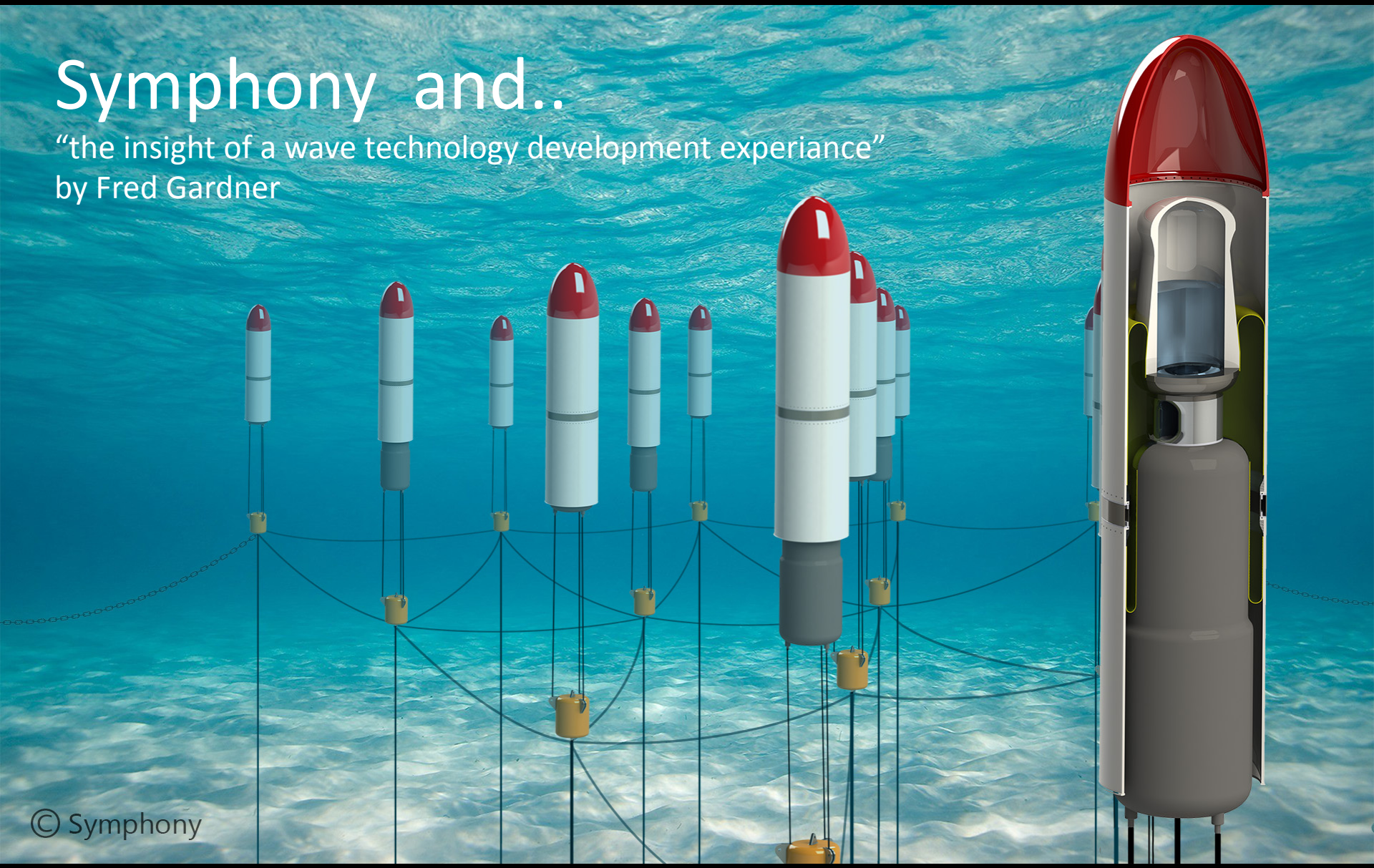
Symphony and..

