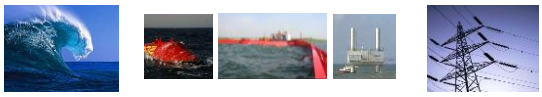


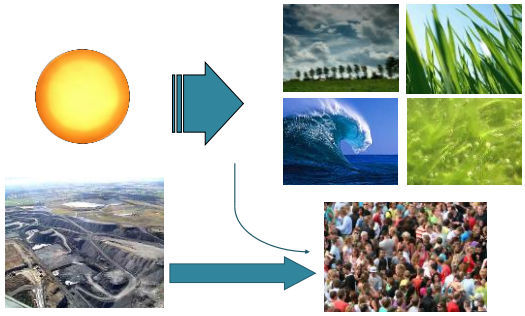
Technical and Non-technical Issues Towards the Commercialisation of Wave Energy Converters

Julia Fernández Chozas

J. P. Kofoed (Aalborg University)
H. C. Sørensen (Spok ApS)

ENERGINET.DK AALBORG UNIVERSITET wavetrain2

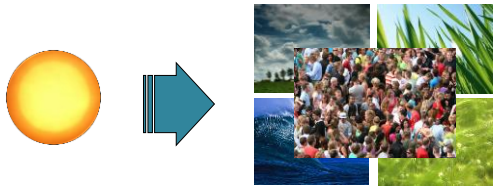
Motivation



[M. Prado, Teamwork Technology, 2009]

2

Motivation



[M. Prado, Teamwork Technology, 2009]

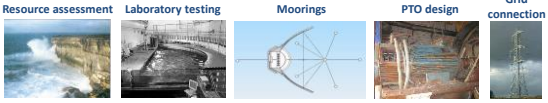
3

Motivation

[M. Prado, Teamwork Technology, 2009]

4

Resource assessment | Laboratory testing | Moorings | PTO design | Grid connection



22 young researchers

wavetrain2

5

ENERGINET.DK

AALBORG UNIVERSITET

Wave Dragon

wavetrain2

6

Outline

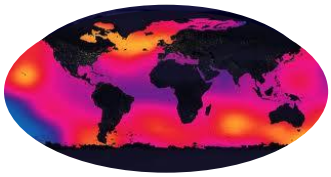
1. Introduction
2. Public opinion towards wave energy
3. Performance evaluation based on sea trials
4. Offshore grids and wave generation
5. Combined production of wave and wind
6. Waves predictability and electricity markets
7. Summary of results

7

Wave Energy Characteristics

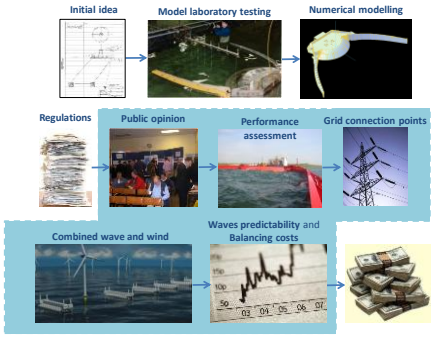
The wave energy resource is:

- ✓ Concentrated
- ✓ Widely available
- ✓ Close to consumption points
- ✓ Predictable (to some extent)
- ✓ Sustainable
- ✓ Provides security of supply



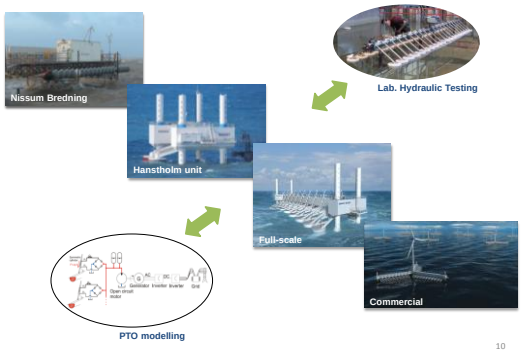
8

From an idea to a commercial reality



9

From an idea to a commercial reality



10

Outline

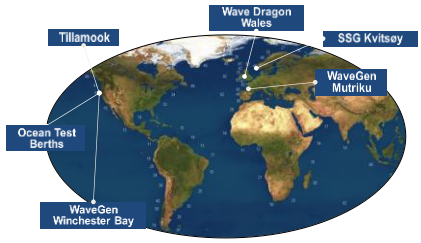
1. Introduction
2. **Public opinion towards wave energy**
3. Performance evaluation based on sea trials
4. Offshore grids and wave generation
5. Combined production of wave and wind
6. Waves predictability and electricity markets
7. Summary of results

11

Public Opinion towards Wave Energy

12

Public Opinion towards Wave Energy



Developer engagement?
Stakeholders involved?
Community meetings?
Local groups?
Residents?
Influential people?

