Høgskulen på Vestlandet

MarinLab

Reducing Cost of Energy for Tidal Stream Turbines through Co-location

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Presentation for Bergen Energy Lab

Høgskulen på Vestlandet

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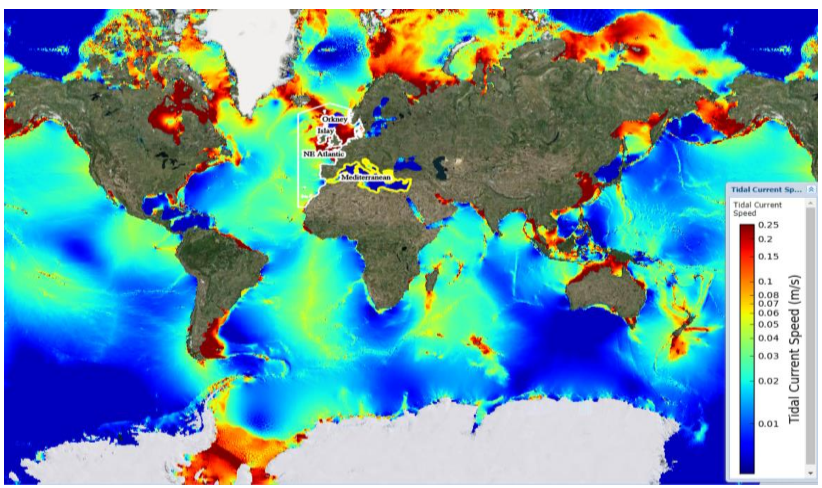
Tidal stream technology

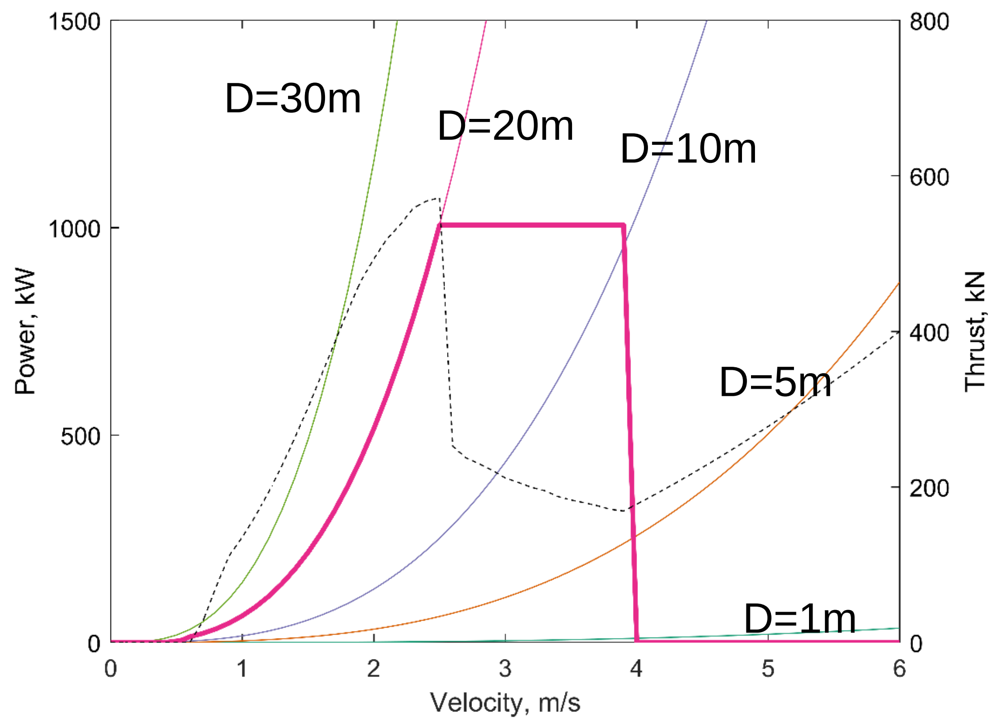
Tidal Power Generation

$$F = \frac{1}{2} C_T \rho A U^2$$

$$LCOE = \frac{P_V(CAPEX + OPEX)}{P_V(E)}$$

$$P = \frac{1}{2} C_p \rho A U^3$$





Høgskulen på Vestlandet

Background

OFFSHORE WIND

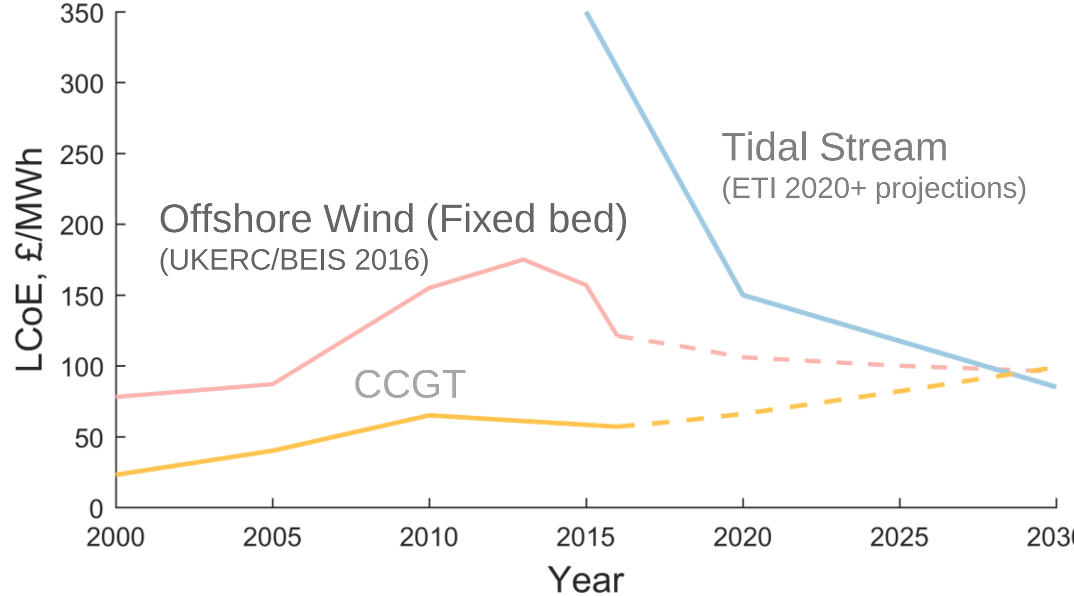
2030

90TWh/yr

30-60m(depth)