"the insight of a wave technology development experiance"

by Fred Gardner

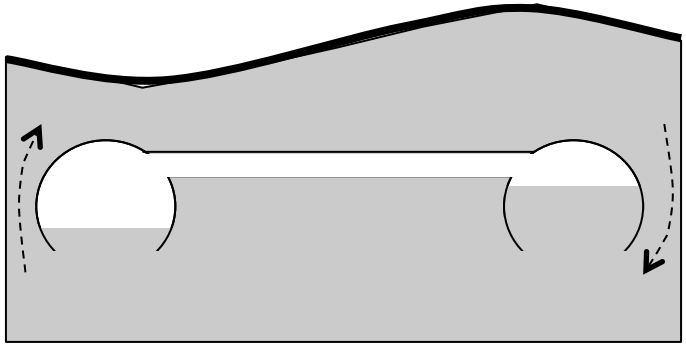


© Symphony

Where do we come from?

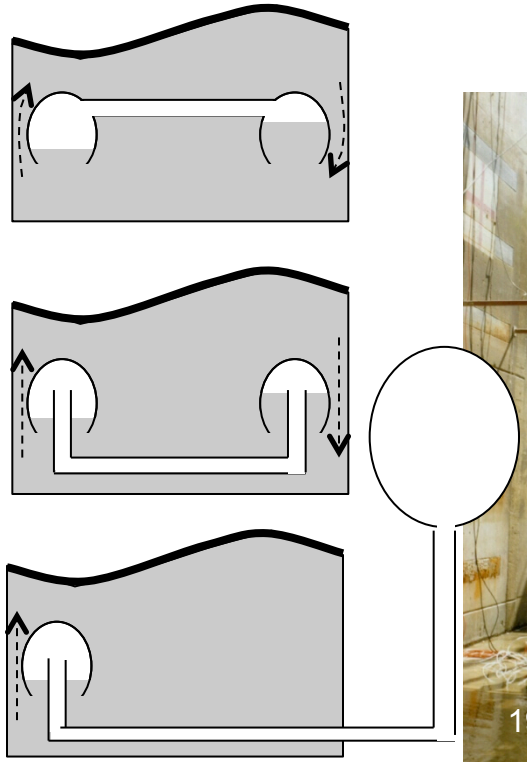
Some history

- Started 1993
- 1997 prototype 1:20 in Deltaflume

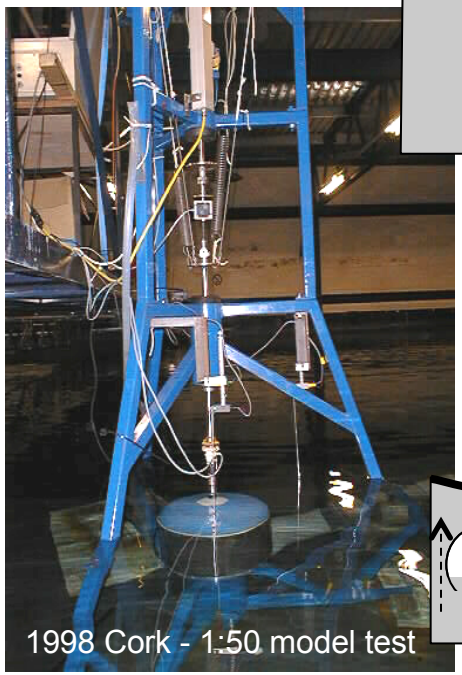


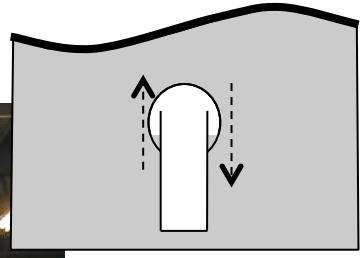
Artist impression of one of the first designs.