13

Outline

1. Introduction
2. Public opinion towards wave energy
3. **Performance evaluation based on sea trials**
4. Offshore grids and wave generation
5. Combined production of wave and wind
6. Waves predictability and electricity markets
7. Summary of results

14

Performance Evaluation based on Sea Trials

EquiMar methodology: analysis and presentation of data obtained from sea trials

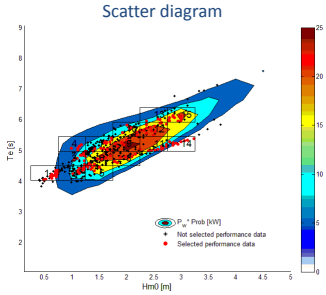
Reference location:
Nissum Bredning
P_{wave}=0.3-0.6 kW/m

Target location:
Hanstholm
P_{wave}=6 kW/m

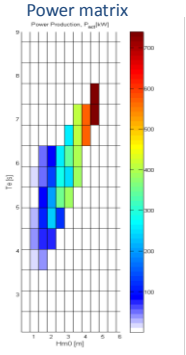
15

Performance Evaluation based on Sea Trials
Hanstholm

Scatter diagram



Power matrix



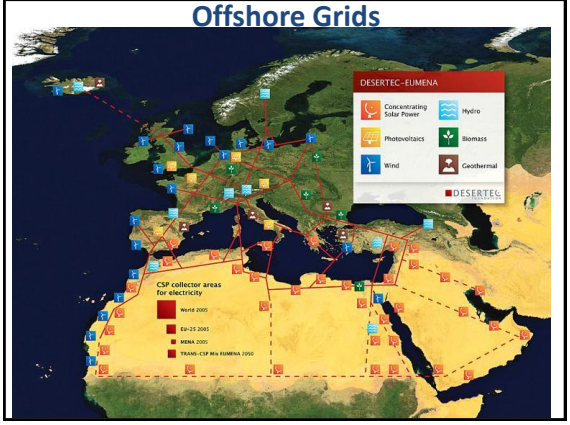
16

Outline

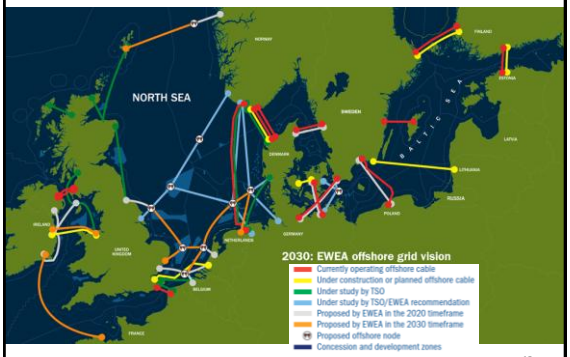
1. Introduction
2. Public opinion towards wave energy
3. Performance evaluation based on sea trials
4. **Offshore grids and wave generation**
5. Combined production of wave and wind
6. Waves predictability and electricity markets
7. Summary of results

17

Offshore Grids



Offshore Grids



19

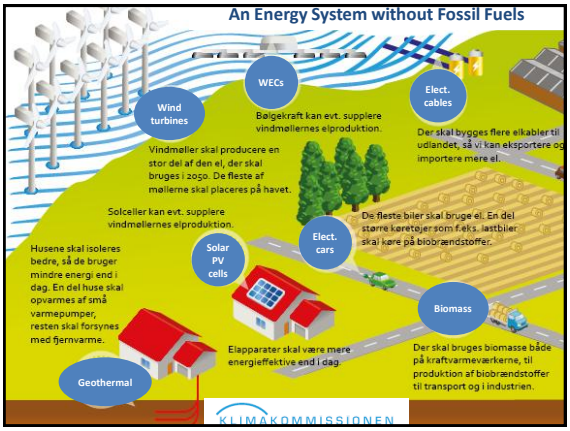
Outline

1. Introduction
2. Public opinion towards wave energy
3. Performance evaluation based on sea trials
4. Offshore grids and wave generation
5. **Combined production of wave and wind**
6. Waves predictability and electricity markets
7. Summary of results