UK Total Consumption: 380 TWh (2015)

CCGT - Combined-cycle Gas Turbines



TIDAL STREAM

2030+

20TWh/yr(potential)

40-80m(depth)

~5% UK consumption

2x London's consumption

Aim & Objectives

Feasibility of adding wind turbines to tidal arrays to reduce LCOE by:

Increased and less variable power-output

Co-located energy yield model

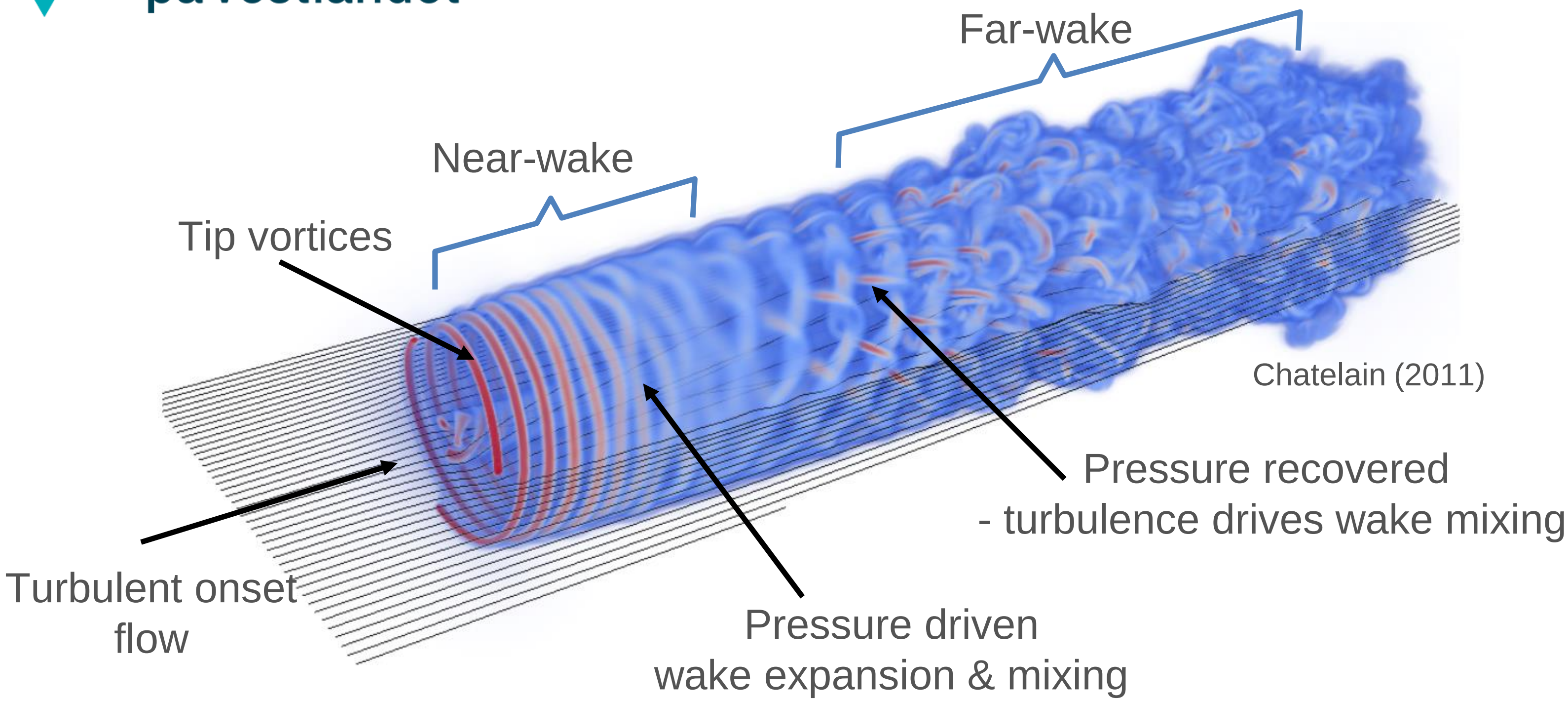
Shared Support Structure & Infrastructure

Assessment of extreme loads

Reduced €/MW(capacity)

Economic assessment

Turbine wakes



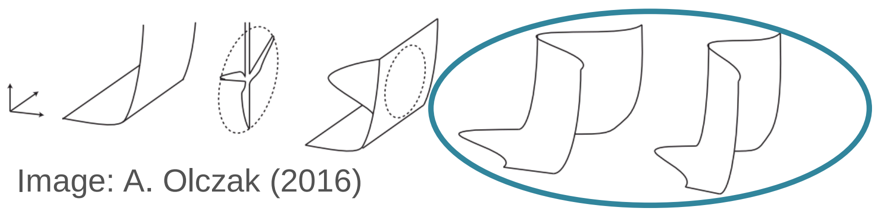
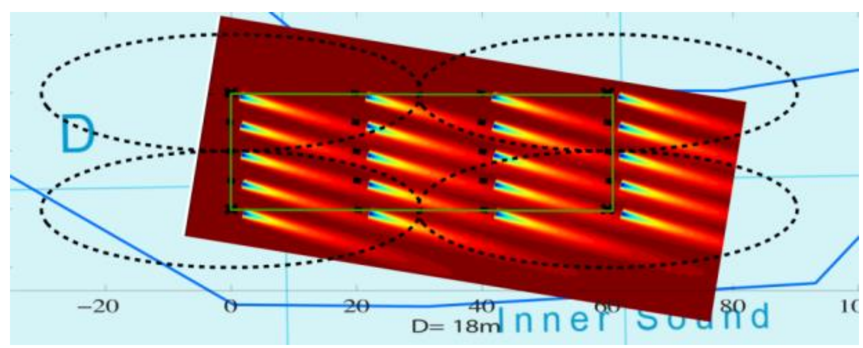


Image: A. Olczak (2016)

Wake superposition: $\Delta U_w = \sum_{i=1}^{k} \Delta U_i$



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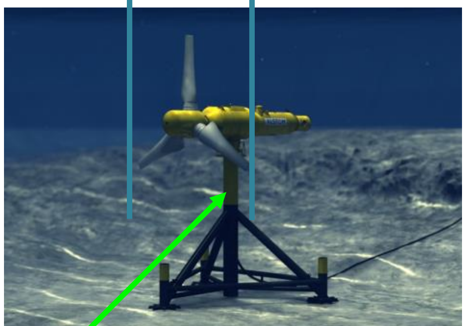
What size for a shared support?