Concept development
1993 – 1995 - 1997

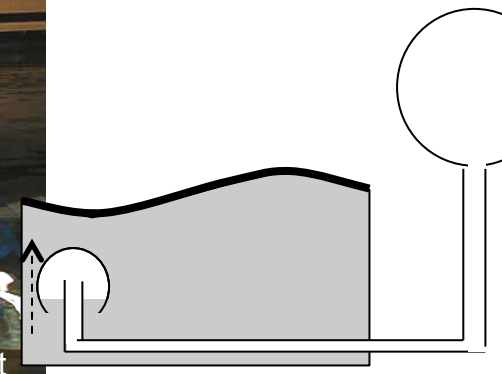


1: 20 scale testing





principle



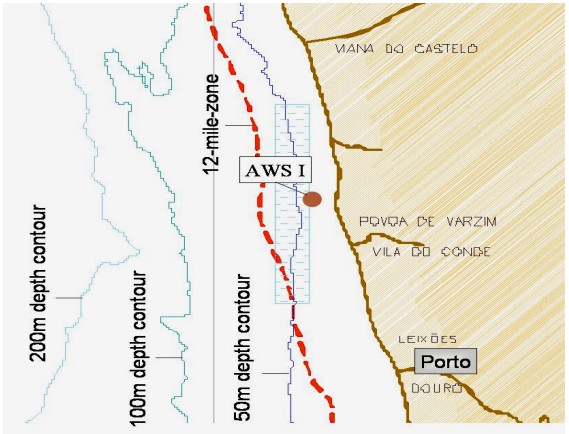
1: 50 scale testing

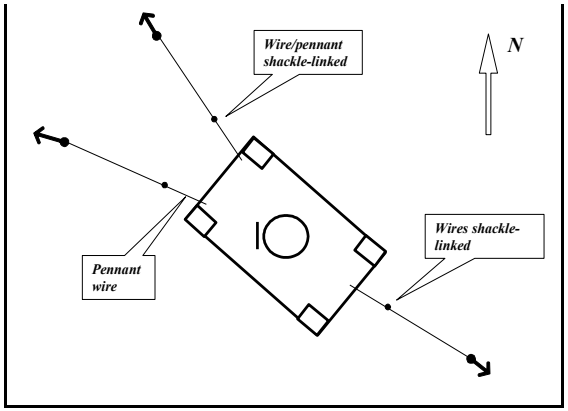
Next step = pilot plant with:

Real size components
(generator and grid connection)
No membrane (open gap)
Proof of technology.

Being towed to the Atlantic Ocean in Portugal

Submerging @ may 2004





Learning experience from prototype testing at sea

- Easy to control / natural behaviour.
- Can be switched off. (For survival.)
- Underwater is good accessible by diver or ROV < Hs 2.5m.
- Theory fits, and can be used for future design.
- For submerge use a semi autonomous system< Hs. 2.5m
- No mechanical connections between vessels, dynamics are dominant.
- Standard offshore technology was not suitable for installation.

Conclusions presented at conference in 20017

Learning experience from prototype testing at sea for design next system.

