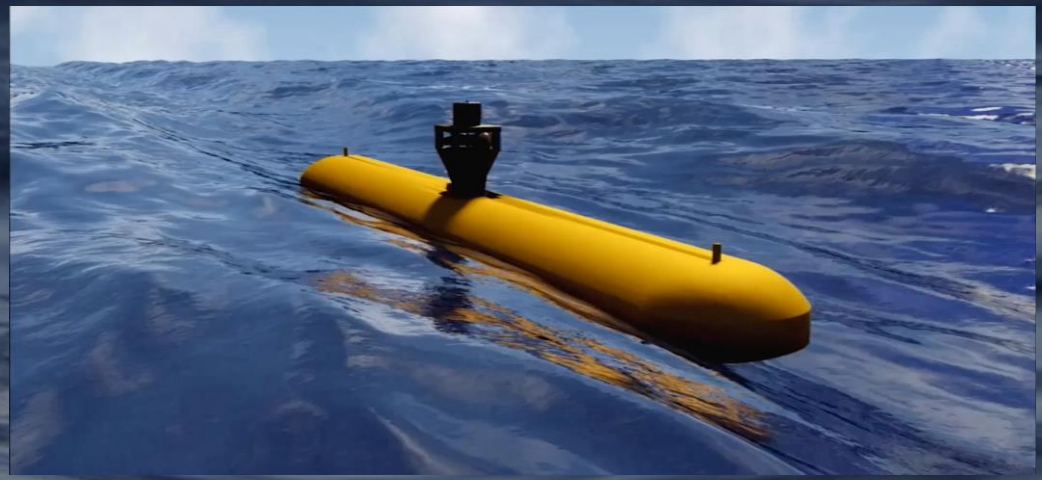

NoviOcean™
Breakthrough Wave Energy Technology
Novige

NoviOcean™

by Novige

LCOE calculated to 60-120 EUR/MWh – depending on wave heights, falling to 25 EUR/MWh with medium **learning curve – lower than all other energy sources.**

A **doubly patented** and breakthrough **wave energy converter**, four models – 500 kW, 2 MW, 5MW and 7MW rated power



Grafik: Jonas Askergren Fakta: Linda Nohrstedt

NyTeknik

FUNCTION EXPLAINED:

A)
When the wave is descending, water is sucked into the cylinder´s lower section

B)
When the wave is rising, simple hydraulic locking/latching of the system, holds the float vertically in the same position. When 1-3 meters of the float has been pressed down in the rising wave, equaling 150-800 tons of lifting force, a valve is opened, letting high pressure water hit the turbine with tremendous force. A flywheel keeps the generator spinning on the way down, when free-floating with only 0.3 meters of draft, relievieng any loads on the anchoring.

KTH UNIVERSITY, PILOT, STUDENTS AND PROFESSORS, LABORATORY TESTS

Float Test Launch

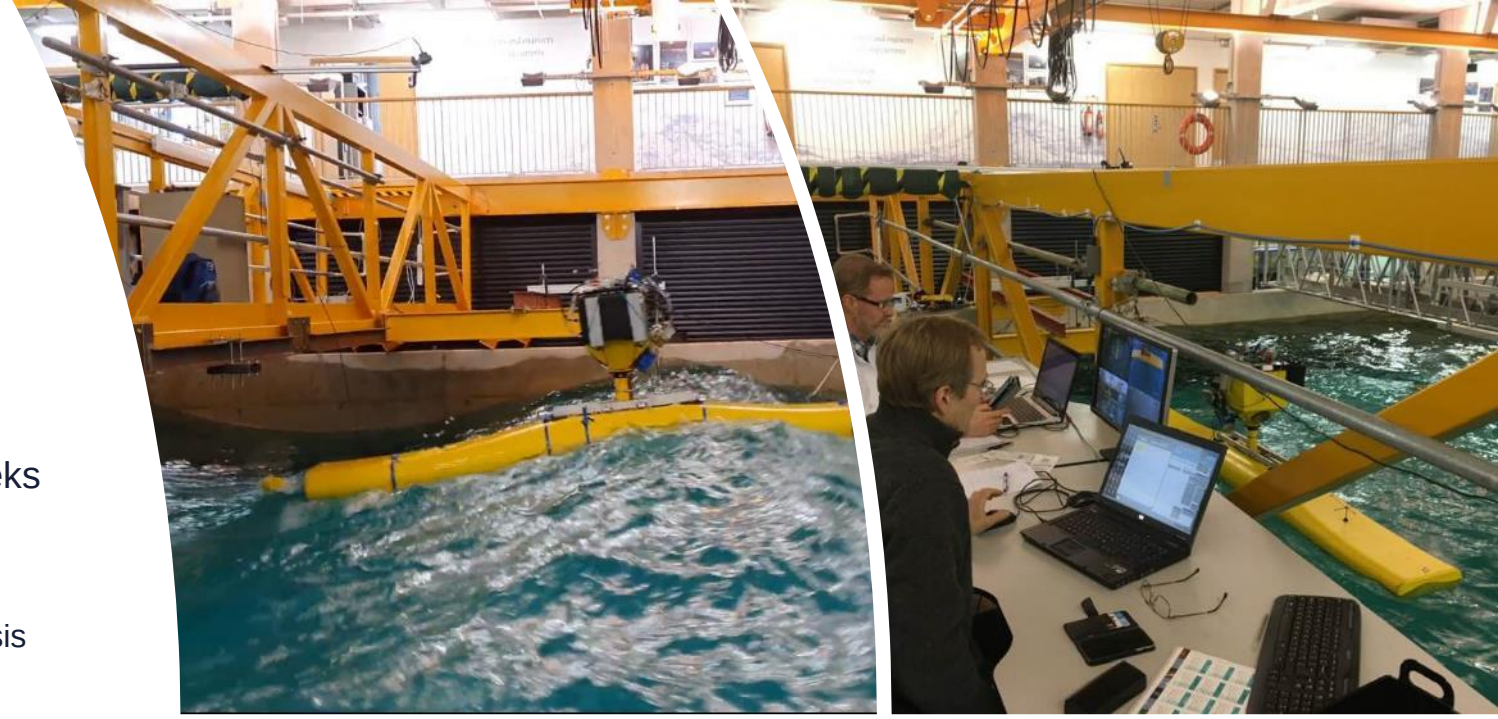
- Sep. 2019, Stockholm archipelago, 1 day
- Objective:
  - Lifting capacity and stability of the float
- Results:
  - Stable
  - Lifting capacity verified
- Challenges:
  - None
- Lessons learned:
  - Float is suitable for initial sea testing

Sea Testing

- Nov./Dec. 2019, Stockholm archipelago, 6 weeks
- Objectives were to test the following before tank testing:
  - Survivability & self-aligning principle to wave front
  - Mechanical functions, & effective sealing
  - Interface between PTO and float, & sea-floor connection
- Results:
  - Perfect self-alignment and mechanical functioning
  - 1.2 mil. lit of water pumped (≈1 mil. cycles)
  - Both calm and stormy seas (snow & below freezing temp.)
- Challenges:
  - Inverter died + some leakage and rust in the system
- Lessons learned:
  - Better sealing measures needed (solved for tank testing)
  - Mechanical functions and survivability validated
  - Improvements needed to the control software (solved)
  - The NO500 can reach to 0.2-0.5 MWh in 1.5-3 m waves

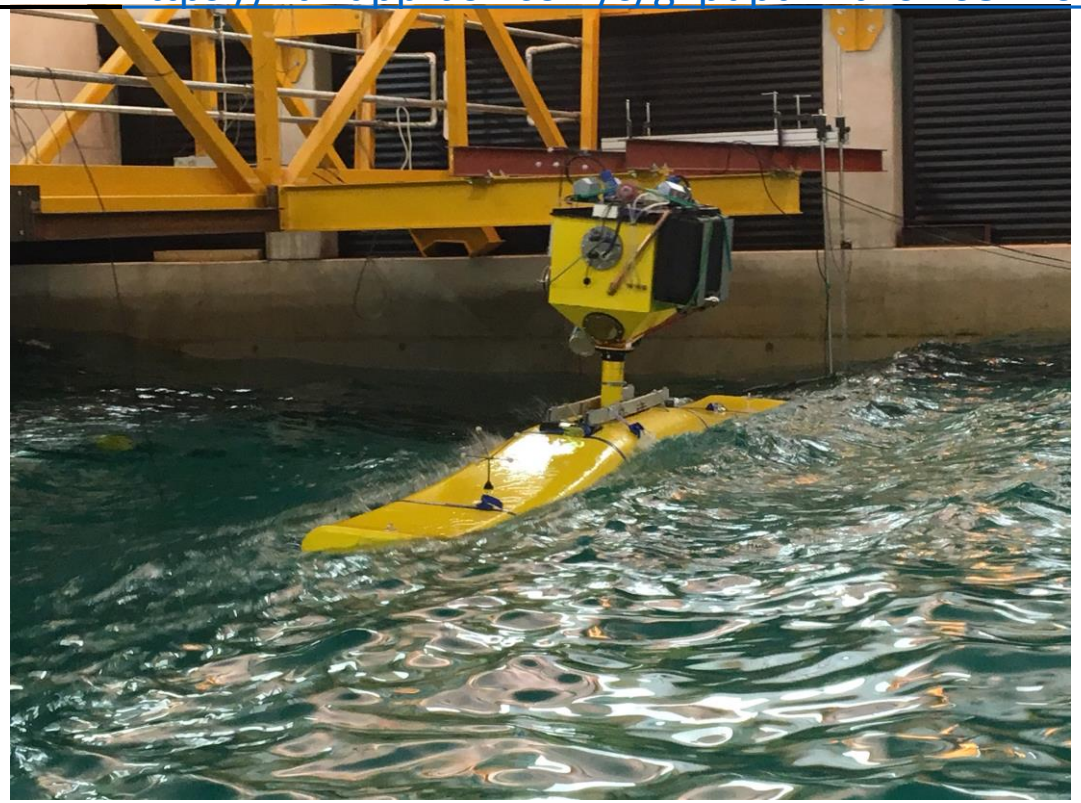
Tank Testing

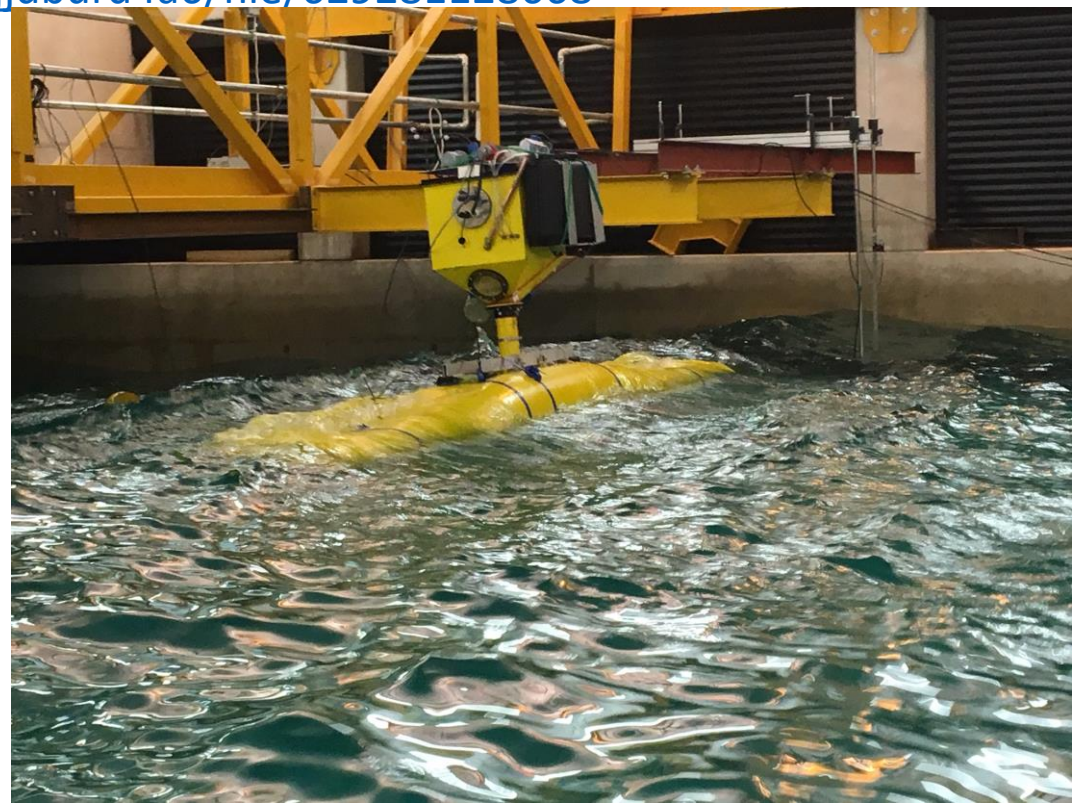
- Mar. 2020, COAST Lab. Ocean Basin, Plymouth, 2 weeks
  - Under MaRINET2 support, transnational access period
- Objectives:
  - Validate numerical models, power output, and CFD analysis
  - Validate the control software/system
  - Verify the dynamic response and loads on the mooring lines
- Results:
  - 54 runs in different sea states (analysis ongoing) *(Annex 2)*
  - Low load on mooring lines due to surf-board design
  - Survivability in steep rogue waves and latching capability verified (even tested at max. possible waves for lab., 0.9 m)
  - Software to remotely control different functions: successful
- Challenges:
  - Early Bluetooth connection issues for control software (solved)
- Lessons learned:
  - Successful so far, but some design improvements are needed to reduce friction losses in the system
  - Analyzing the experimental results will help in improving the techno-economic model (analysis ongoing)



FROM COAST LABORATORY, PLYMOUTH, MARCH. 2020

https://kth.app.box.com/s/gkpupd47bnsrr68fm6e7pwjjdburd4a6/file/629281128668





It is here latched/restricted by the common hydraulic principle, so that the only way it can move upwards, is by providing water jet to the turbine, of up to 150 km/h.... The latch release is set by a simple pressure sensor, opening when the pressure is achieved, allowing water to flow to the turbine.