20m

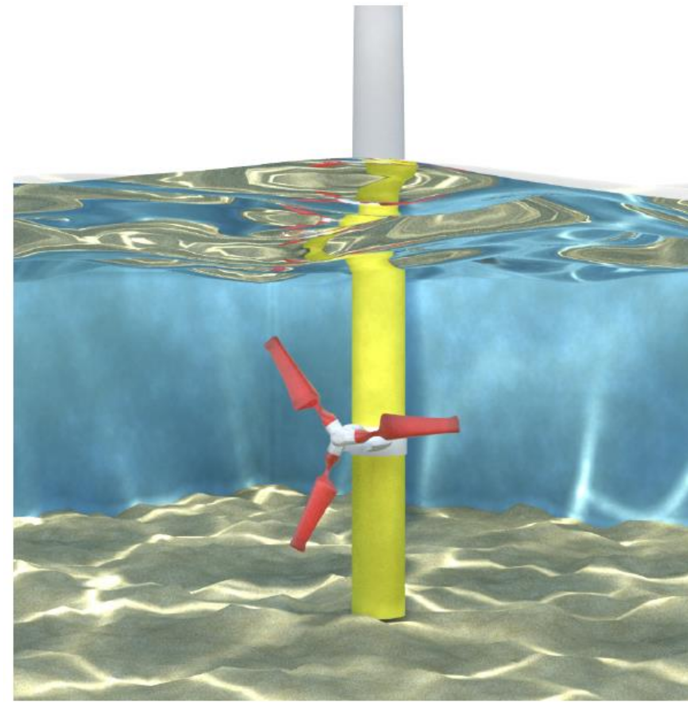


2m

3.6 MW

100m

5m



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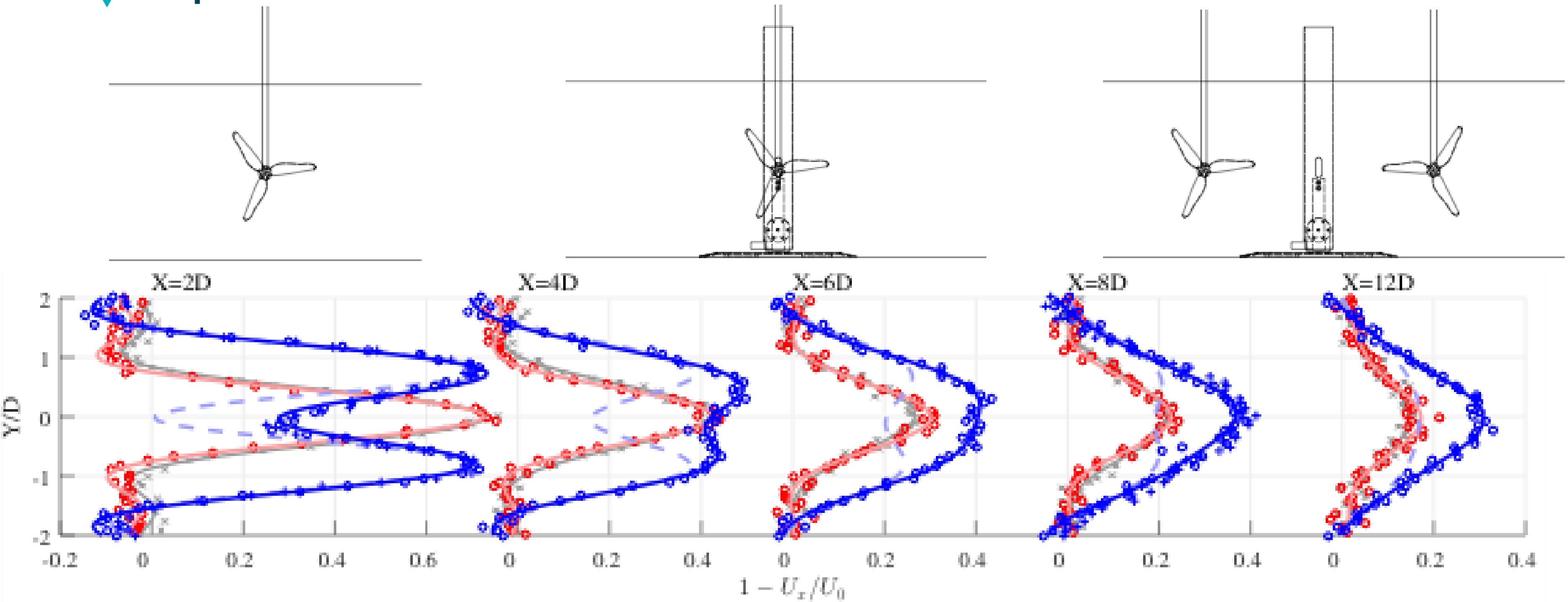
Experimental validation