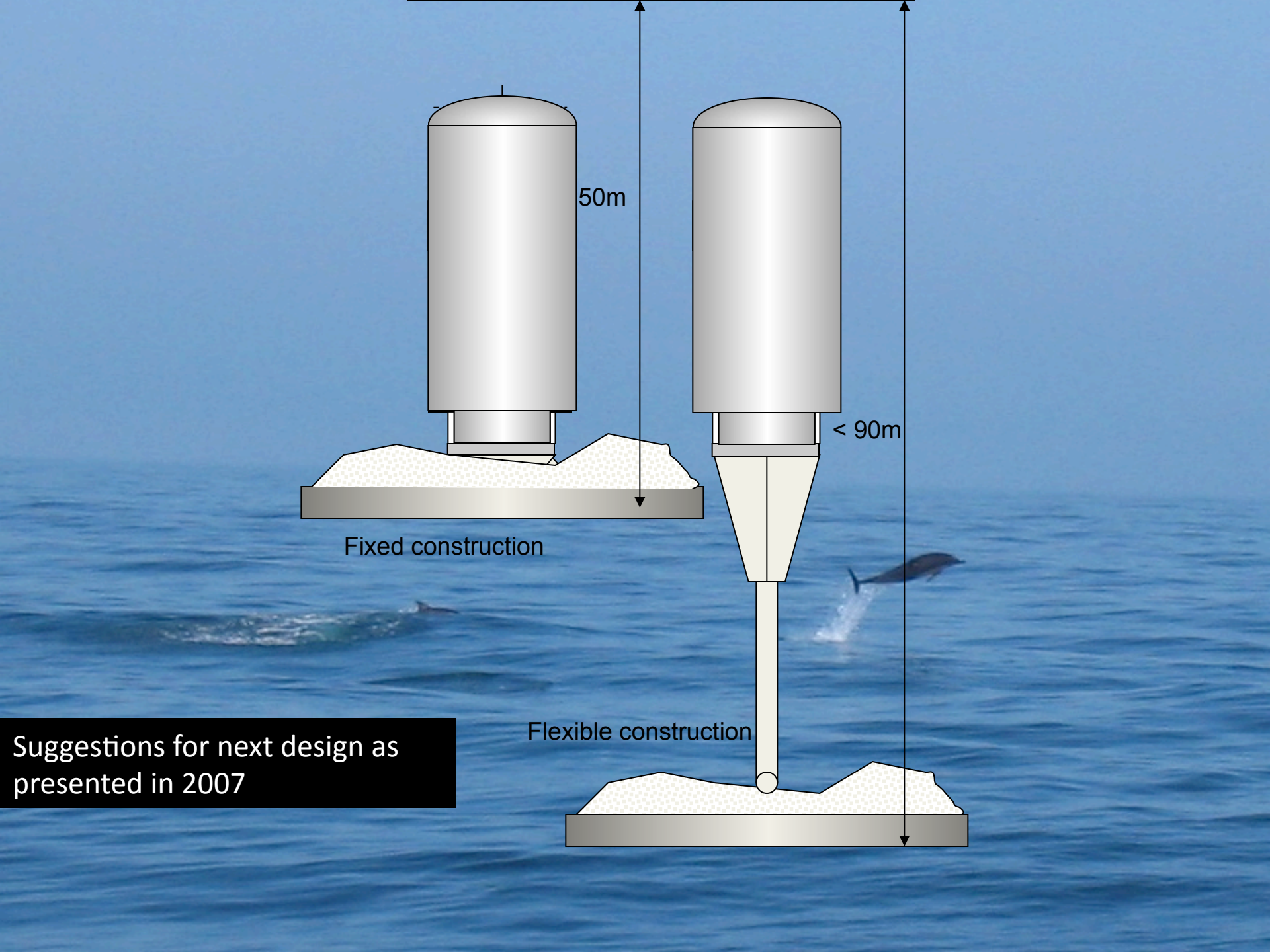
- No pontoon (it was specific for the pilot plant)
- Build horizontal.
- All controls at the outside, to be able to exchange.
- All electric, avoid Christmas-tree constructions.

Conclusions presented at conference in 20017

Conclusion and next steps

- Results are good enough, technology is proven
- Next device is first of a park
- Park development has started