Here it is just coming out of the wave, the whole float has been submerged, lifting 600 kg upwards, (with extra flotation), about the half of the wave height, equaling 800 tons in the next version... By having a limited height of the float`s outer sections, three meters in the next version, the vertical and horizontal forces, even in storms, will not differ much compared to what you see in this picture. This ensures that the moorings will hold and that it will survive, even in the toughest conditions.

Why NoviOcean?

- Doubly patented wave energy conversion (WEC)
- LCoE equal to offshore wind from start, then going below with learning curve
- Based on few, simple, well proven components and principles
- Very light vs. other wind– and marine energy, in relation to output
- High survivability due to “a surfboard design” floating high in the water
- A larger but cheaper float/barge compared to resonant concepts, produces even in storms
- Less material and less manpower needed to build, transport, deploy and operate
- The solution for oil companies wanting to continue selling liquid fuel. Through electrolysis we will produce immense amounts of clean liquid hydrogen, on location with storage on board, or on shore. Or to supply the oil rigs with clean energy

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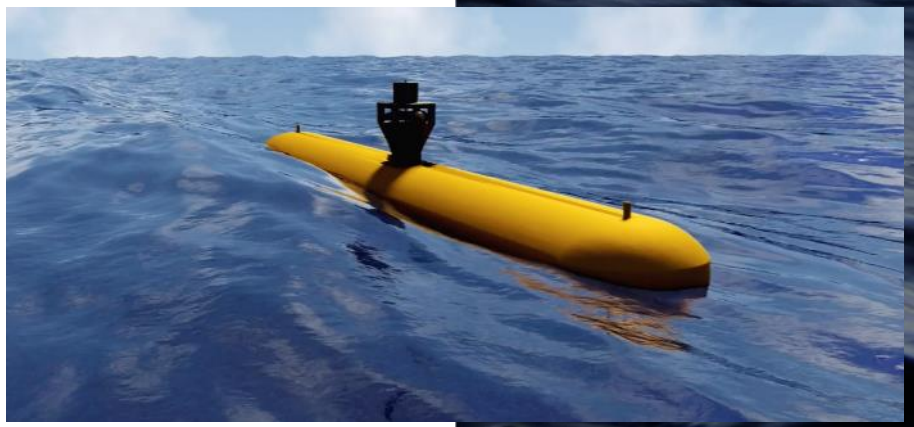
Why NoviOcean?

- Cheaper than offshore wind by early evolution
- More stable energy production 24/7, anti-phased with wind
- Not stopping for high or low winds
- Not visually disturbing
- Less than half the weights and number of parts
- Much closer to land
- Lowest lifetime GHG emission of any energy source by far.
- Much easier deployment and later decommissioning
- In a world desperate for green power, there is no doubt the challenges in wave power will be solved
- We cannot state for certain at this stage, but it might, it might just be that NoviOcean is “THE NEXT BIG THING”



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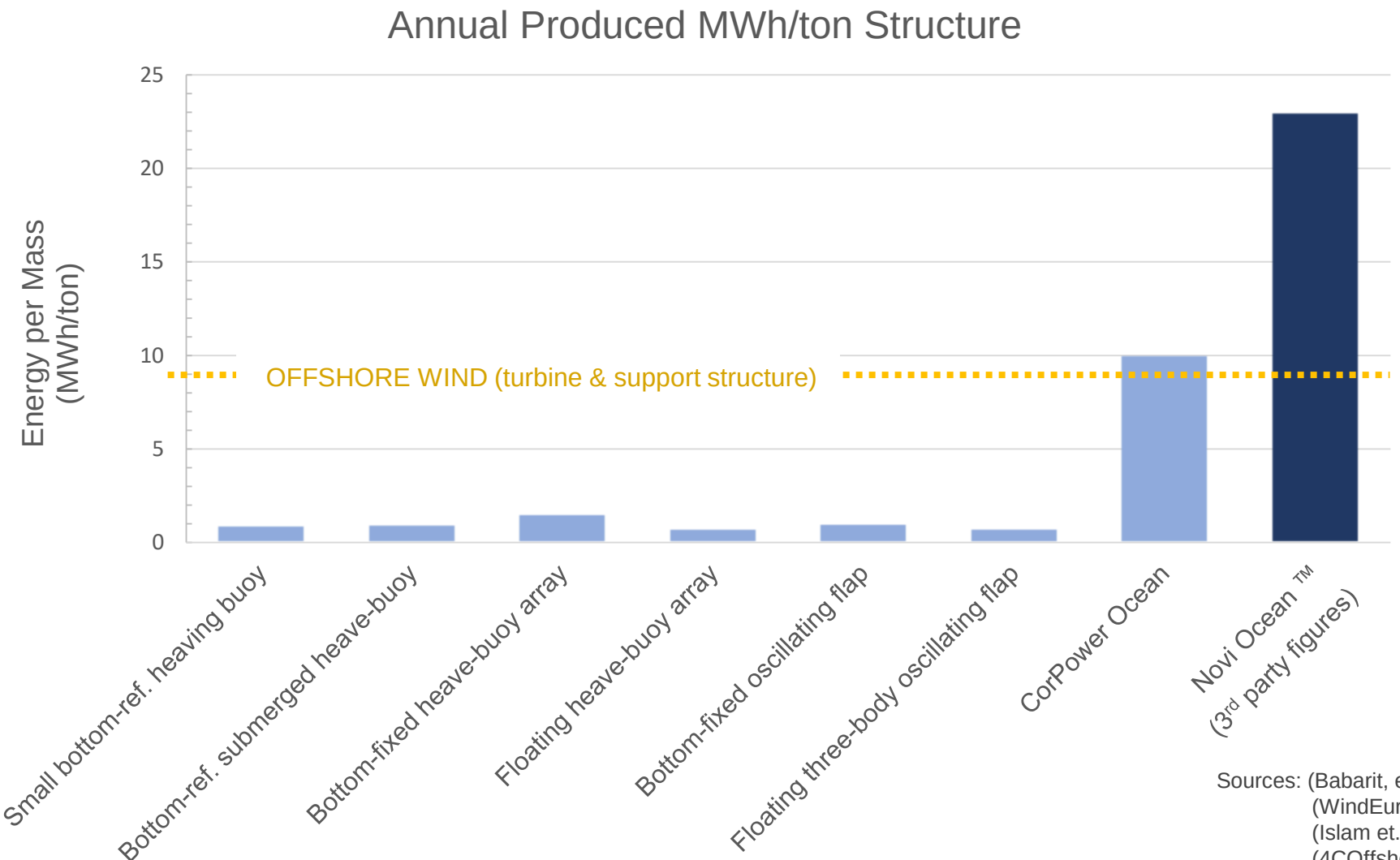
Our Main Advantage to Other WEC



Sources: (Babarit, et al., 2012)
(WindEurope, 2019)
(Islam et.al. ,2014)
(4COffshore, 2018)
(CorPower Ocean, 2019)

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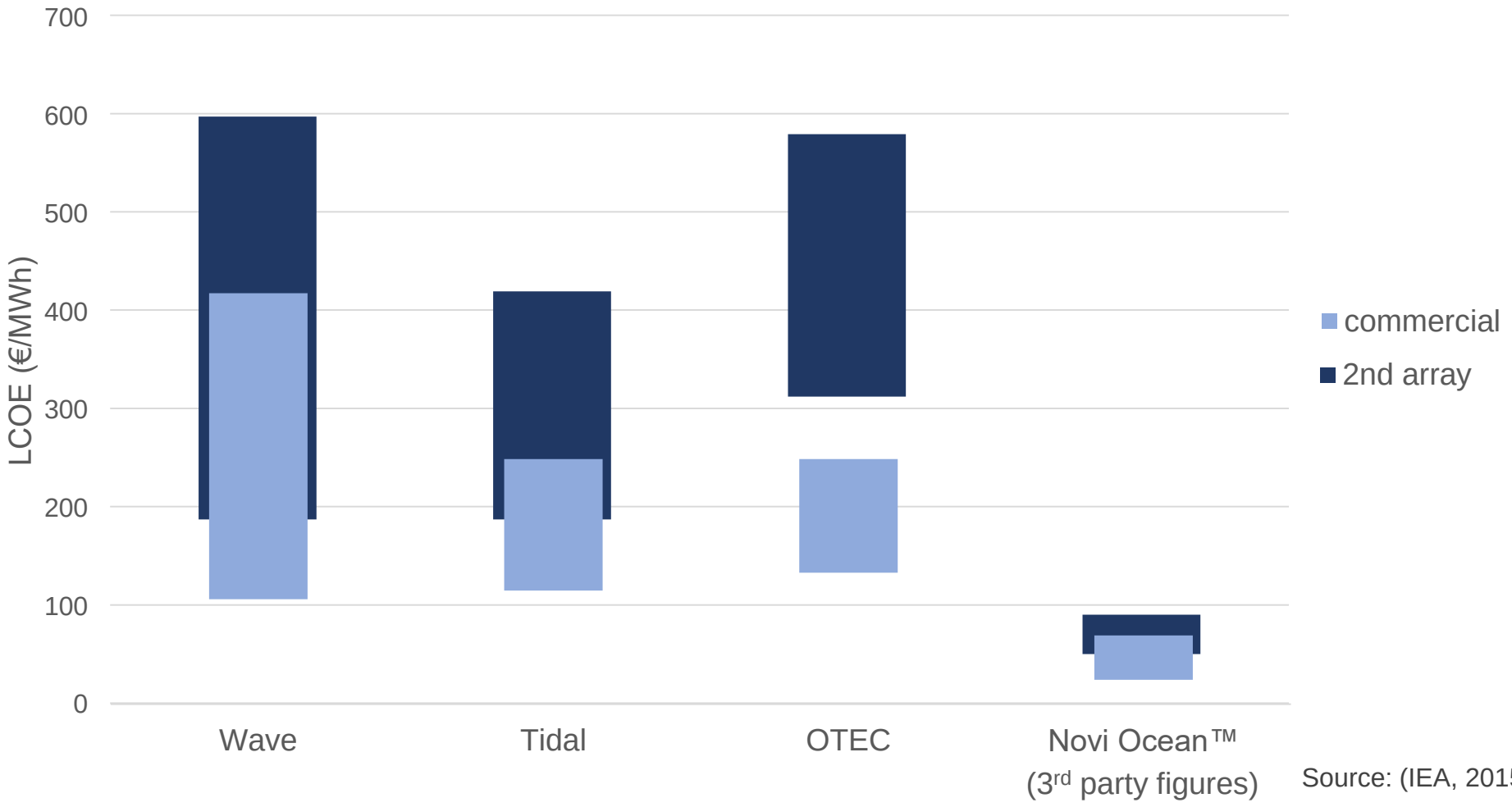
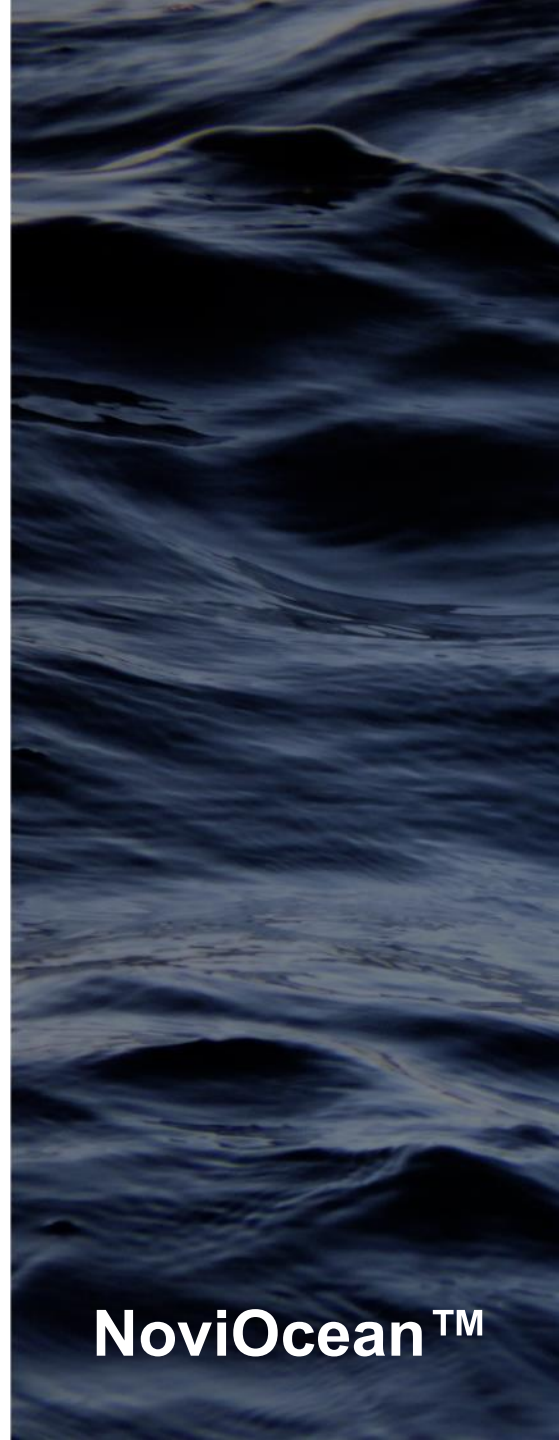
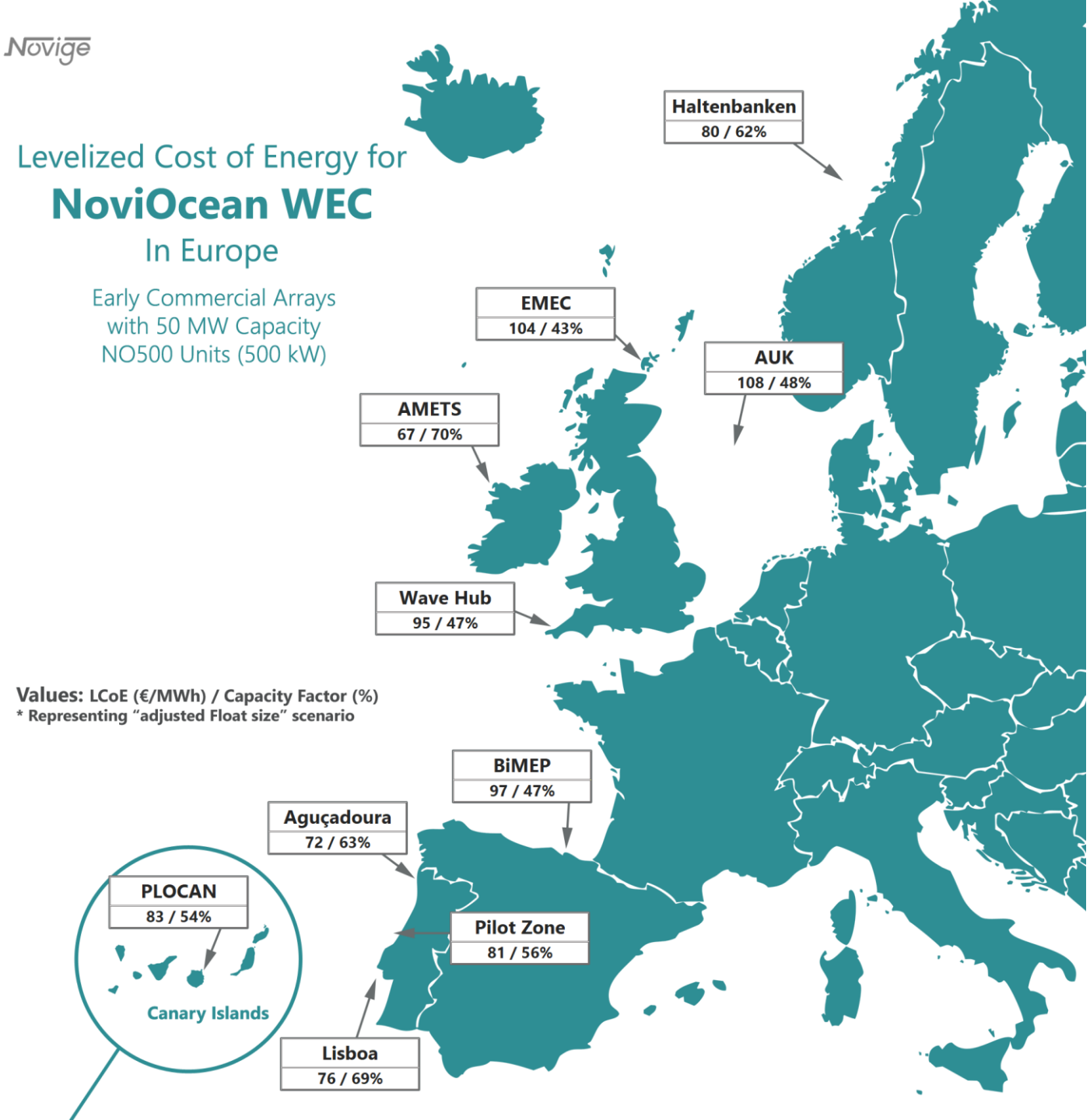
Why can we succeed?