Effect of shared support on wake

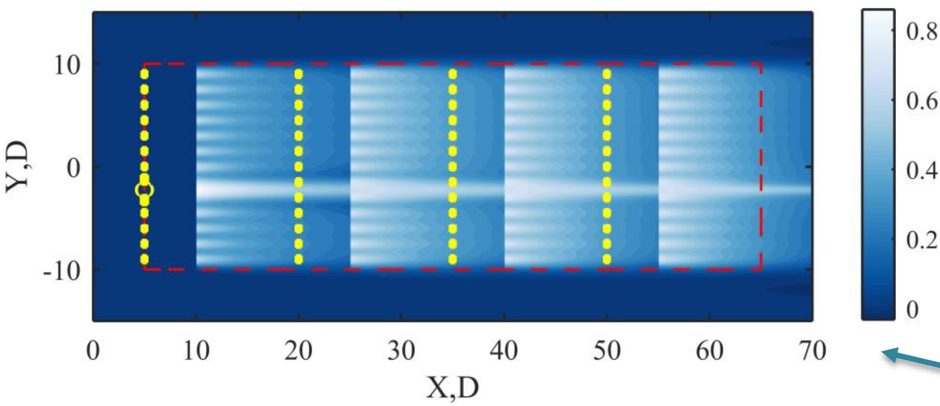


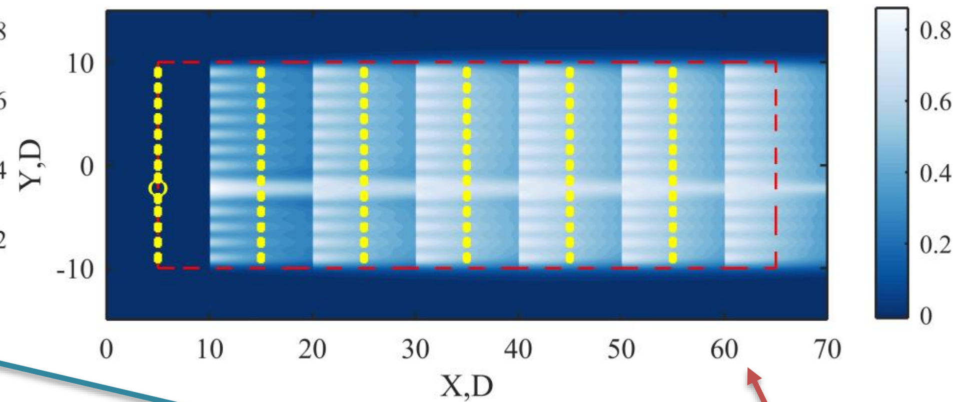
Rotor-only (-x), Rotor & Tower (-o), 2 Rotor & Tower (-o) 2 Rotor & Tower superposition (---)

- Peak deficit with tower is 70-80% greater than without tower.
- Superposition of 2 rotor and tower under-predicts combined wake by almost 30%

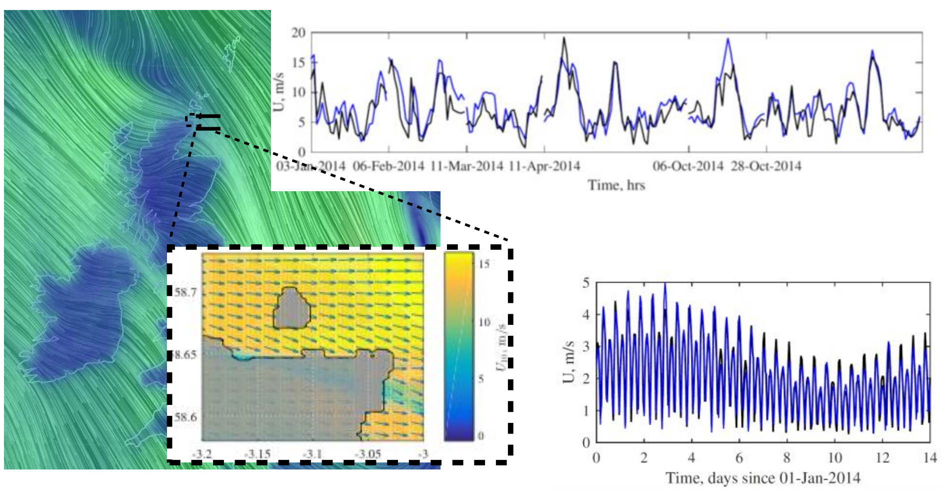
Energy Yield for Unit Area

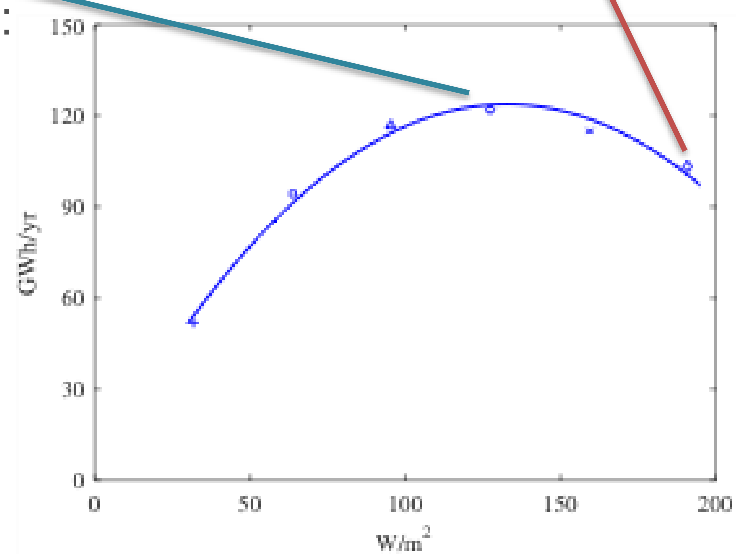
- What is the minimum amount of additional power a wind turbine will provide?





- 3.5 years resource data from Pentland Firth:





- Addition of a 3 MW wind turbine increases yield by at least 12%.