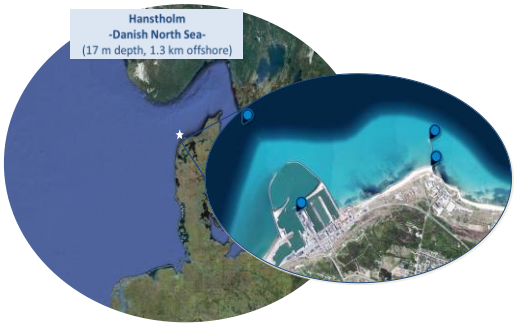
.....  .....

20

An Energy System without Fossil Fuels

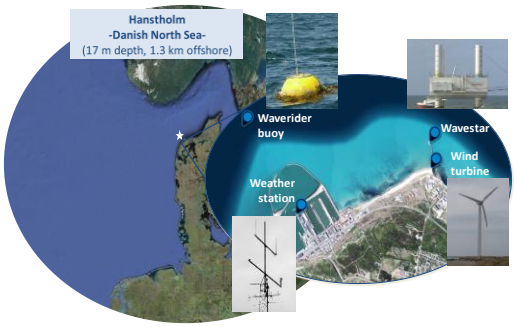


Combined production of wave and wind
Study Location



22

Combined production of wave and wind
Study Location



23

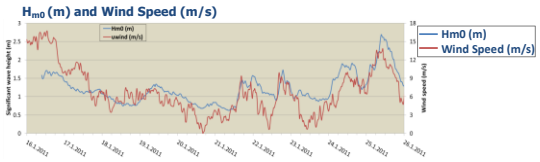
Combined production of wave and wind

- Real power production data
- 5-month period
- Nordic Folkecenter wind turbine: P_{rated} = 525 kW
- Wavestar hydraulic power, limited at 60% production

24

Combined production of wave and wind

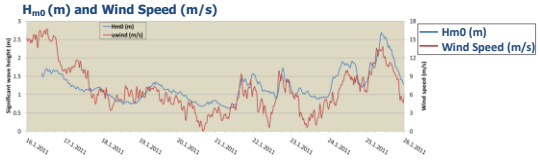
H_{m0} (m) and Wind Speed (m/s)



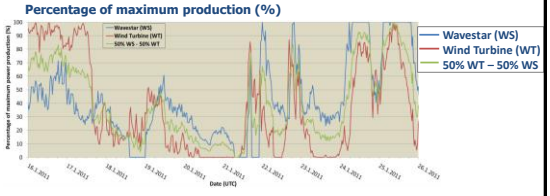
25

Combined production of wave and wind

H_{m0} (m) and Wind Speed (m/s)



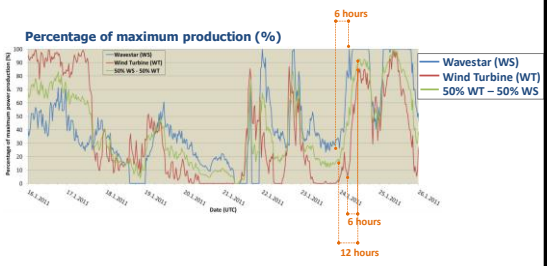
Percentage of maximum production (%)



26

Combined production of wave and wind

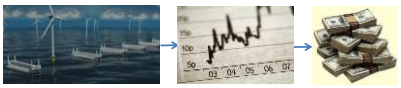
Percentage of maximum production (%)



27

Outline

1. Introduction
2. Public opinion towards wave energy
3. Performance evaluation based on sea trials
4. Offshore grids and wave generation
5. Combined production of wave and wind
6. **Waves predictability and electricity markets**
7. Summary of results