Comparing with other ocean energy technologies



Source: (IEA, 2015)





Levelized Cost of Electricity
(Estimations)

adjusted size float scenario

The map shows our estimated LCoE values for several selected test sites in Europe for the NO500 WEC in the very first 50 MW array. Previous third party (especially WavEC's) reports are the foundation for these numbers. These values have been further adjusted according to water depth and distance to port for each individual site, as well as updated CAPEX and OPEX details.

By adjusting the float size in lower wave areas, these numbers are substantially improved, as the CAPEX increase is rather moderate for higher production.

We are fully aware of the very unusual numbers, but we can only show what we get, neither more nor less.

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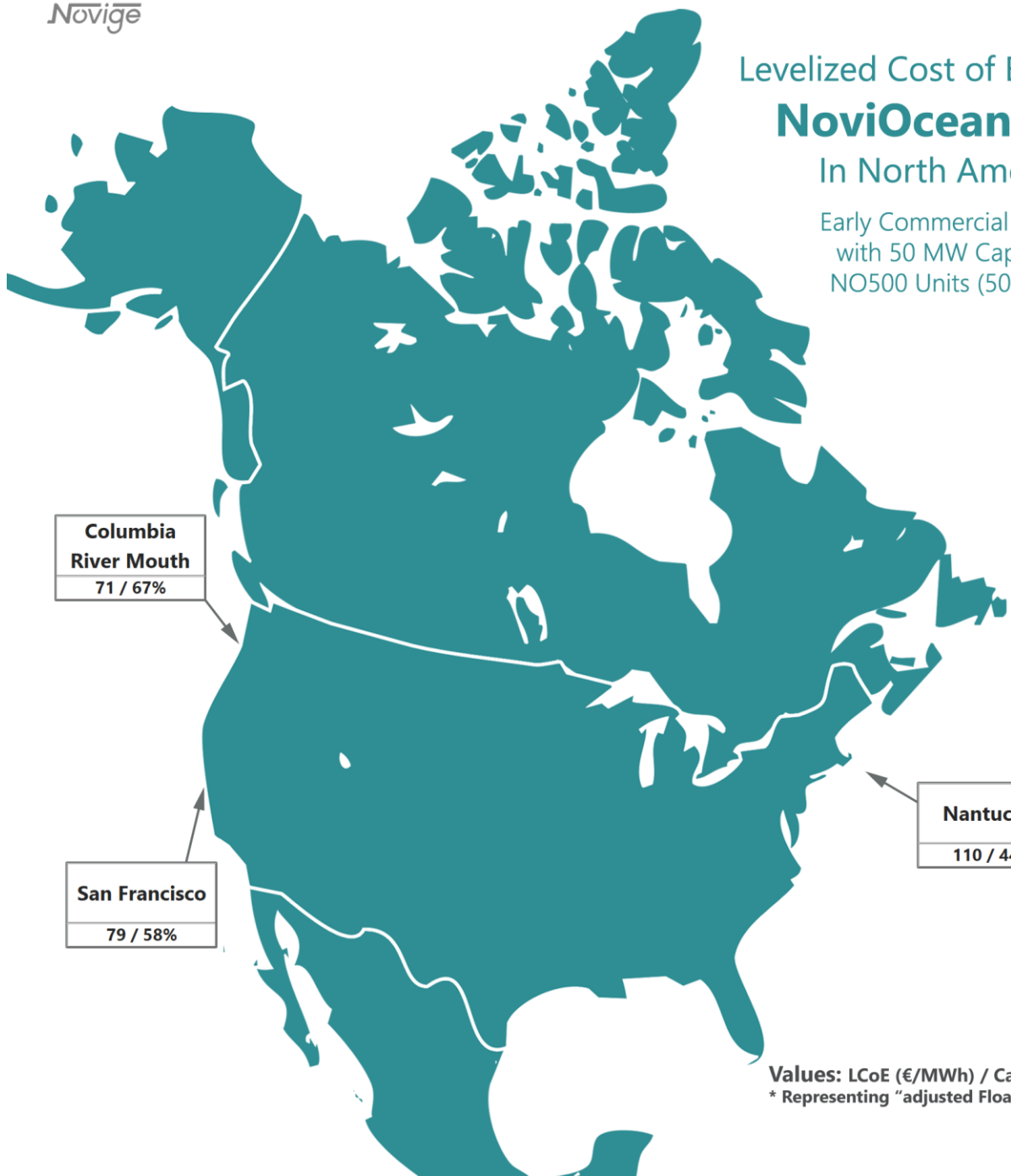
Levelized Cost of Energy for **NoviOcean WEC** In North America

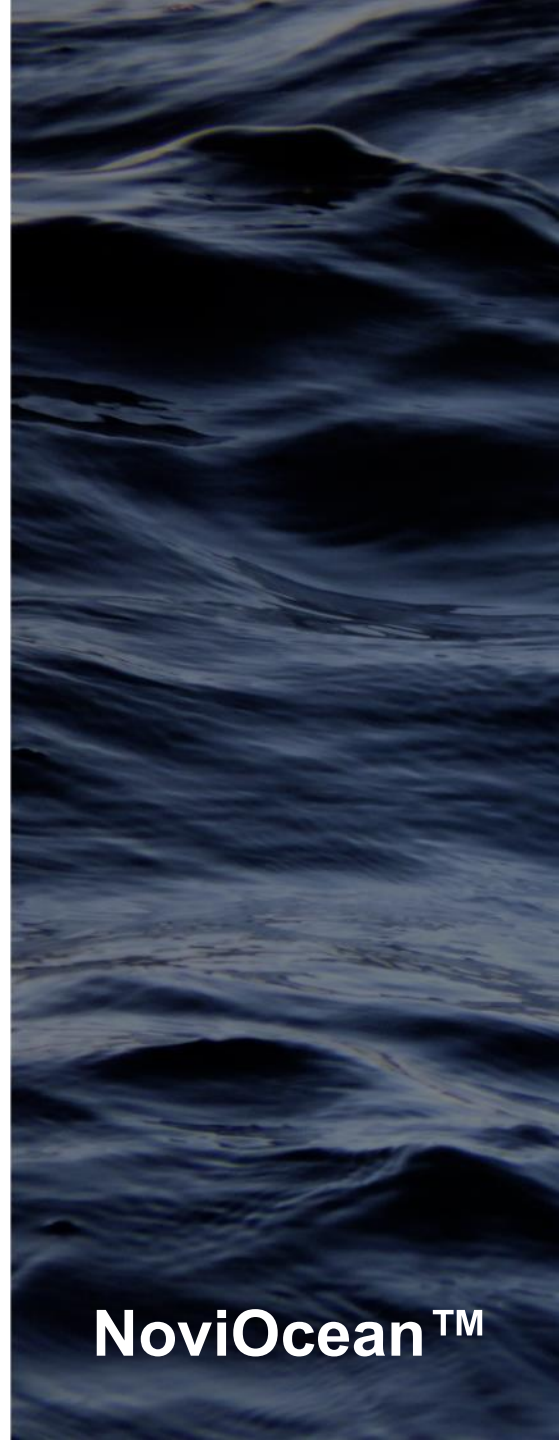
Early Commercial Arrays
with 50 MW Capacity
NO500 Units (500 kW)



Values: LCoE (€/MWh) / Capacity Factor (%)
* Representing "adjusted Float size" scenario

Wave Energy Subsidies in EU

Country	Wholesale Tariff (2018 Average)	Support Measures	Price-based Incentives	Duration	Condition
	(€/MWh)		(€/MWh)	(years)	
Ireland	60	National FIT	260	15	To be introduced
United Kingdom	65	CfD Mechanism	350-365	15	Re-calculated
Portugal	59	National FIT + Tax Incentives	101-260	15	In effect
Spain	58	No Wave Energy Incentive	-	-	-
Denmark	45	Subsidy above market price	80 (1st period), 50 (2nd period) + wholesale tariff	20 (10, 10)	In effect
Norway	44	Capital Grants & Green Certificates	Varied by quota obligation	15	In effect
Sweden	45	Federal Green Certificates	15-42 + wholesale tariff	15	In effect
Germany	44	No Wave Energy Incentive	-	-	-
France	50	National FIT	88-166	20	In effect



Techno-economic Assessment

Wave Hub 3 MW NO500 array (WACC = 7.25%)