Load Modelling

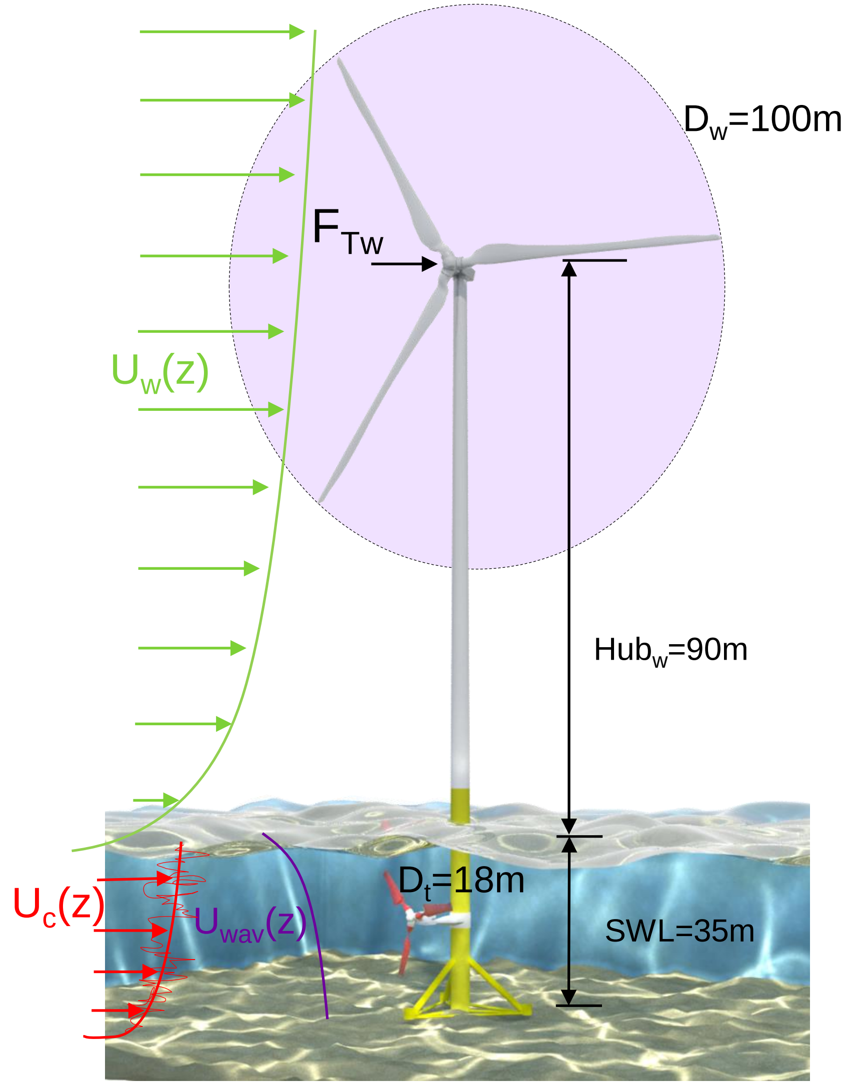
Monopile vs. Braced tripod
Wind-only, tidal-only, combined

Turbulent wind and current (1/7th power law, NTM)

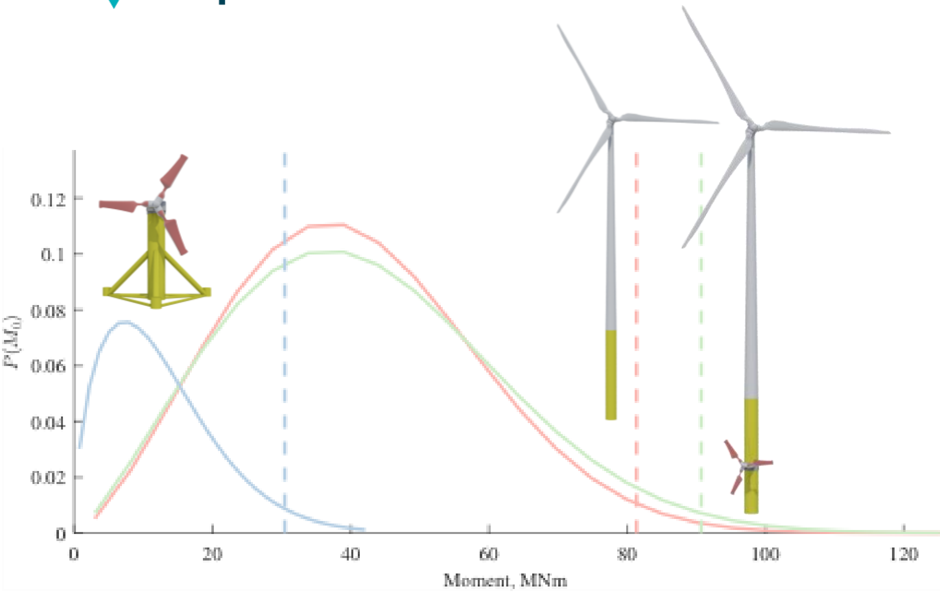
Non-linear wave kinematics - SAWW

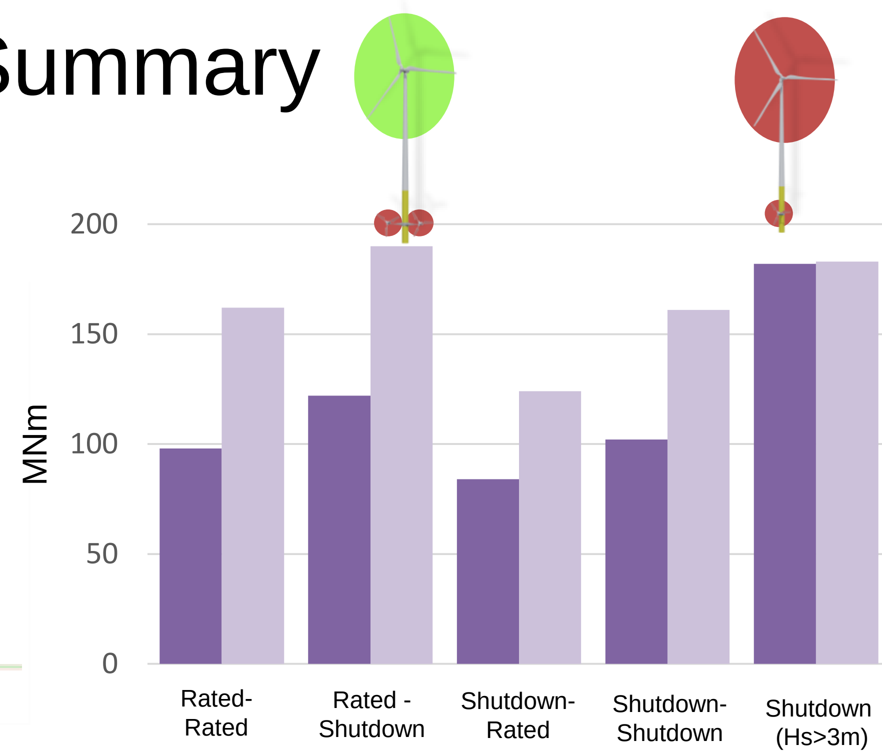
Hydrodynamic loads by Morison eqn. with $U_{wav}+U_c$

Force corrected for breaking waves.