Conclusions presented at conference in 20017

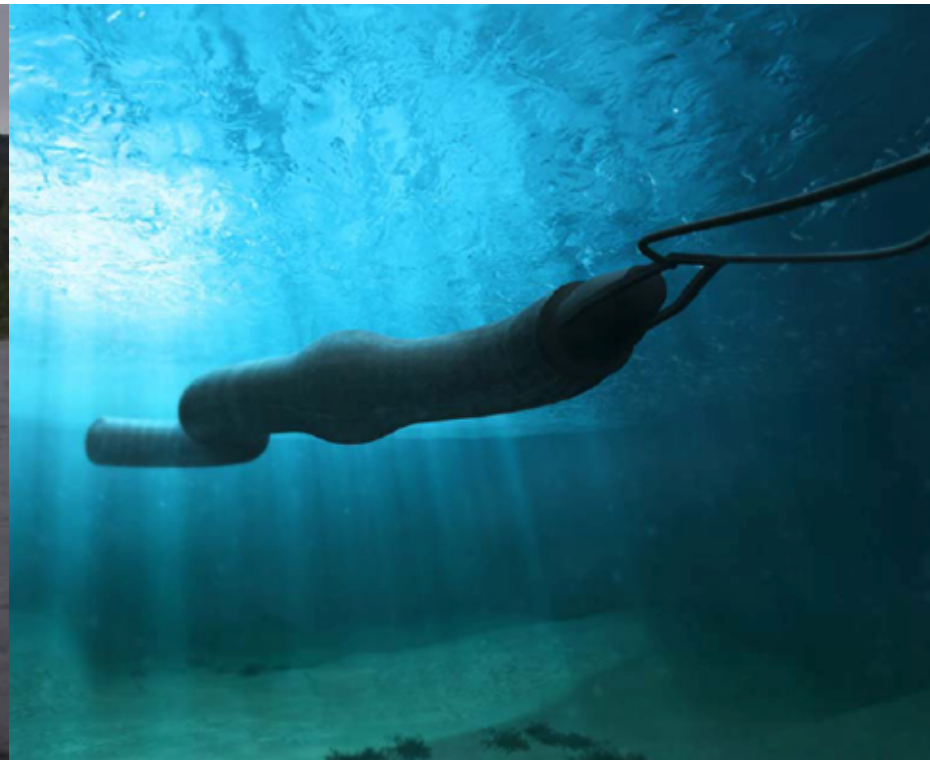


Suggestions for next design as presented in 2007

AWS technology is taken over by company AWS Ocean ltd.

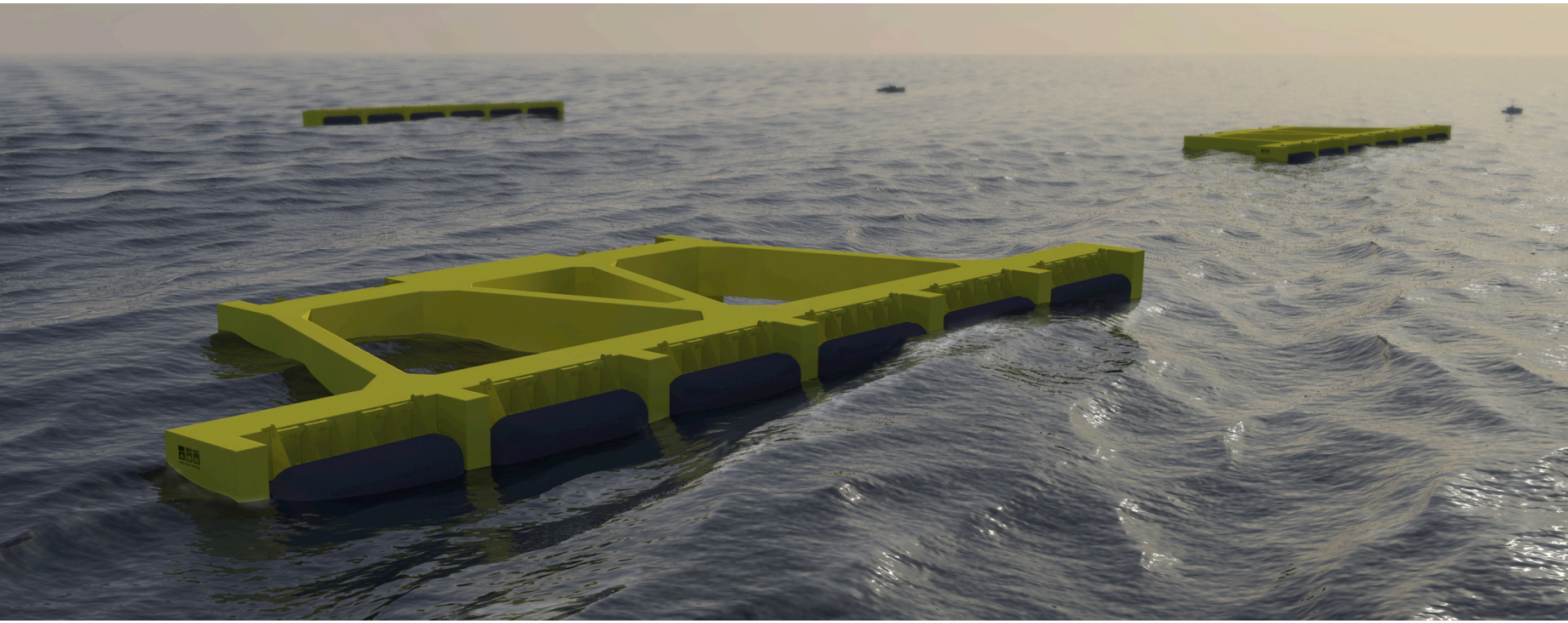
New design suggested by AWSocean ltd.

Concepts AWS ocean is working on



Source :website AWSocean ltd

AWSocean design.



