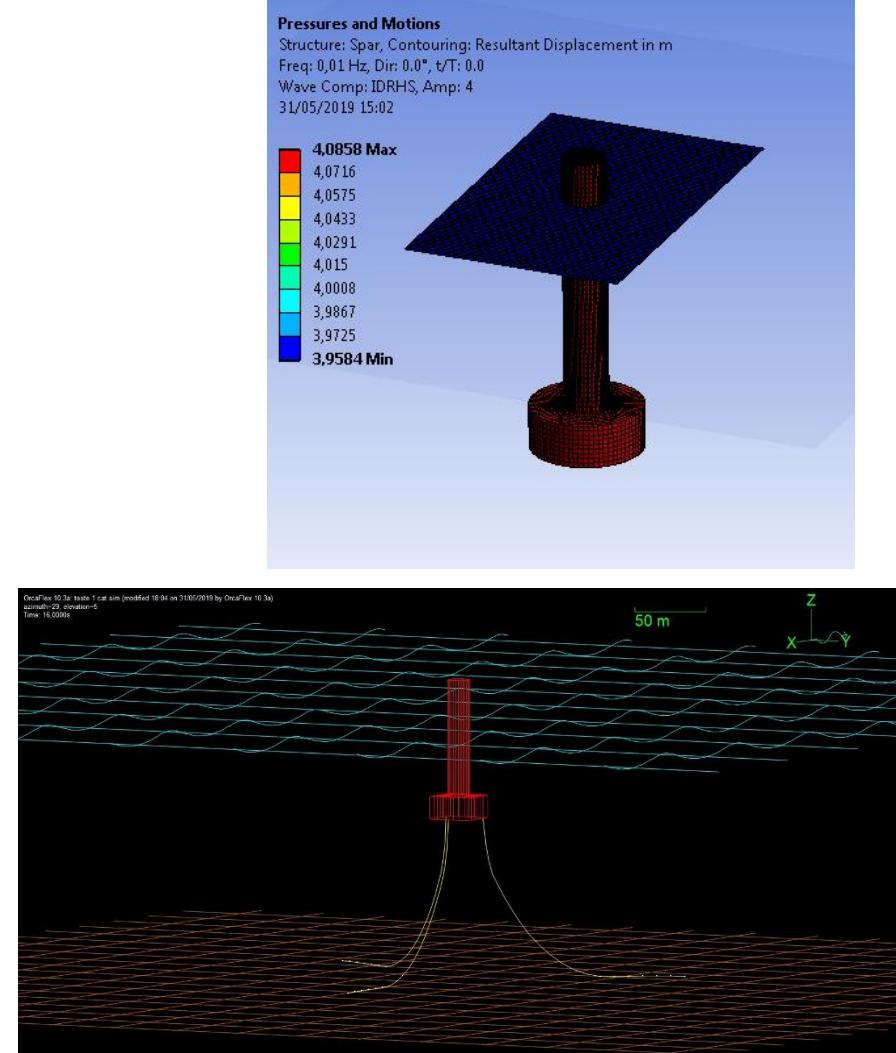


Wave energy converter

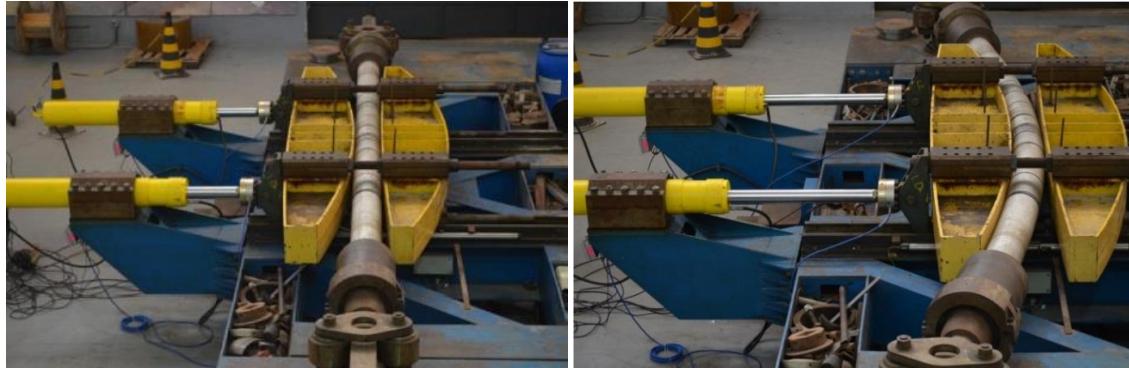
Floating platform



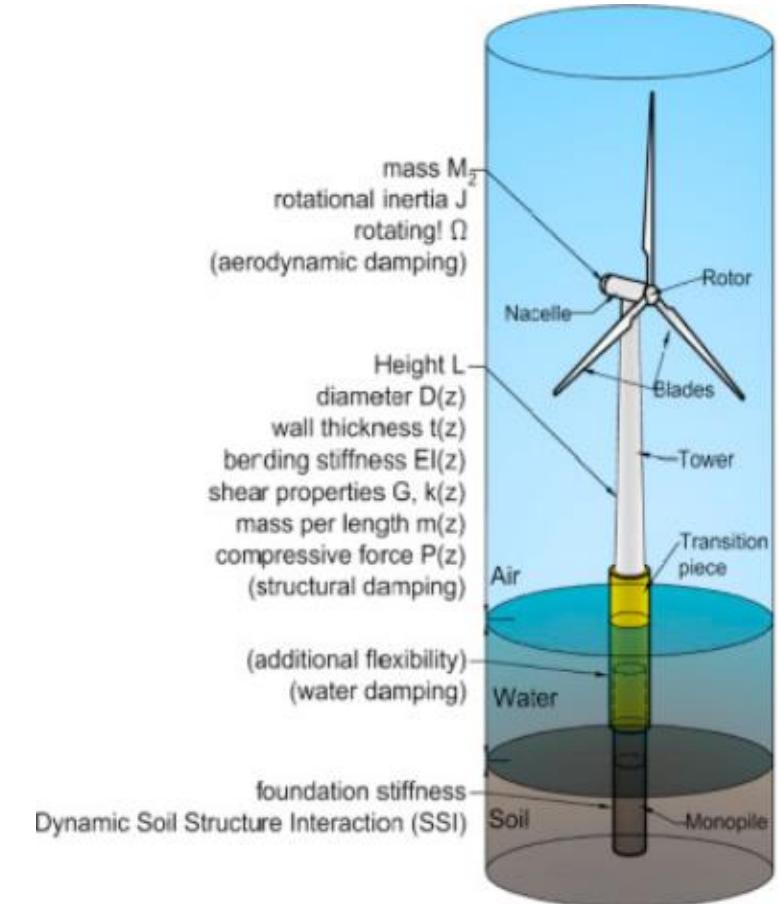
**Meshed body
AQWA/ANSYS**



Techno-economic feasibility of using sandwich-pipe as tower for offshore wind turbines

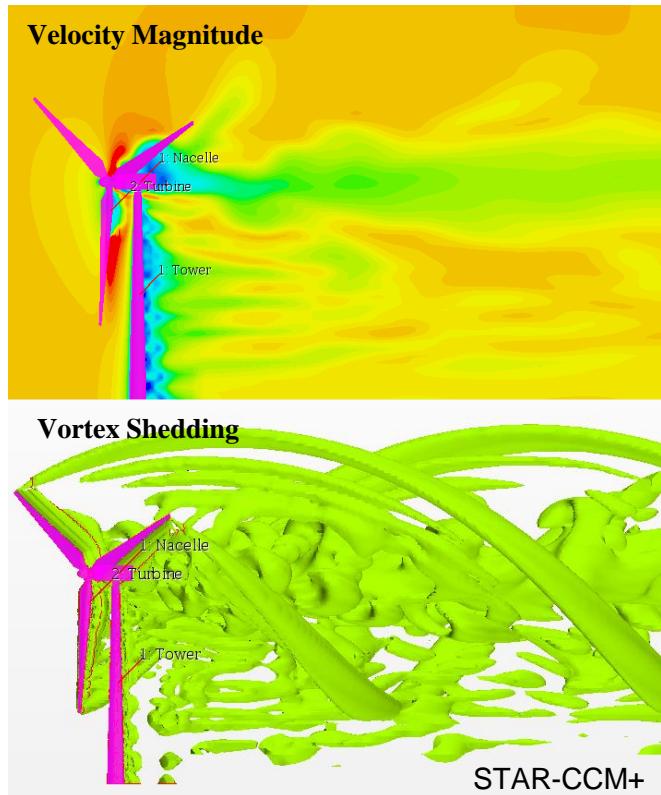


Sandwich-pipe SHCC (*strain-hardening cementitious composites*)
Patented by LTS