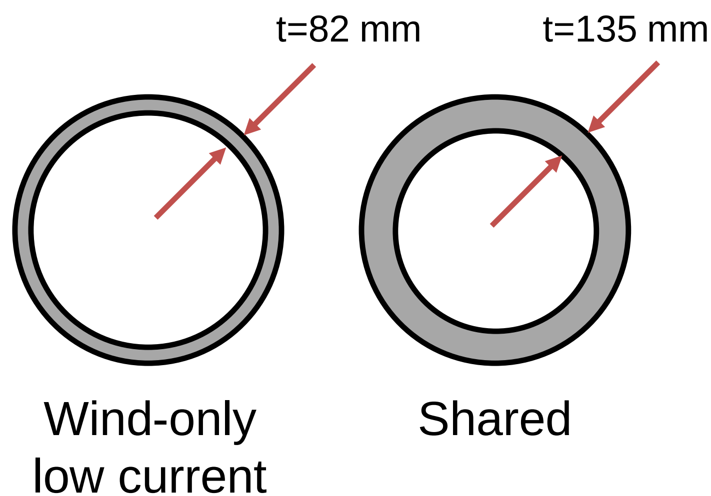


Loads Summary



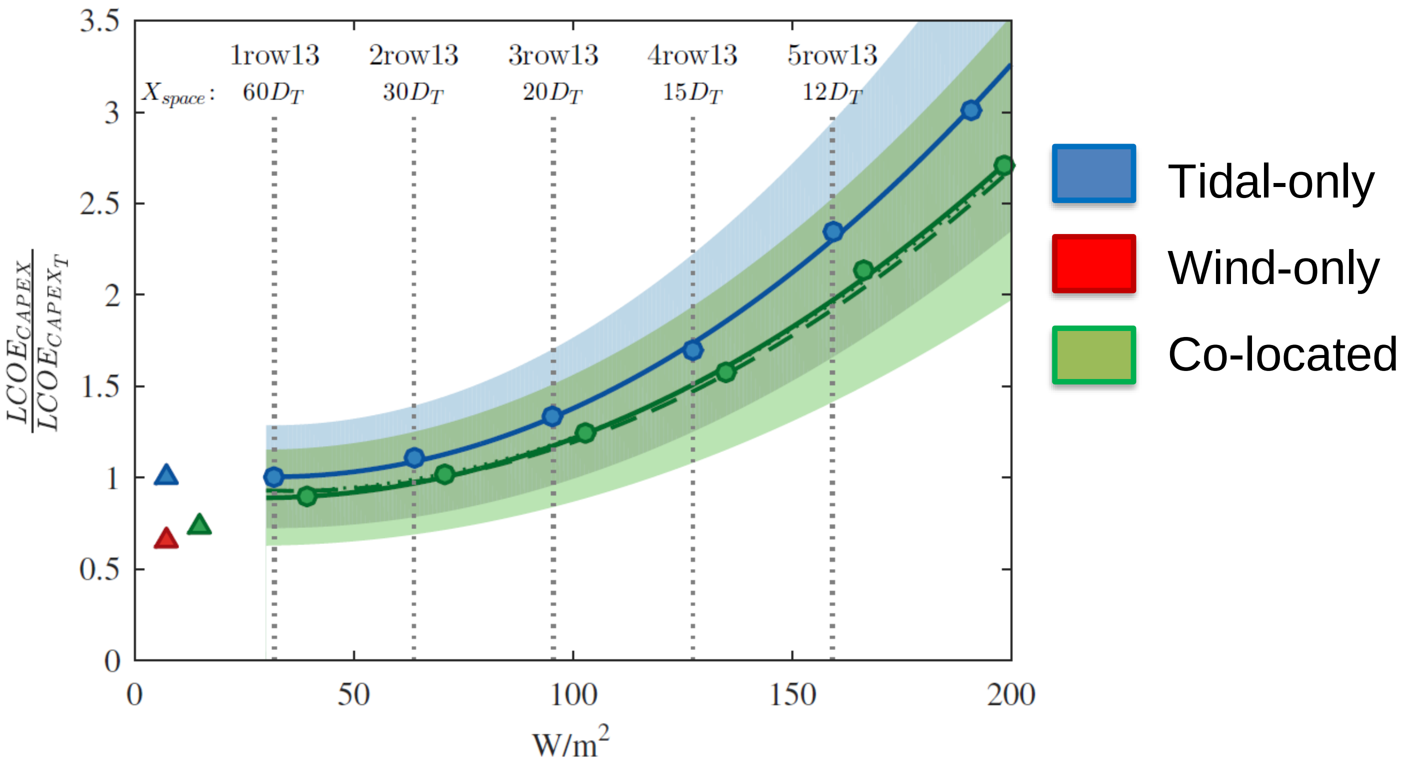


- Overturning moment driven by wind loads due to large moment arm.
- Design load depends on number of generators per support and operating state.
- Wall thickness for 2-rotor-tower shared support is 65% > wind-only.



Levelised capital cost

- CAPEX based on cost-centres for offshore wind and tidal stream turbines



- LCOE increases quadratically with packing-density
- 10-16% saving for co-located farm compared to tidal-only
- Co-located farm generates 20% more power than tidal-only for same cost.
- In all cases, wind turbine contributes to LCOE reduction.

Summary

Demonstrated the potential for co-location to reduce LCOE

- Generalised modelling approach
- Cost saving >10% compared to tidal-only.
- Increased energy yield by at least 12%.
- Peak loads increase by 65%.

- Limitations of simplified wake models established.
- Uncertainties remain around deployment of fixed-bed structures in fast channel flows.

Høgskulen på Vestlandet

Further information

Publications

Sudall, D., Stansby, P. K., Stallard, T. (2015) Energy yield for collocated offshore wind and tidal stream farms, In Proc. European Wind Energy Association (EWEA) Offshore 2015, Copenhagen.

Sudall, D., Olczak, A., Stallard, T., Stansby, P. K. (2015) Simplified wake models for small tidal farms: Reduced scale evaluation and array loading study. In Proc. 4th Oxford Tidal Energy Workshop.

Olczak, A., Sudall, D., Stallard, T., Stansby, P. K. (2015) Evaluation of RANS BEM and self-similar wake superposition for tidal stream turbine arrays. In Proc. 11th European Wave and Tidal Energy Conference (EWTEC) 2015.

Lande-Sudall, D., Stallard, T., Stansby, P. K. (2016) Wake characteristics of a scaled tidal rotor with monopile support structure for co-located wind and tidal farms. In Proc. 5th Oxford Tidal Energy Workshop.