Scenario Results					
Indicator	**Fixed float**	**Adjusted Float**	**Custom Scenario**	**Unit**	**Notes**
Float Width	6	8	8	m	min 6 & max 8.6
Float Length	25	49	35	m	min 25 & max 68.8
Gross production per unit	1,397	2,578	2,140	MWh/yr/unit	-
Production					
Gross production for the array	*8,384*	*15,468*	*12,842*	MWh/yr	before any losses
Net production for the array	*6,280*	*11,586*	*9,619*	MWh/yr	all losses considered
Households powered per MW installed	*634*	*1,170*	*972*	houses/MW	-
Car emissions avoided per MW installed	*194*	*358*	*298*	cars/MW	-
Costs					
Total CAPEX	*10.9*	*12.7*	*11.9*	M€	for aluminium float
Total annual OPEX	*0.7*	*0.7*	*0.7*	M€/yr	cte. in all scenarios
Capacity Factor (CF)	*23.9%*	*44.1%*	*36.6%*	%	-
Levelized Electrocity Cost (LCOE)	*264.1*	*156.8*	*181.2*	€/MWh	-
LCOE after software and sensor optimization	*158.4*	*94.1*	*108.7*	€/MWh	preliminary estimates
Financial Indicators					
Net Present Value (NPV)	*1.0*	*14.2*	*9.5*	M€	Good if NPV>0
Internal Rate of Return (IRR)	*9.1%*	*24.1%*	*20.0%*	%	Good if IRR> WACC

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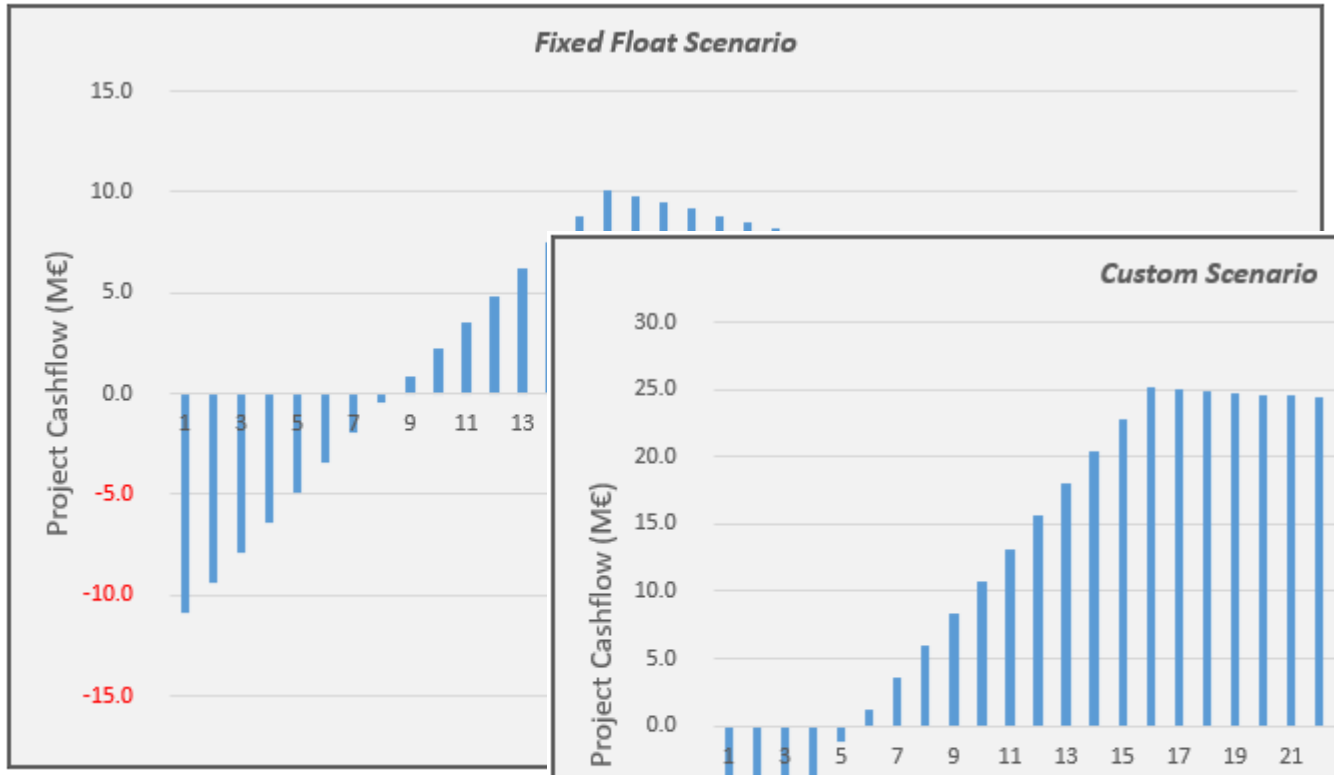
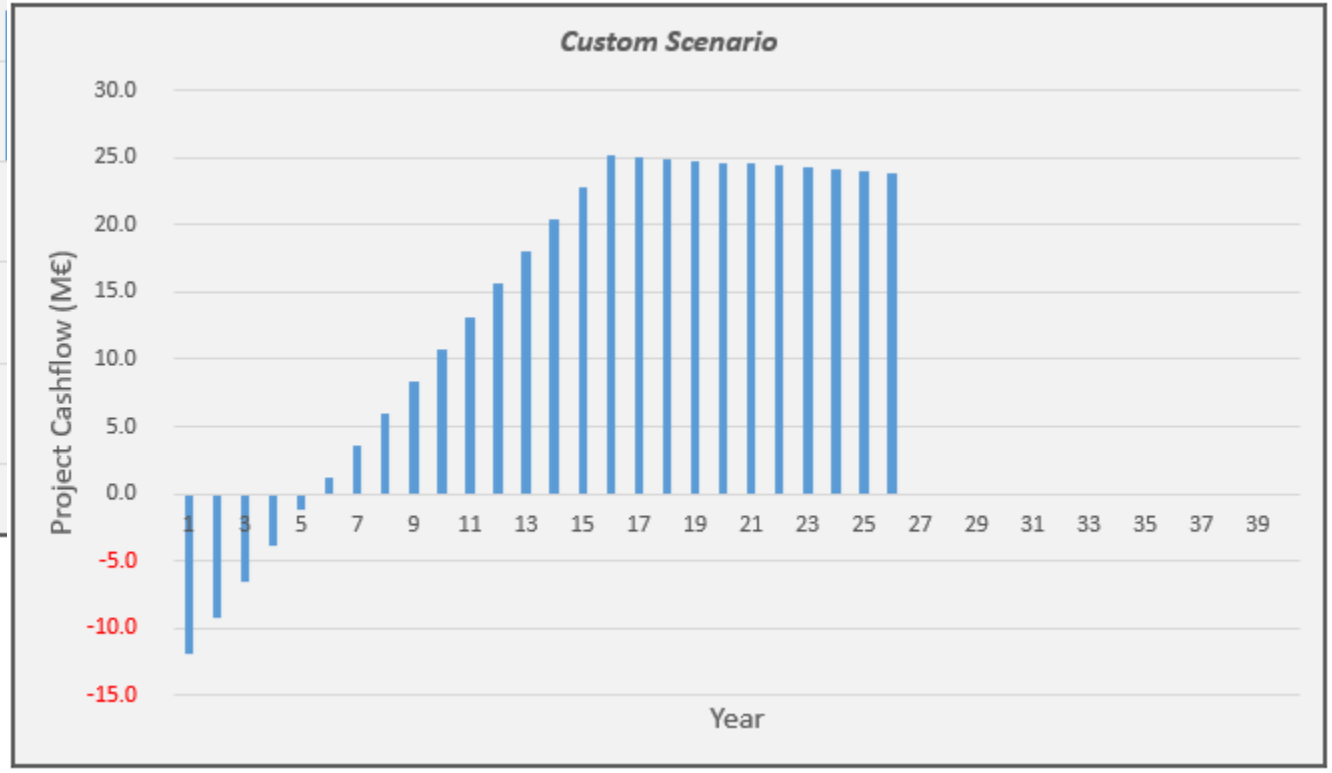
Lifecycle Cashflow Analysis

Wave Hub 3 MW NO500 array (WACC = 7.25%)





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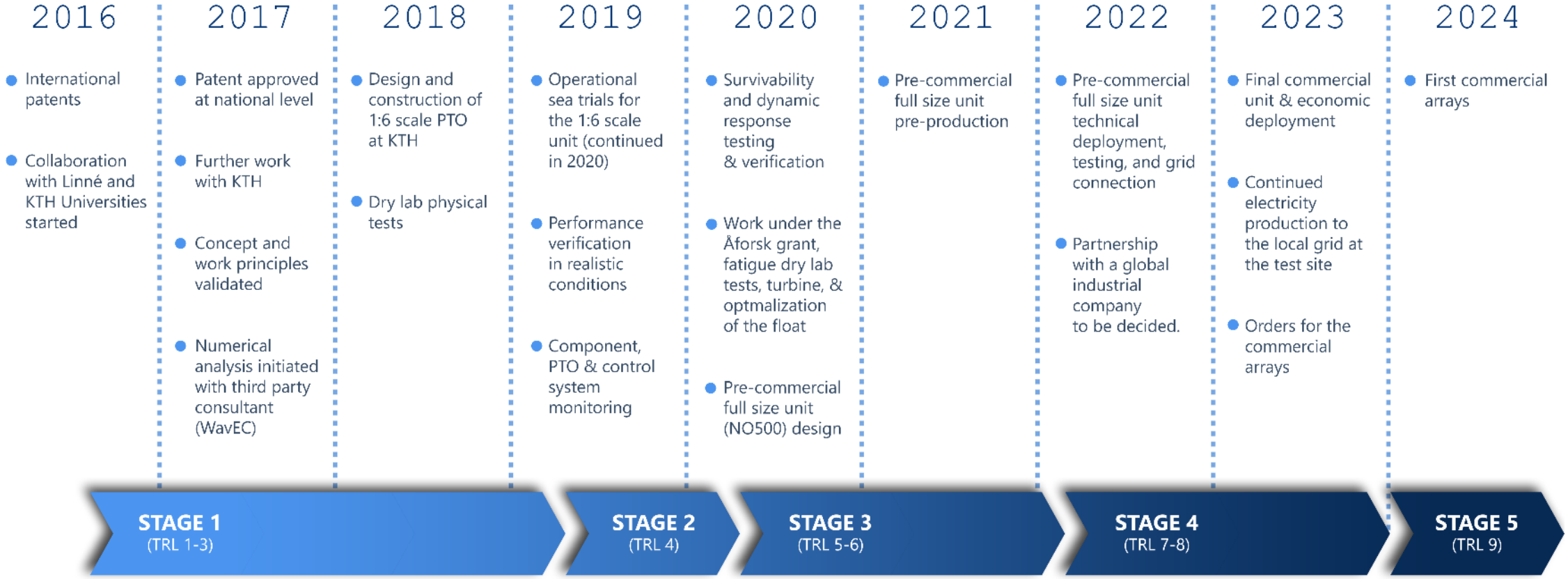
Our stages and plan going forward



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Initial and future goals

Initial: 1% relative the offshore wind market = 500 million/year
then 10% = 5 billion/year, etc.

Future: The close-to cost wave energy potential is seven times larger than the total wind power deployed on land and sea for the last forty years, value 2000 billion EUR, for the few economically viable concepts

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Novige Team

- **Jan G. Skjoldhammer**, founder and CEO, Lieutenant, Bus. Adm., Air Transport Pilot. Full time.
- **Mårten Keijser**, COO, MSc KTH, experienced from wave energy and similar work. Full time.
- **Danial Hassani**, CAO, MBA + MSc KTH-Renewable energy, experience working with wind-and solar. Full time.
- **Johan Mürer**, CTO, MSc KTH,. 38 years experience from design and analysis work in the aerospace and space industry. Part time.
- **Timo Pohjanvuori**, IP Manager. 25 years experience as such plus CEO of consultancy firm Prospero. Part time

- **Marcus Grünewald**, Director-Government Affairs. Part time.
- **Tomas Carlmark**, lawyer, Allians Advokatbyrå. Part time.
- **Hans-Göran Branzell**, MSc, retired, long and varied career. Part time.

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Novige Team

- **KTH University**: Six master students, professor Björklund and Andersson. Designing, constructing and testing various parts for float and Power Take Off. 30 MSc students in total last three years.
- **Uppsala University**: **Irina Temiz**, PhD, long scientific and practical experience from Swedish wave power. **Maria Angeliki Chatzigiannakou** PhD, doing deployment strategy and cost analyzis.
- Member of **Create incubator**, Alumni from **SynerLeap**, powered by **ABB**
- **WavEC** in Portugal, completed extensive data animations, consulting regularly.
- Several consultants and sub-contractors at work in various areas.