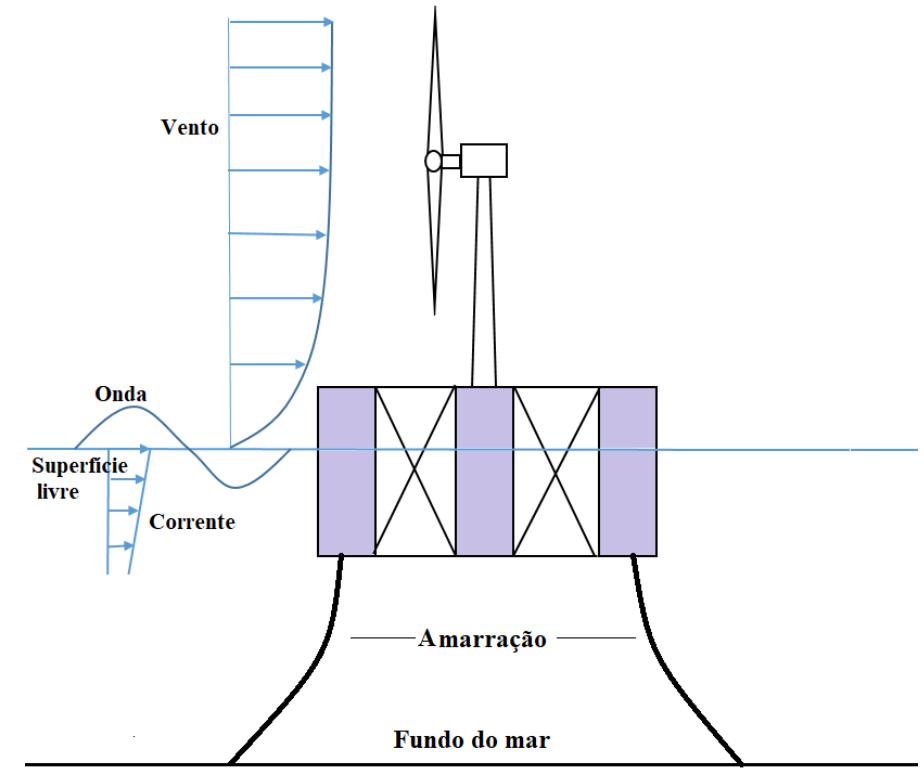
CFD modeling of floating wind turbine

Numerical Results



Full-scale model
Blade diameter = 126 m
Tower height = 90 m
Capacity = 5 MW

**RANS Equations +
a Turbulence Model +
Continuity Equation**



- Considering viscous and nonlinear Hydro-aero effects.
- Avoiding high costs and complexity of performing experiments.

THANK YOU!

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