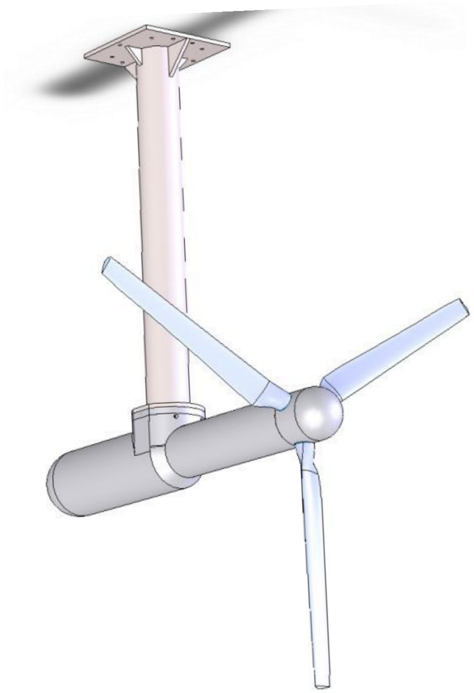
Lande-Sudall, D., Stallard, T. and Stansby, P. K. (2016) Energy yield for co-located offshore wind and tidal stream turbines. In Proc. 2nd International Conference on Renewable Energies Offshore (RENEW) 2016 Conference, Lisbon.

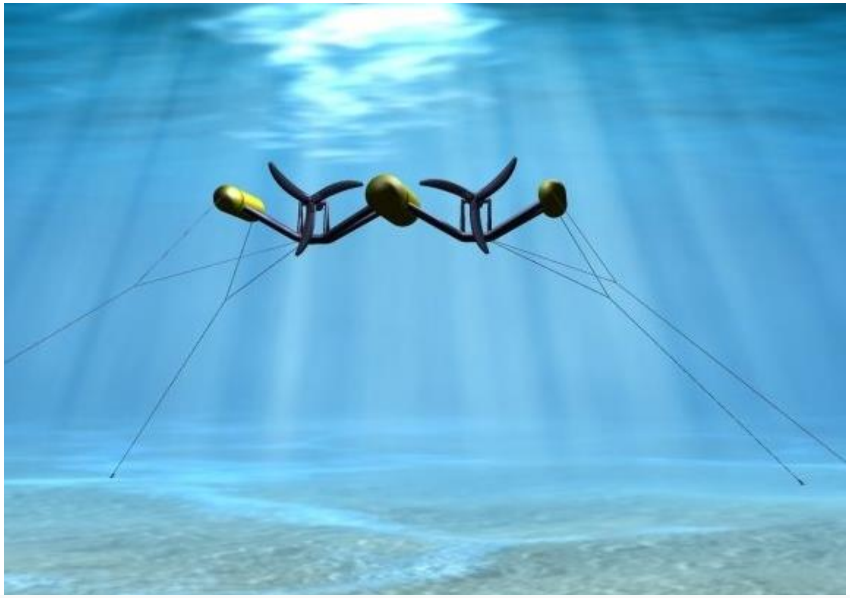
Lande-Sudall, D., Stallard, T., Stansby, P. K. (2017) Experimental study of the wakes due to tidal rotors and a shared cylindrical support. In Proc. 12th European Wave and Tidal Energy Conference (EWTEC), Cork.

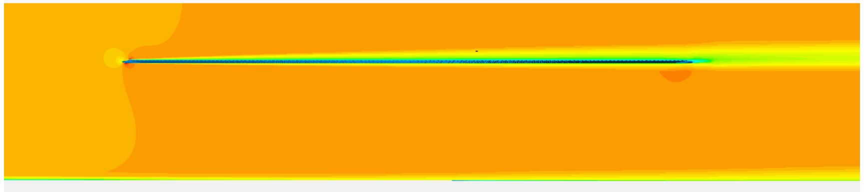
Lande-Sudall, D., Stallard, T., Stansby, P. K. (2018) Co-located offshore wind and tidal stream turbines: assessment of energy yield and loading, Renewable Energy Journal

Lande-Sudall, D., Stallard, T., Stansby, P. K. Deployment of offshore wind turbines with tidal stream turbine arrays to improve levelised cost. Nature Energy Journal (pending submission)

Future Work







- Building of test-bed tidal turbine
- Investigation of floating turbines – operational loads
- Turbulence generation for experimental towing tank
- Scale modelling of mooring solutions
- Offshore marine operations