“This innovative PTO appears to allow implementing in a quite straightforward way latching control, which may lead to a significantly increase in power generation reducing the levelized cost of energy cost (LCOE)”

WavEC- **Dr. Marco Alves**

(WavEC completed 800 hrs of data simulations for Novige, in four different studies covering numeric analysis, CFD survival analysis, time domain performance studies and LCOE calculations)

“The main advantage of the ”extremely thin” surf- type platform is the very low surge loads, which can simplify the mooring system and consequently reduce the LCOE”

WavEC- **Dr. Marco Alves**

talk WITH NORDEA PRIVATE BANKING

EKONOMI INNOVATION FACTFULNESS HÅLLBARHET KULTUR

PERSONLIGT

Vågmästaren

Det började med ett ekonomiskt jätteklipp på en markaffär. Nu satsar förre flygkaptenen Jan Skjoldhammer allt på ett innovativt vågkraftverk med potential att förändra hela energibranschen.

Jan Skjoldhammer kommer från Norge, men det var en markaffär utanför Stockholm som gjorde honom ekonomiskt oberoende. Här med en mindre prototyp till vågkraftverket Novi Ocean.

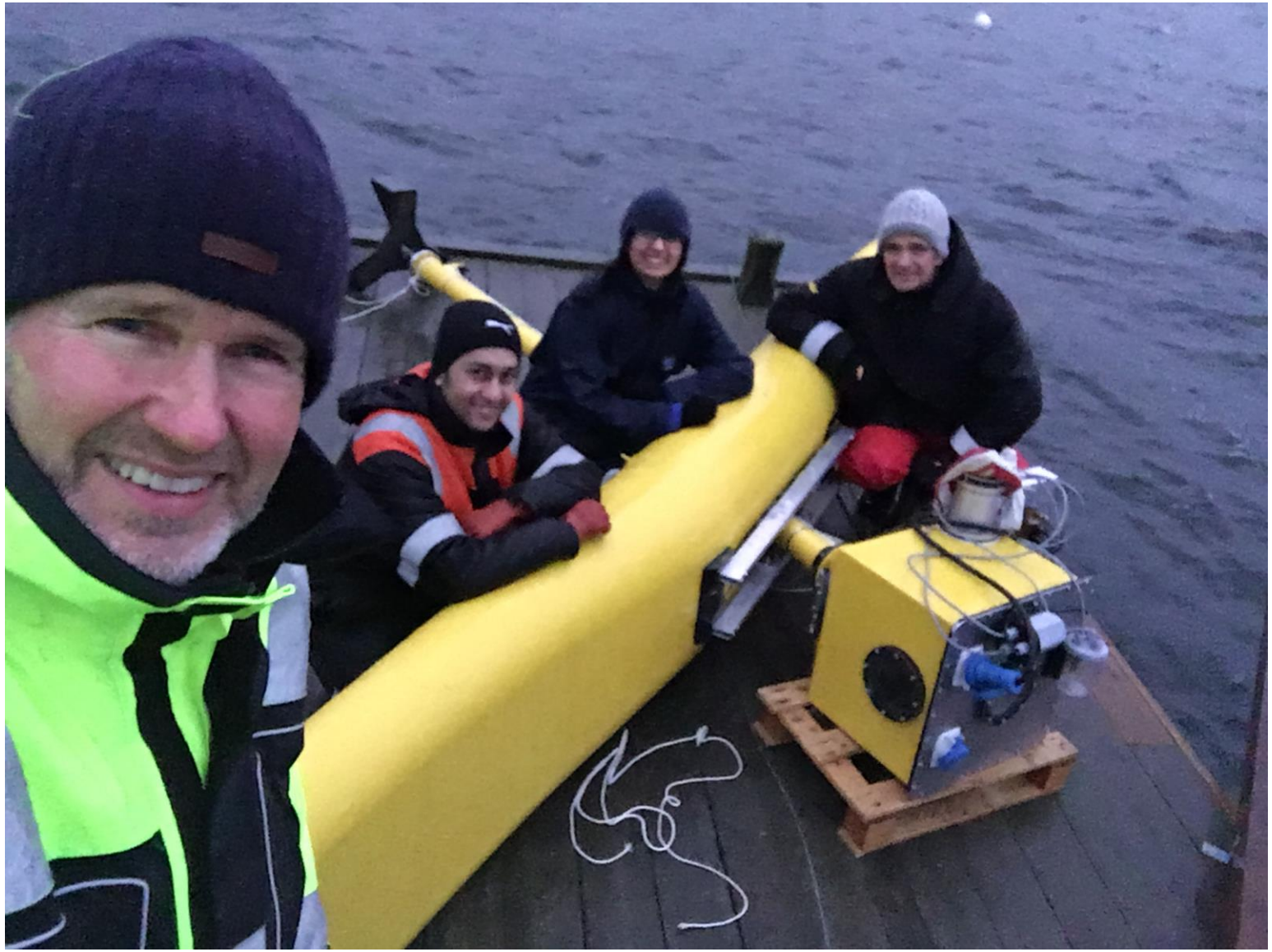
Front page article in the Private Bank magazine for The Nordic´s largest bank Nordea, Nov. 2019, 100 000 readers.
https://talk.nordea.se/privatebanking/vagmastaren/

NyTeknik

Hemlig plats för nytt svenskt vågkraftverk

Front page article in NyTeknik, Sweden´s largest technical newspaper, 250 000 readers. December 2019.
https://www.nyteknik.se/premium/hemlig-plats-for-nytt-svenskt-vagkraftverk-6980949

DEPLOYING IN DECEMBER 2019



HARSH WEATHER AT OFFSHORE TESTSITE OUTSIDE STOCKHOLM

Video test-site Stockholm:
https://kth.app.box.com/s/gkpupd47bnsrr68fm6e7pwjjdburd4a6/file/574683241235

As can be seen in the video, the core of the design philosophy is that it always aligns itself automatically perpendicular to the wave front. This by having an aspect ratio up to 1-10. It allows a lifting area up to 10 times higher than what is possible with a round buoy, for the same wave length.

The horizontal surge forces is measured to be only 1/20 of the vertical lifting, unique for wave power!

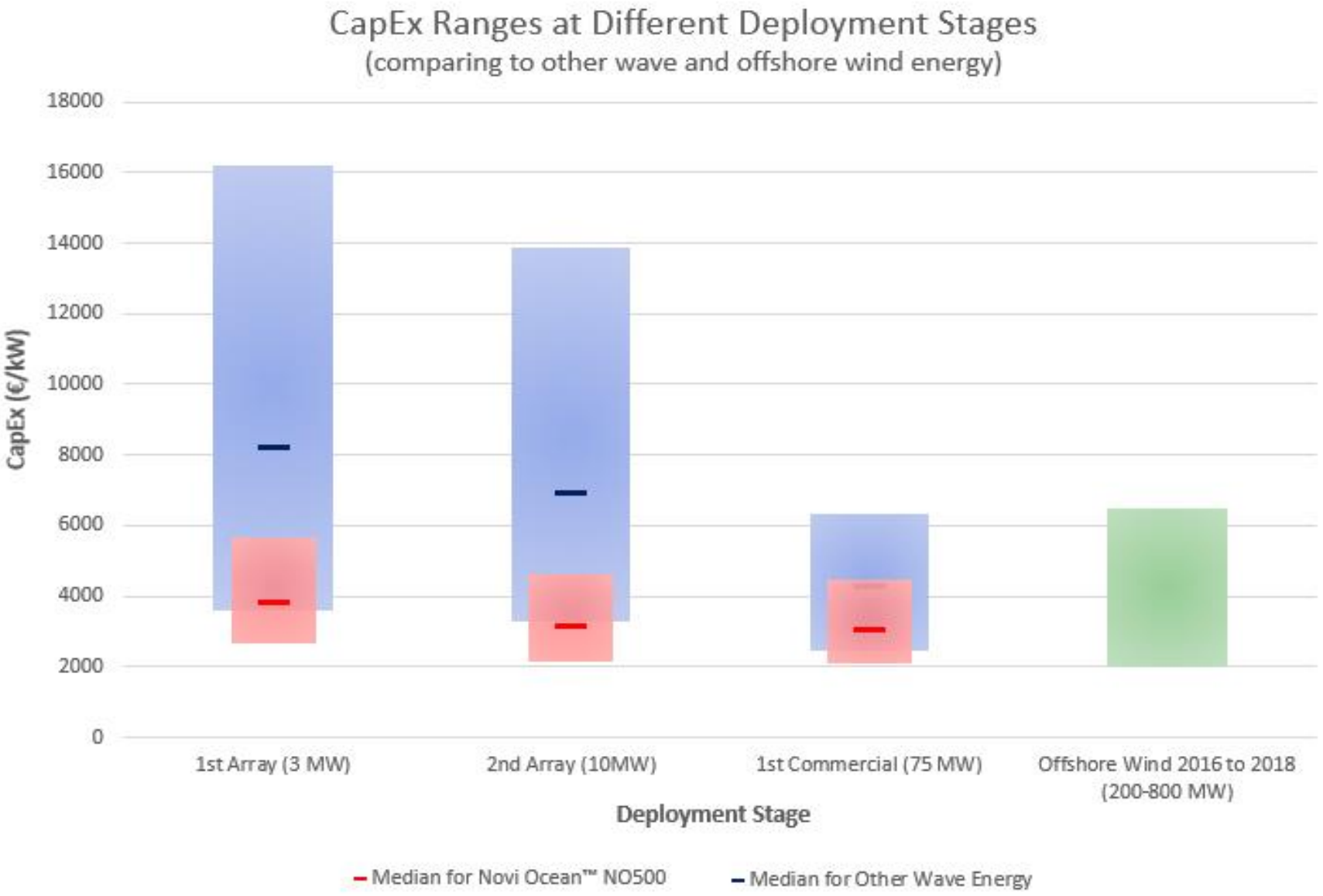
After six weeks in the sea it has pumped more than 1.2 million liters of water and survived 1 000 000 cycles in snow and temperatures well below zero.

2013: OLD PATENT IDEA FROM DRAWER, MODIFIED

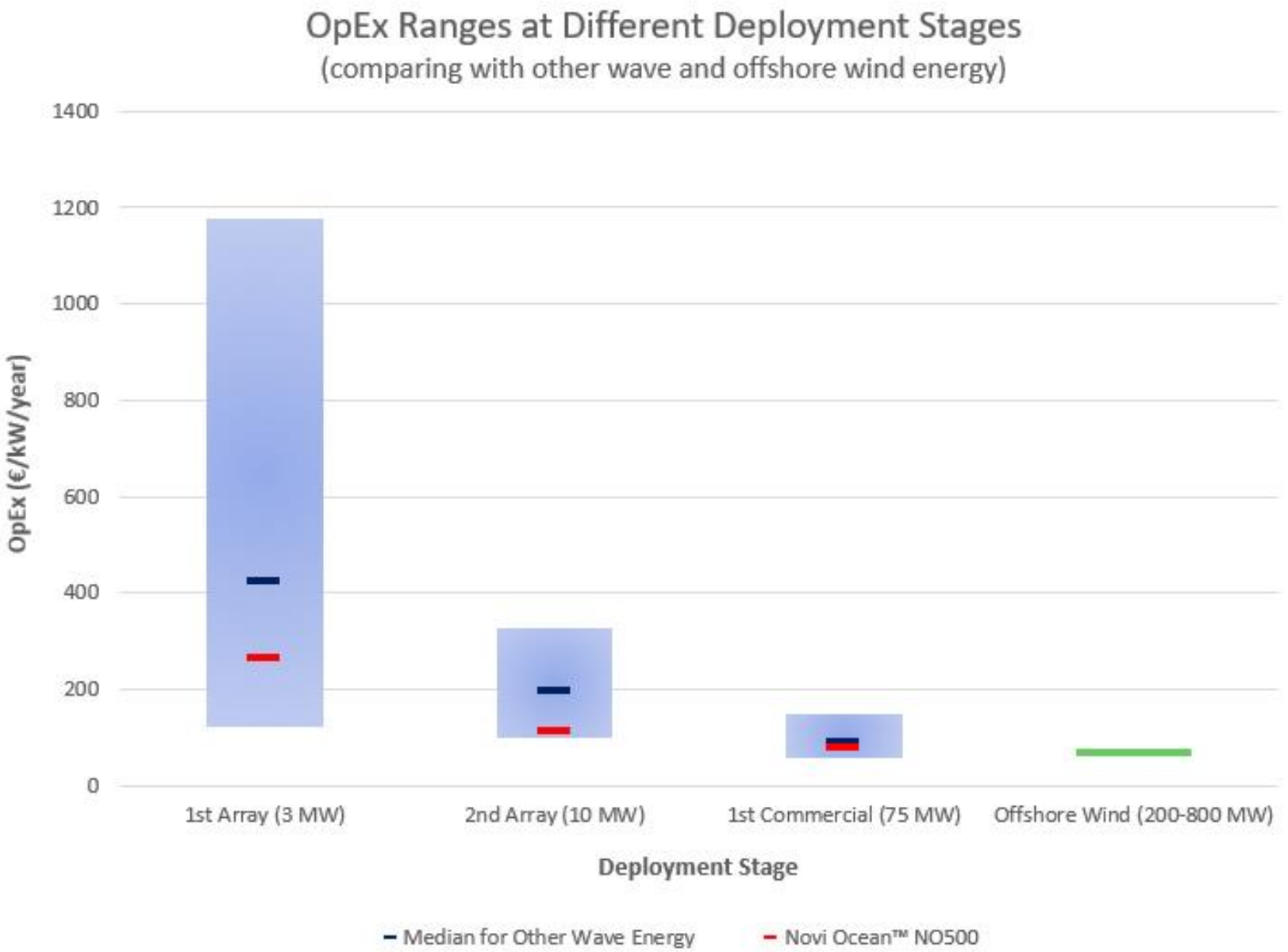
OUR UNIQUE NUMBERS ARE THE RESULT OF THE VERY STRICT DESIGN REQUIREMENTS SET FROM THE VERY BEGINNING, WHICH WAS AND STILL IS:

- LIGHT, SIMPLE, FEW PARTS, PROVEN TECHNOLOGY, DURABLE, LOW MAINTENANCE REQUIREMENTS, HIGH SURVIVABILITY, LOW COST AND IMMENSE POWER OUTPUT.
- THE FOUNDER THREW AWAY DRAWINGS CONTAINING THE USUAL PRINCIPLES USED IN WAVE POWER FOR A WHOLE YEAR, AS THEY ALL COLLIDED WITH THE SET REQUIREMENTS. (DID NOT LOOK AT OTHERS BEFORE DONE, TO KEEP AN UNBIASED MIND)
- UNTIL THE SOLUTION FINALLY SURFACED: THE LARGE NON-RESONANT RECTANGULAR FLOAT WHICH THE FOUNDER DREW AT 25 YEARS OF AGE, COMBINED WITH A WELL PROVEN PELTON TURBINE, CONNECTED TO THE LIKEWISE WELL PROVEN HYDRAULIC CYLINDER. FINALLY MATCHING THE SET STRICT REQUIREMENTS ABOVE!
- THE “INVERTED HYDRO POWER PLANT AT SEA” WAS BORN

Where Do We Stand, Capital Costs



Where Do We Stand, Operational Costs



Where Do We Stand, Levelized Cost of Energy

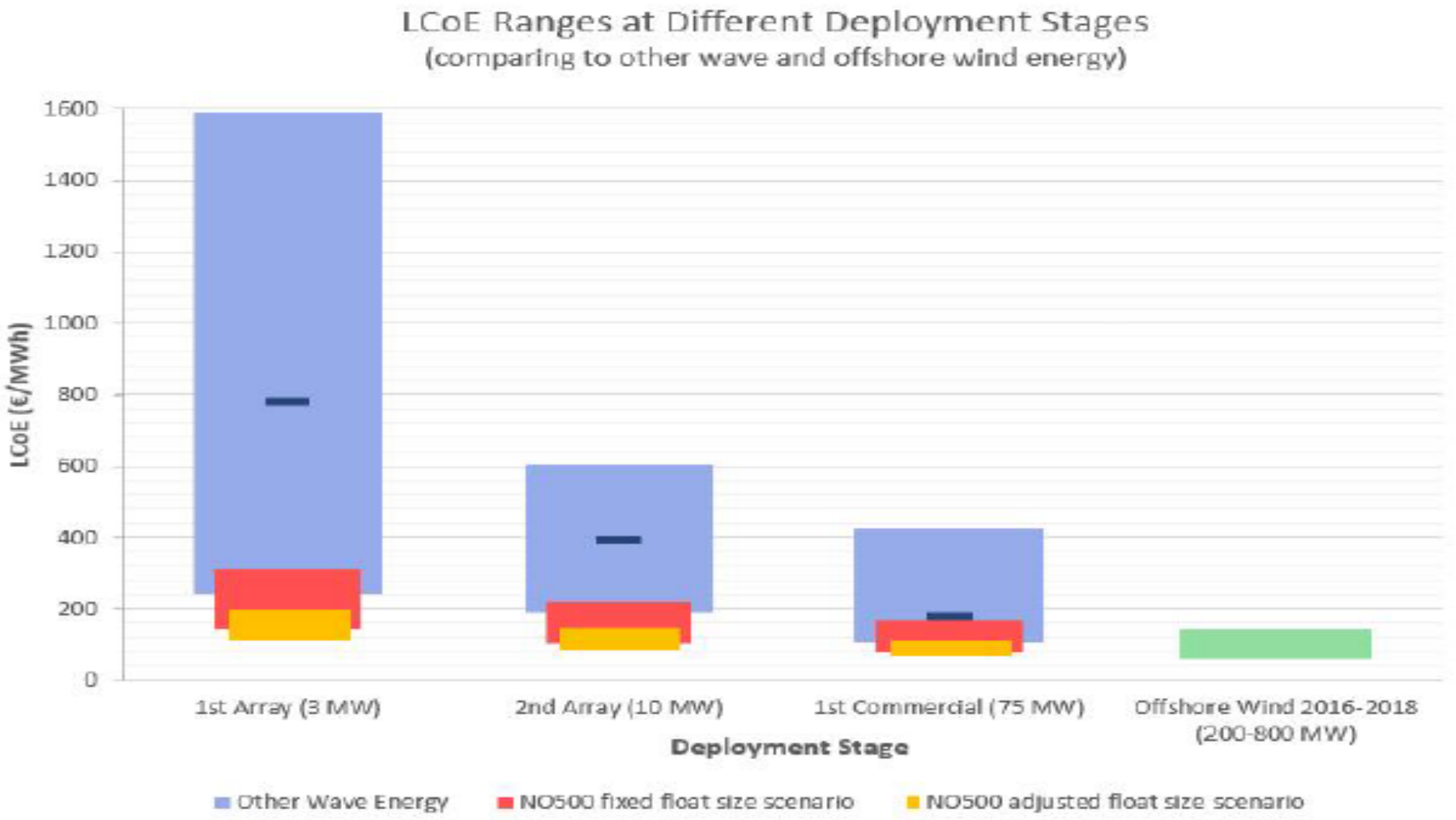
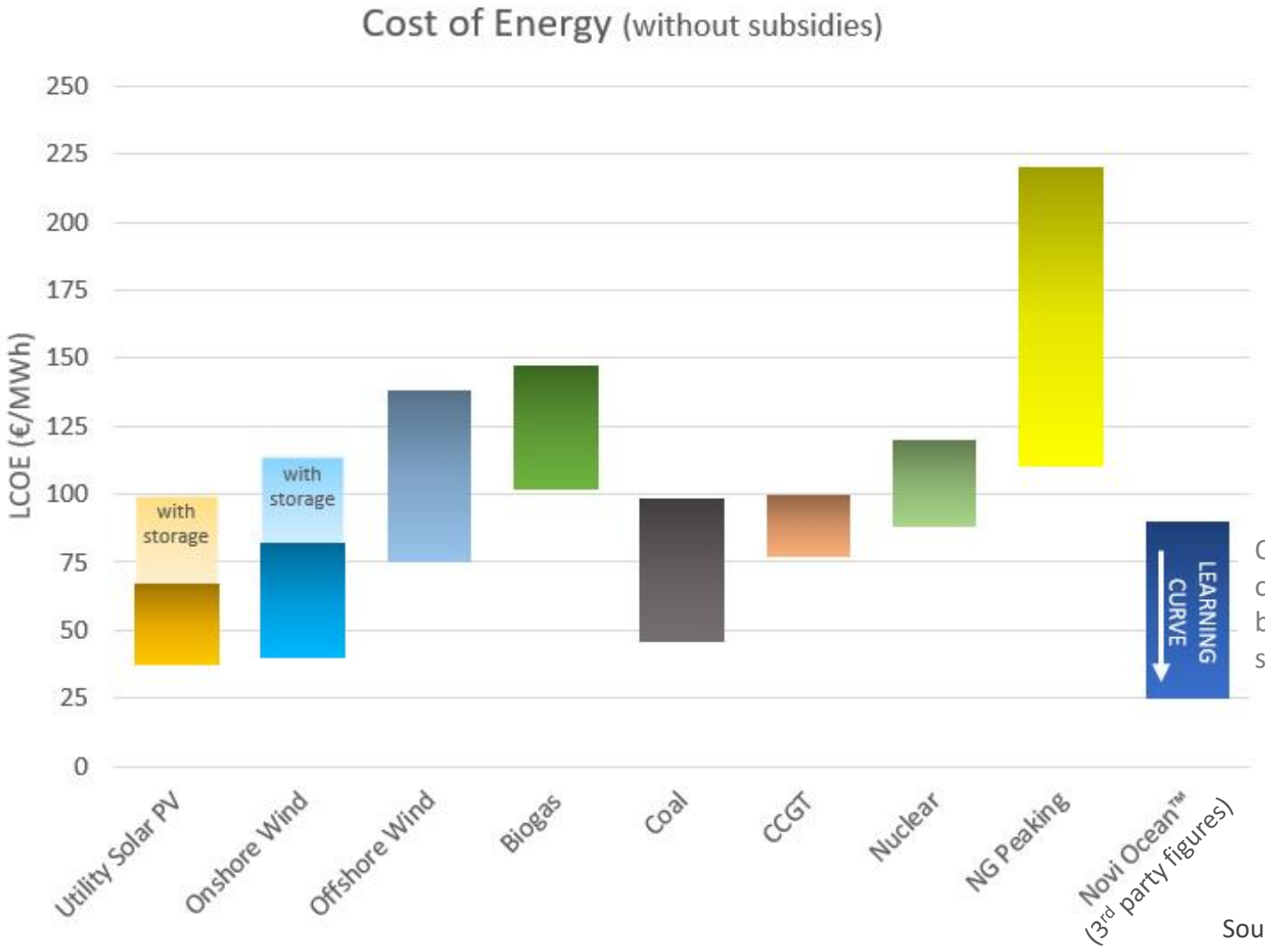


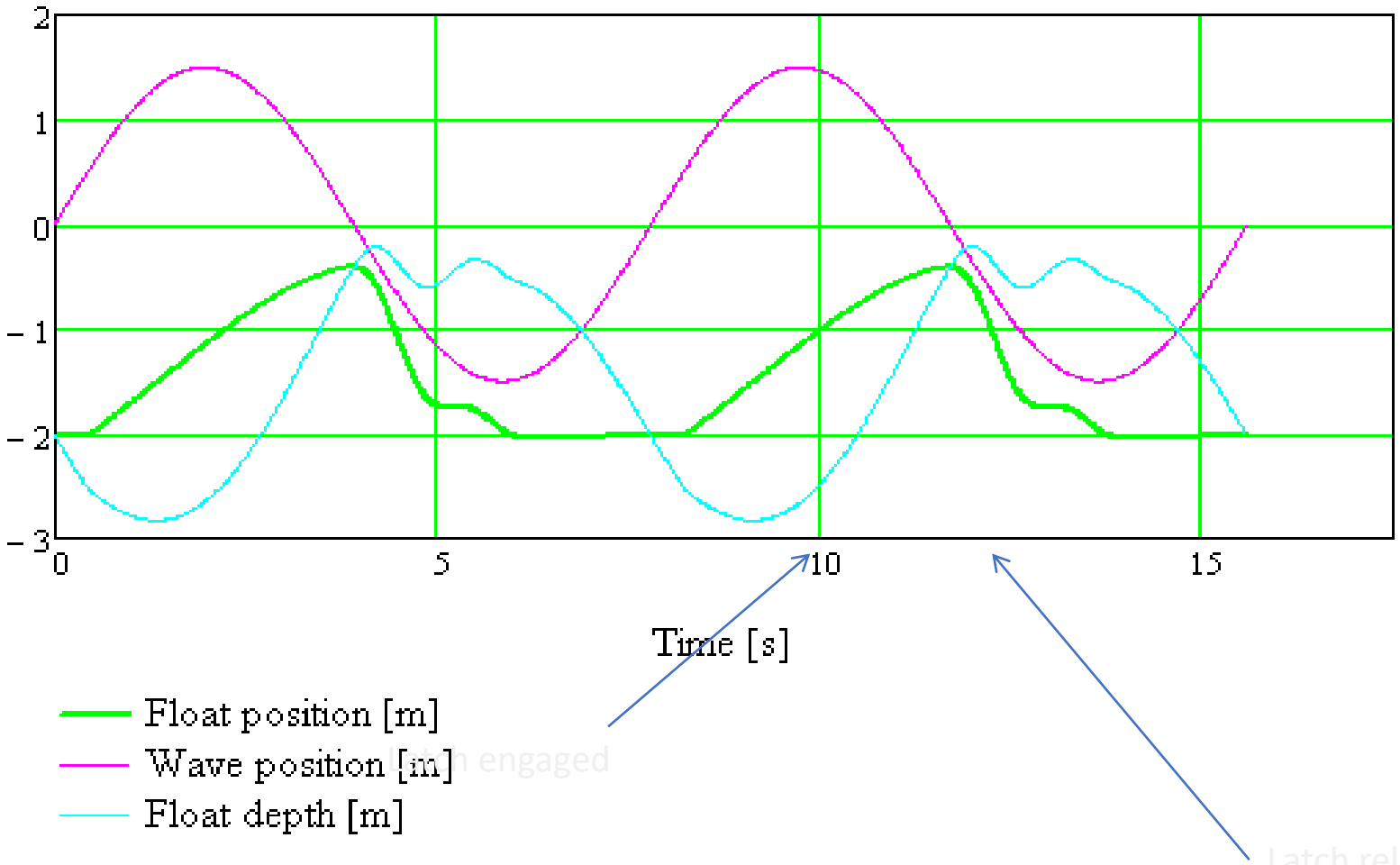
Figure 5: Wave energy LCoE ranges at different deployment stages in comparison to NoviOcean™ NO500 WEC and offshore wind energy (IEA, 2015) (IRENA, 2018)