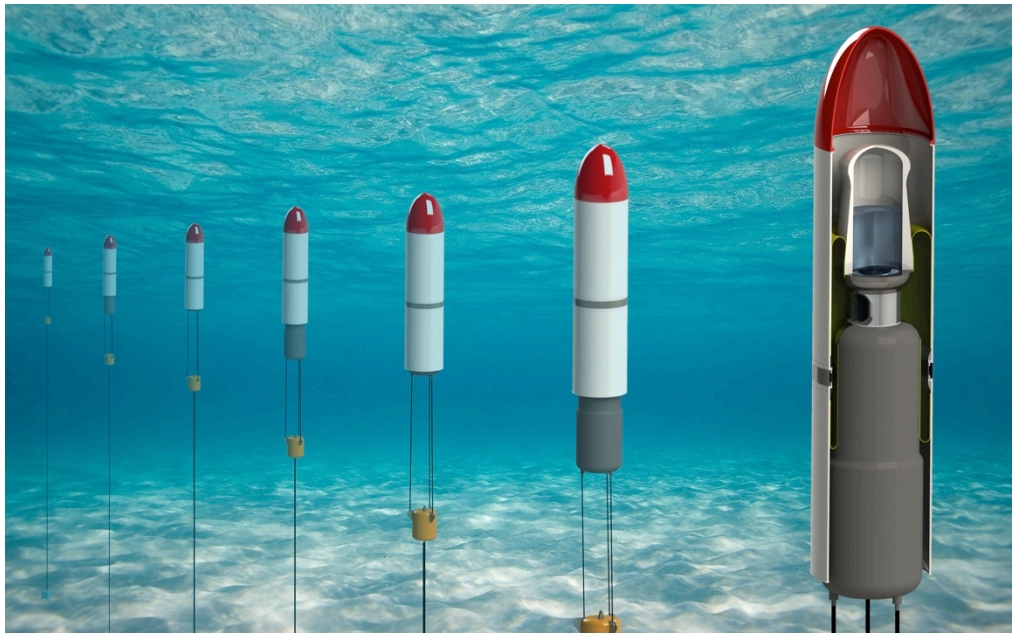
Source : AWSocean ltd

These designs converge from the original design route from the original AWS design as a vertical heaving submerged system.

In 2014 the originators of the "old AWS systems took up the original design path.
They were granted an EU subsidy to develop several key technologies

2014
New start for old Idea.

- symphony wave power
  - a "new" Dutch - Portuguese wave energy project.
  - With a new strategy

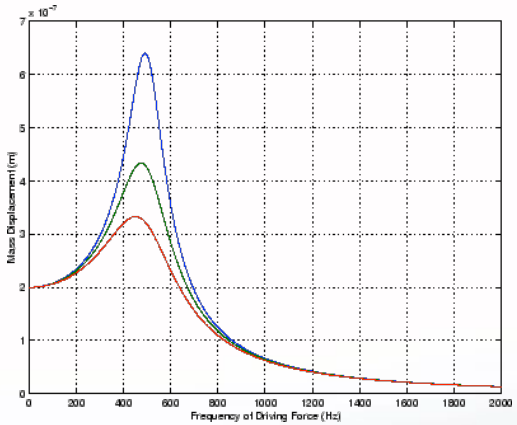


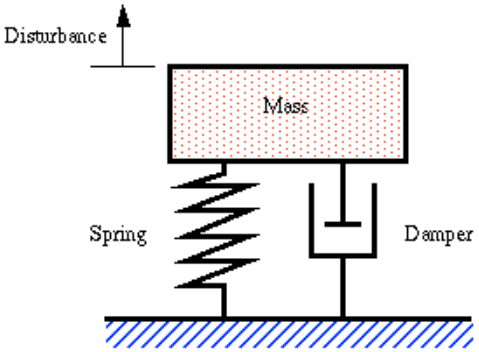
Comment:
Apart from the new technology the developers added to the old concept a new strategy was introduced. In the basics this is based on de-risking components and the whole technology on the smallest possible scale. With this small device extensive experience will be archived before larger and more costly systems are build. Since at this scale energy production against a commercial price is impossible, the project is considered a R&D project.