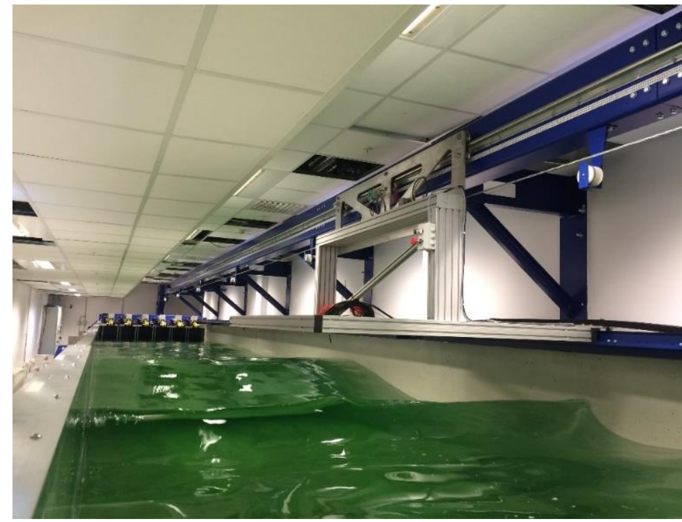
MarinLab towing tank

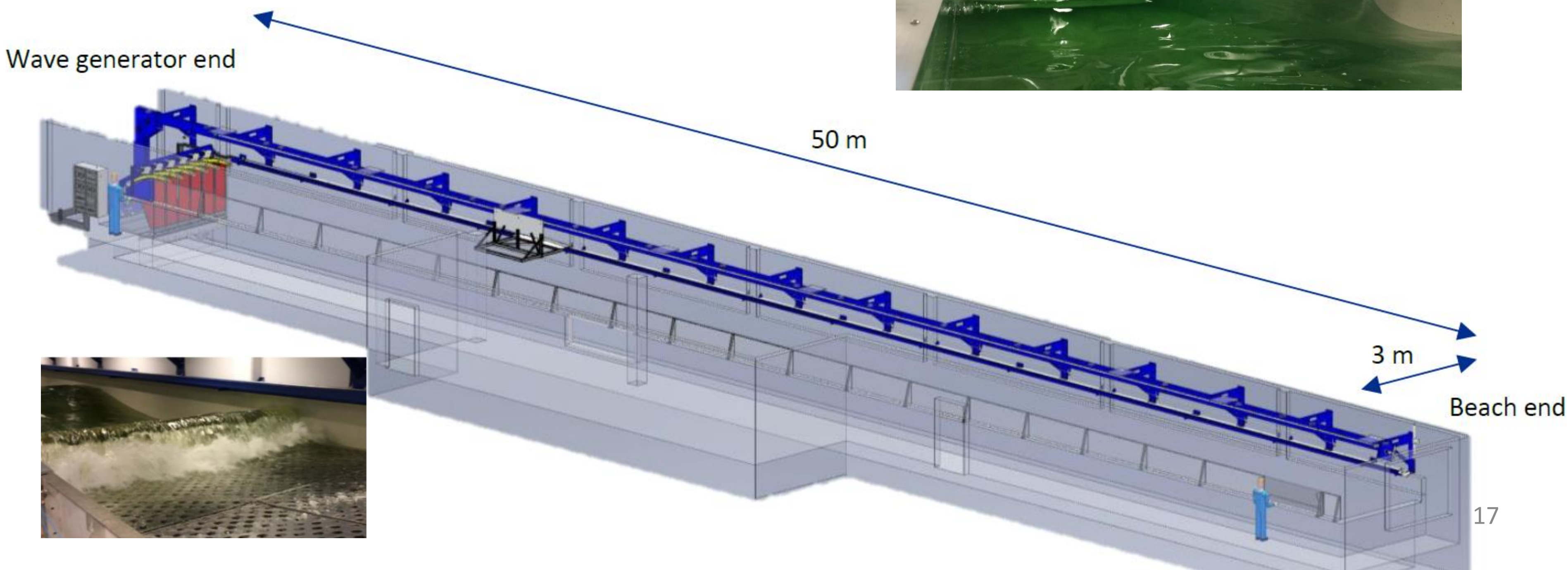
Main features:

0.5m maximum wave height

6 flaps to absorb steep wave angles

5m/s carriage speed & 1.2m/s^2 acceleration





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In-house Model Manufacture

Marin Lab

Welding

MIG/MAG/TIG/SMAW

Plasma cutting

max 20mm plate thickness

all metals

CAD/CAM controlled

Lathe

CAM controlled

Milling

4-axis

Table size 800x1200 mm

all materials

CAD/CAM

3D Printer

Volume size ≈ 300x180x200 mm

Material cost ≈ 3000 NOK/kg

MarinLab Access

Bachelor project:

Run Jan-May

Proposals to be submitted by 1st September.

Master project:

Self-study module Jan-May

Project August-June

Proposals to be submitted by Oct/Nov before self-study

Commercial/private project:

Tank hire: 10 000 NOK/day

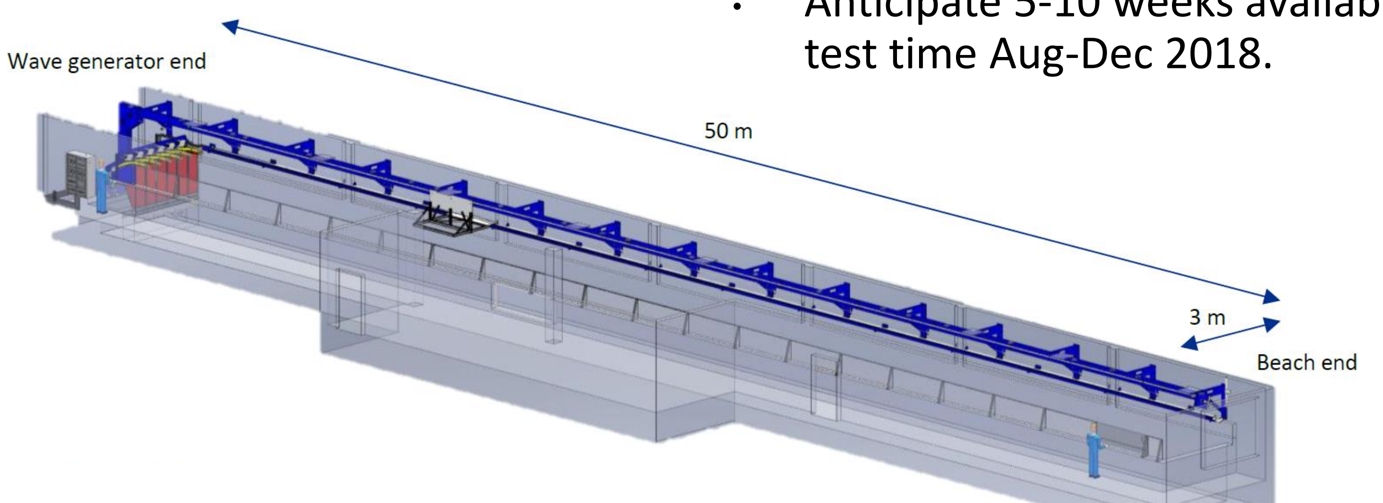
Additionally at least 1 HVL lab engineer (number depends on nature of project)

Full-day test is 8 hours (9am-5pm)

4hrs/day overtime testing available – lab personell rate at 1.5x

Availability:

- Jan-June unavailable
- Anticipate 5-10 weeks available test time Aug-Dec 2018.



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MarinLab towing tank

MarinLab

MarinLab is a towing tank test facility situated on the Bergen campus. The state-of-the-art laboratory is used for teaching purposes, student projects and industry-led research.

About MarinLab

MarinLab features a 50 x 3 x 2.2 m test-section towing tank, fitted with an Edinburgh Designs force-feedback wave maker and towing carriage with a maximum speed of 5m/s. MarinLab is mainly used for traditional ship stability and resistance testing. In recent years, there has been an increase in motion testing using motion capture cameras, where floating bodies, such as marine vessels and renewable energy devices are tested frequently. In addition, the new towing carriage has enabled resistance testing on tidal turbines, underwater vehicles and heavy (asymmetric) structures, such as fish farm designs and jacket structures.

Marin Lab

- Technical information
- Froude-scaling calculation

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