On the way to beating fossils



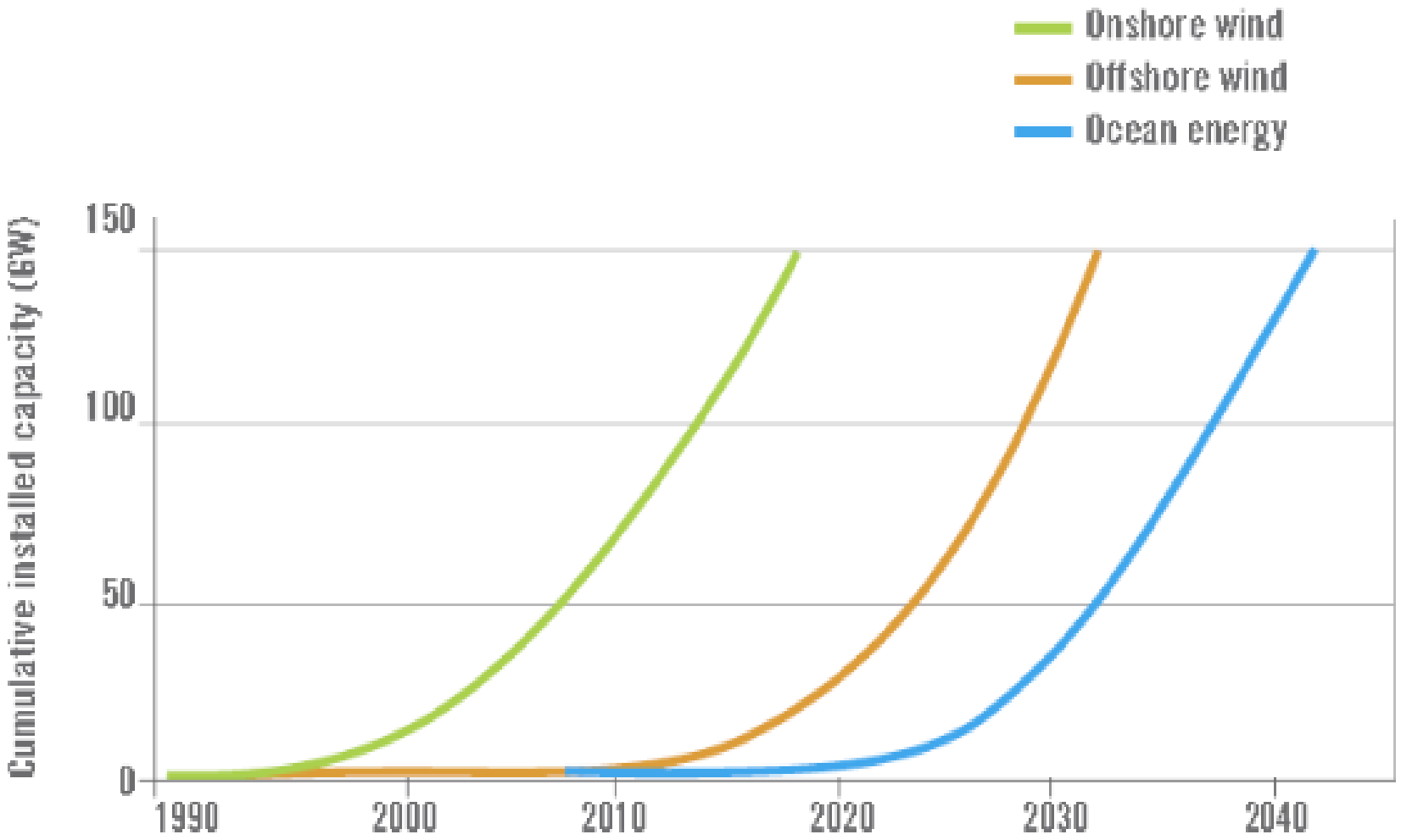
Our numbers are based on WavEC, plus resulted by optimization of control system and size of float

Source: (Fraunhofer ISE, 2018)



Dynamic simulation of platform stabilized motion in ideal 3m sine shaped waves with 7.8 period and latching at deepest position, creating lift force of up to 600 tons, depending on wave height. A simple valve then opens and releases high pressure water to the turbine. Free floating with a depth of only 0.3 meter and creating slack moorings on the way down. The flywheel then powering the generator with stable energy until next latch release. The green curve horizontal line shows the hydraulic latching period, giving the position of the bottom of the platform. The blue curve is meters pressed down in the water.

Commercial exploitation of marine energy from 2020 is forecast to parallel the current development of offshore wind power and earlier trends in onshore wind.



Wave Energy Advantages

- Unlike wind and solar, wave power is not intermittent, giving us the possibility of producing electricity 24/7, off-phased with wind power
- No need for batteries, not obstructive to the eyes, quiet
- No land use and requires significantly smaller sea areas compared to offshore wind.
- Resource availability near shores with consequently lower maintenance and transmission costs

NoviOcean advantages:

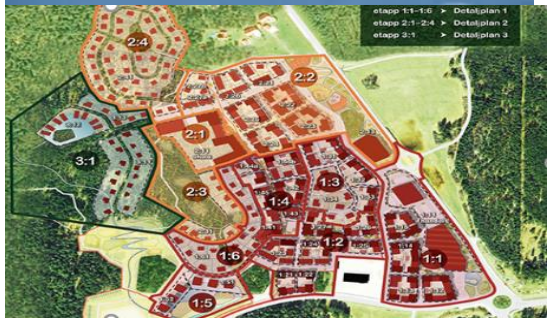
- Light, simple principle, few parts, based on well proven components, large sections can be produced at local shipyards enhancing local productivity and know-how, easy transport and deployment, low surge forces due “surf board design” with only 30 cm draft, high survivability, will always produce, even in storms, lowest lifecycle Co2 costs, which in total results in low CAPEX and OPEX, which ultimately results in low LCOE/costs per MWh.
- Low decommission cost compared to offshore wind, the natural benchmark in all of the above

PLAN GOING FORWARD:

- NOV/DEC 2019: SEA TESTS WITH FULLY FUNCTIONING PILOT, COMPLETED
- FEB. 2020: WAVE TANK TEST COAST LABORATORY, PLYMOUTH, COMPLETED
- 02-2020/06-21: DESIGN OF NO500, 500 kW, 25X6X5 METER AS BASIS
- 2019/20: APPLY FOR NORDIC AND EUROPEAN GRANTS. 15-25 MKR. (WE HAVE SO FAR RECEIVED 240 000 EUR FROM SWEDISH AUTHORITIES AND ÅFORSK FOUNDATION)
- 2020/21: INVITE PHILATROPHISTS TO SUPPORT OUR MISSION
- 2020/21: CHOOSE INVESTOR FOR 5-20 MKR, DEPENDING ON GRANTS/SUPP.
- 2021/22: CONSTRUCTION OF NO500
- 2022/23: DEPLOYMENT AND TEST OF NO500, ENGLAND/SCOTLAND OR BEST OFFER. INVITE ON BOARD GLOBAL INDUSTRIAL COMPANIES. CHOOSE FUTURE MAIN PARTNER
- 202324: FIRST TEST/COMMERCIAL ARRAY, 3MW
- 2024 AND ONWARDS. COMMERCIAL DELIVERIES, LARGER ARRAYS, PROFIT
- INITIAL GOAL: 1% RELATIVE OFFSHORE WIND MARKET, WORTH 500 MILL. EUR
- FINAL GOAL: THE ABOVE X 1000, AT THE EXPENSE OF FOSSILS, OUR MISSION!
- HOW? LOW COST, LOCAL PRODUCTION, CHEAP LICENCES, HYDROGEN PROD.

BACKGROUND JAN G. SKJOLDHAMMER, CEO AND FOUNDER NOVIGE AB

BI NORWEGIAN BUSINESS SCHOOL



- OFFICER, ROYAL NORWEGIAN AIRFORCE
- BUSINESS DEGREE, BI-NORWEGIAN BUSINESS SCHOOL
- ATLANTIC FERRY FLIGHT 1988, THEN DISPLAY PILOT 1988-2003 ON THIS BEAUTY, A 1944 A-26 INVADER (GOOD FUN!)
- PILOT, CAPTAIN, INSTRUCTOR, NORSK FLYTJÄNST, WIDERÖE AND SAS 1986-2011
- BOUGHT 42 HECTAR LAND IN 2001, SOLD TO NCC/BONAVA IN 2008 WITH HIGH PROFIT. THE AREA NOW CALLED SIGTUNA STADSÄNGAR
- WHAT NEXT CAME UP AS THE QUESTION? FLY FOR 15 MORE YEARS, OR DO SOMETHING MORE IMPORTANT…?

Our mission: To contribute massively on the goals 7,9,11 and 13, while also affecting several others

PS: By a an added technical solution, we can operate at deep waters. Then there is absolutely no limit to how much energy we can provide to the world, soon, given the right priority!

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Quote

- The calculated power output which is far greater than others per unit, the unusual low relative weight, the simplicity with few parts as well as the capability to latch the upwards movement in a simple way, are features that make the concept unique.
- You are welcome to contact us for any further information or cooperation.

- Stefan Björklund, Associate Professor, Machine Design, KTH
- Kjell Andersson, Professor, Machine Design, KTH

Quote

- Based on the presentation of Noviges wave energy concept and the collaboration with Novige AB during the Mechanical Engineer students' final degree project we have found the concept to be very interesting and promising. In particular, the simplicity of the mechanical parts combined with the lifting capability of the presented wave energy concept as well as the utilisation of a robust and reliable water turbine technology in combination with the estimated power output per unit, are all features that make it a new promising wave energy concept that should be further investigated.

- Andreas Linderholt, Assistant Professor, Linneaus University
- Lars Håkansson, Professor, Linneaus University
- Valentina Haralova, Assistant Professor, Linneaus University,

LINKS:

Homepage:
https://noviocean.energy

Video Coast Laboratory Plymouth, wave tank testing/verification of numerical simulations. Lifting 600 kg in every wave cycle, equaling 800 tons in NO500, our 500 Kw first commercial unit:
https://kth.app.box.com/s/gkpupd47bnsrr68fm6e7pwjjdburd4a6/file/629281128668

Video test site Stockholm:
https://kth.app.box.com/s/2f25nhkbv4swrr6n3xqubj5afl17lnw6

Video, non-NDA platform part, explaining the basic functions. (Disregard the note about 85x11 meters, that is for a later potential 7MW unit):
https://drive.google.com/file/d/17bhko_wM64TDS_RfF2dM-vKDVlUQflAe/view?usp=sharing

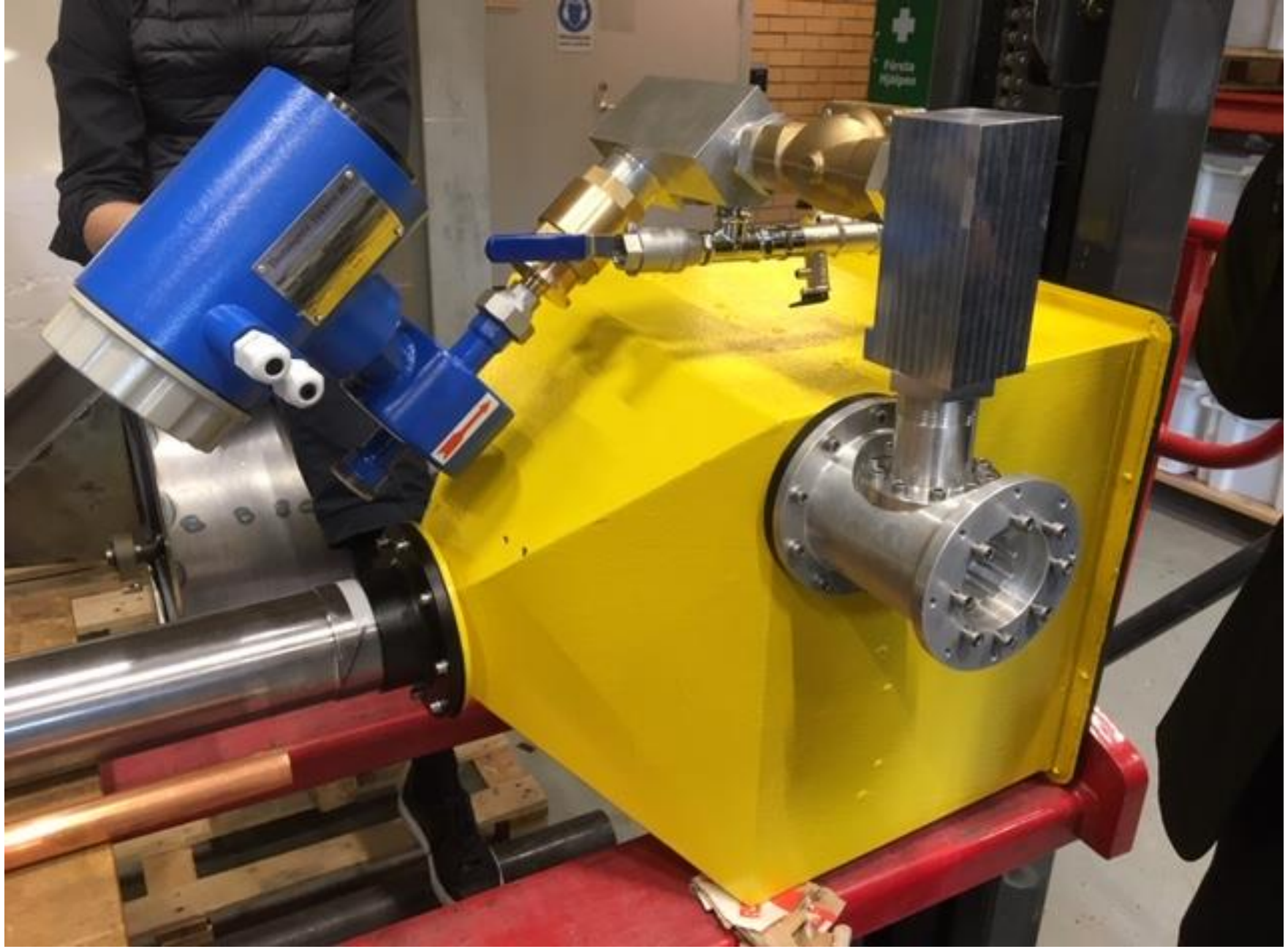
LinkedIn NOVIGE:
https://www.linkedin.com/company/novige-ab/Jan G. Skjoldhammer on LinkedIn: #energy #climate #renewable | 20 comments