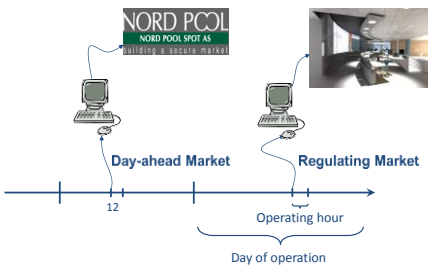


28

"Waves are more predictable than winds"

29

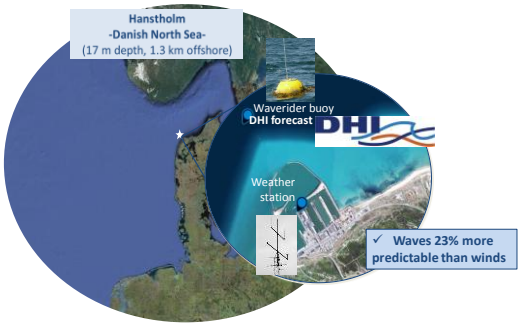
Waves Predictability and Electricity Markets



ENERGINET.DK

30

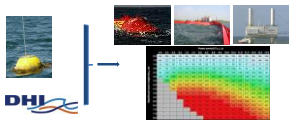
Waves Predictability and Electricity Markets
Study Location



31

Waves Predictability and Electricity Markets
Data and Model

❖ Wave Energy Converters Power productions

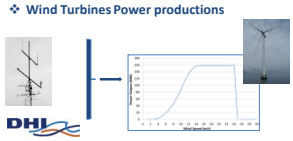


$P_{Real\text{-}time\ wave\ production}$

$P_{Forecast\text{-}wave\ production}$

✓ WECs production 45% more predictable than wind turbines production

❖ Wind Turbines Power productions

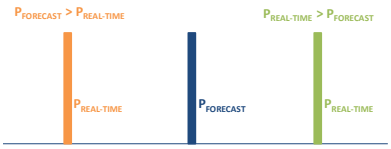


$P_{Real\text{-}time\ wind\ production}$

$P_{Forecast\text{-}wind\ production}$

32

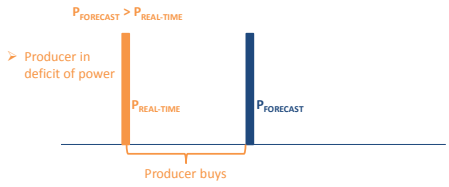
Waves Predictability and Electricity Markets
Balancing costs: the two-price model



33

Waves Predictability and Electricity Markets

Balancing costs: the two-price model



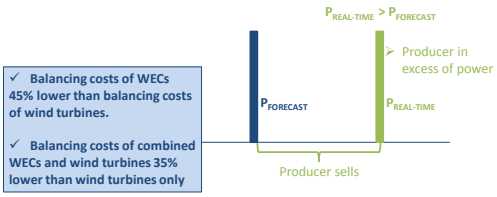
Buying price:

- If system in deficit of power:
  - Up-regulation price
- If system in excess of power:
  - Market price

34

Waves Predictability and Electricity Markets

Balancing costs: the two-price model



- ✓ **Balancing costs of WECs 45% lower than balancing costs of wind turbines.**
- ✓ **Balancing costs of combined WECs and wind turbines 35% lower than wind turbines only**

Selling price:

- If system in deficit of power:
  - Market-price
- If system in excess of power:
  - Down-regulation price

35

Outline

1. Introduction
2. Public opinion towards wave energy
3. Performance evaluation based on sea trials
4. Offshore grids and wave generation
5. Combined production of wave and wind
6. Waves predictability and electricity markets
7. **Summary of results**

36

Summary of results

- ✓ An early, dynamic and open public engagement approach helps to achieve public acceptability of wave energy projects.
- ✓ The EquiMar methodology provides an uniform and transparent procedure to analyse and present performance data obtained from sea trials.
- ✓ There is lack of offshore grid connection points offshore and wave energy is not being considered in the planning of grid upgrades.
- ✓ Benefits when combining power production of WECs and wind turbines:
  - ✓ Cost benefits: shared infrastructure and O&M costs.
  - ✓ Technical benefits: smooth and high availabe power output.
  - ✓ Grid benefit: reduced balancing costs and balancing power.

37

Thank you very much for your attention

and a very special thank you to:

AALBORG UNIVERSITET ENERGINET.DK wavetrain2