LinkedIn profile Jan G. Skjoldhammer
https://www.linkedin.com/in/jan-g-skjoldhammer-8807996/

https://guldstank.se/ (Nominated as Innovator of the Year)

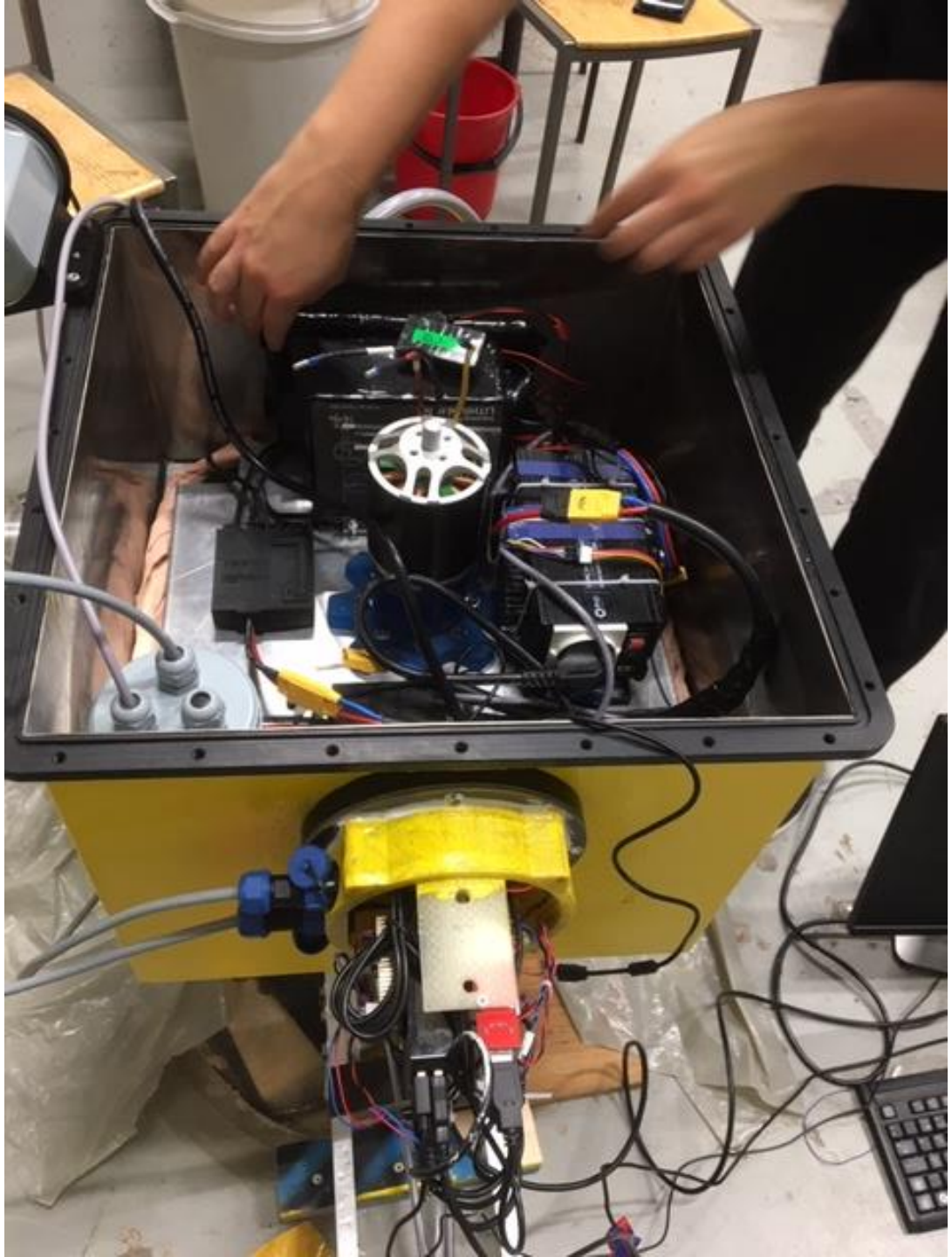
Front page Nordea Private Banking magazine, Nov. 2019.:
https://talk.nordea.se/privatebanking/vagmastaren/

Front page Ny Teknik Dec. 2019:
Hemlig plats för nytt svenskt vågkraftverk



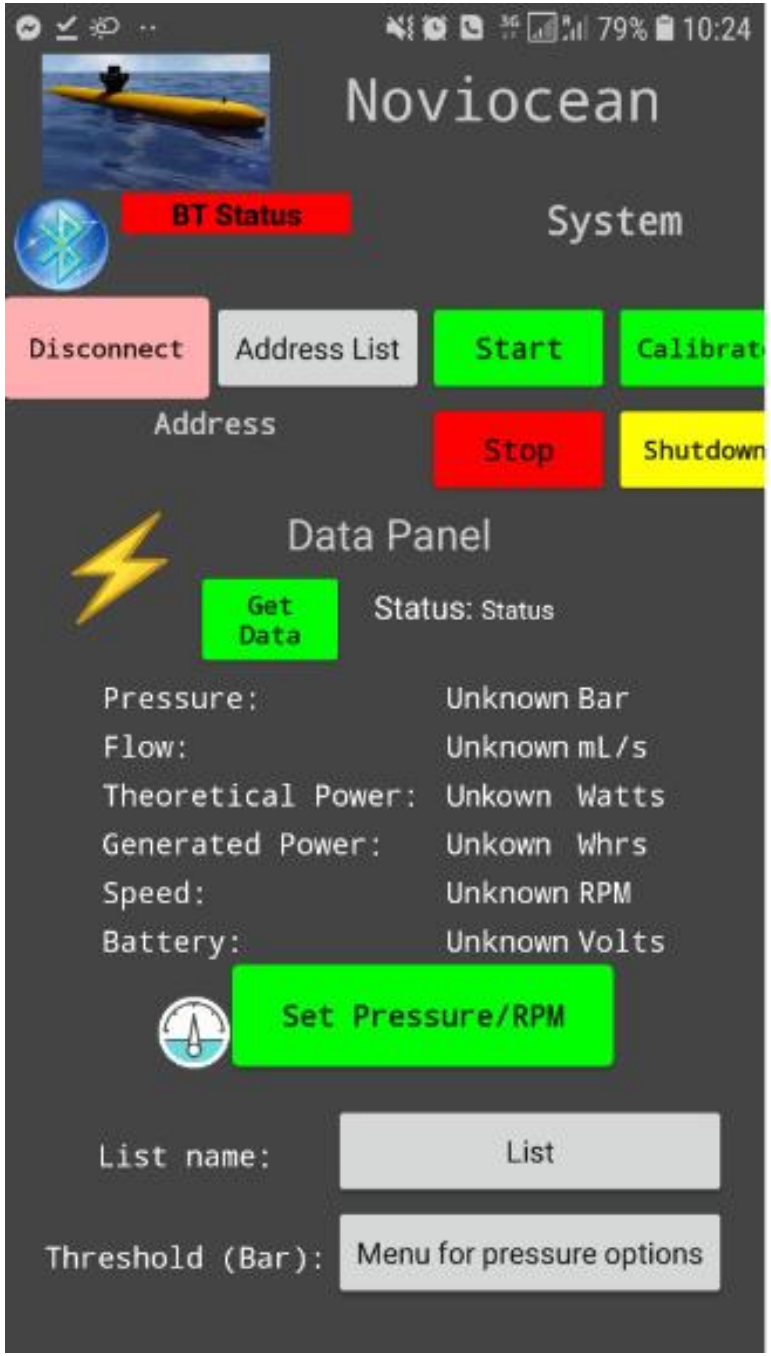
The cylinder and turbine housing laying horizontally. Valves and sensors

Turbine as seen through inspection hole



Even if it is a simple design, a control system is needed. The information from various sensors, RPM, loads etc., triggers valve governing.

Our portabel solution with batteries and part of the control system



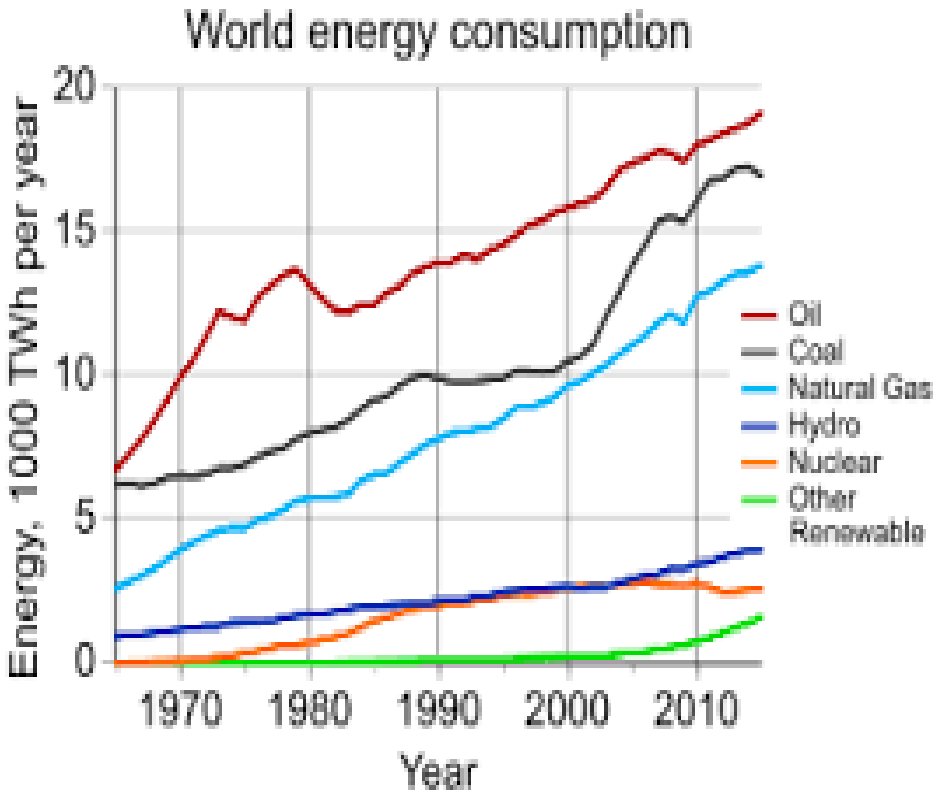
Our main control panel, an app connected via Bluetooth. It is used to run the control system. Full datalogging of every wave cycle. The purpose of this being to optimize the control algorithms and thereafter verify our quite exceptional performance numbers.

Just an example of some of our parts made with high precision. In this case the lower cylinder bushings. One holding the scrape ring, the next for resisting horizontal loads, and the upper for compression and connection to the cylinder

THE MOTIVATION FOR COMMITTING THE LAST SIX YEARS TO THIS:

Humanity is facing one of our toughest challenges with climate change

There is a need to dramatically increase the renewable production at the expense of fossil fuels



If we can beat oil, coal and gas within a few years, we can make a dramatic, positive climate impact, combined with giant profit and extremely positive green branding for partners, win-win-win. What can be better?

Wave power energy close to shore is estimated to be able to supply 1/4 of the worlds total energy consumption, seven times all installed wind power globally! (We can with a supplemental solution go to deep waters. Then there is absolutely no limit to the energy we can supply!!)

We work to produce a large part of this supply, with huge benefit both for mankind, investors and partners. Want to join or be a bystander?