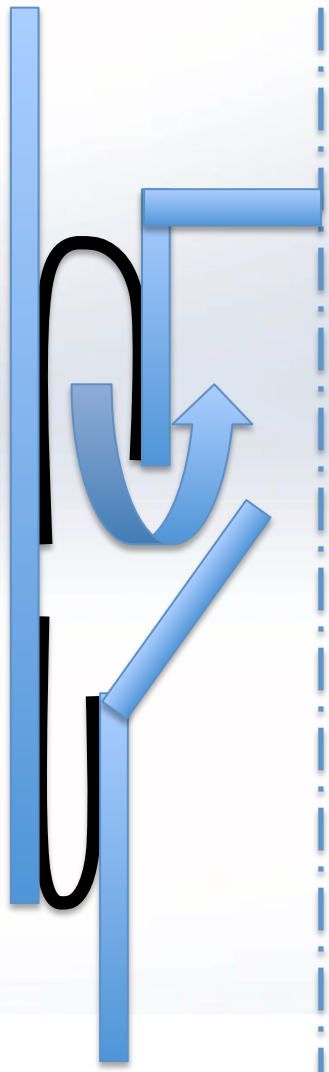
New setup from 20 years of experience.

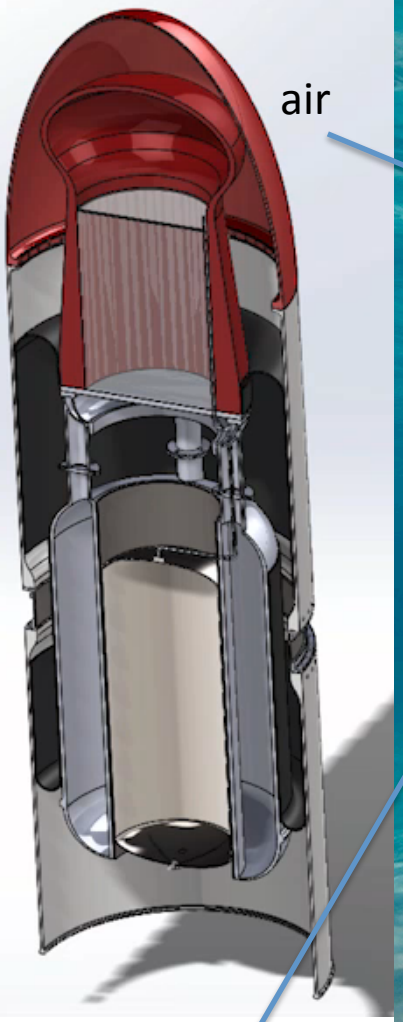
- Anticipate learning curves
- Start small and learn
- Do not follow the money, let the money follow you
- Partner as much as possible within the triple helix

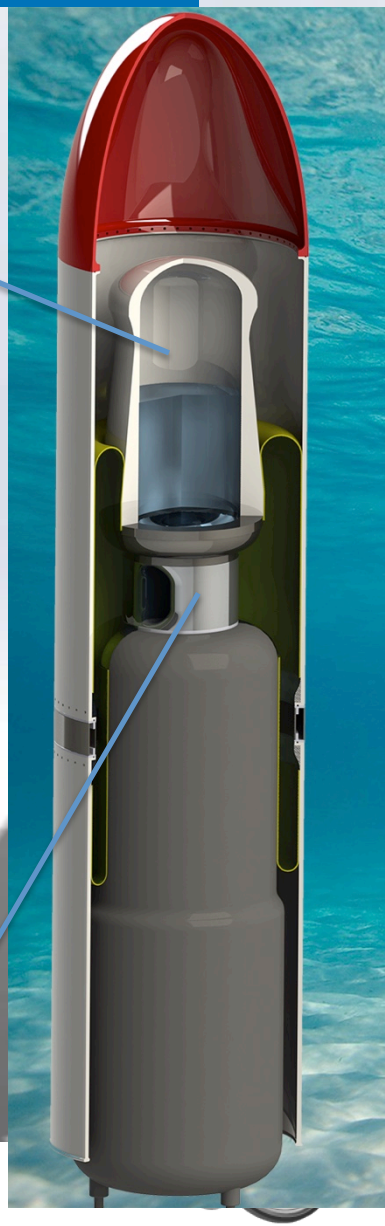
Symphony wave power





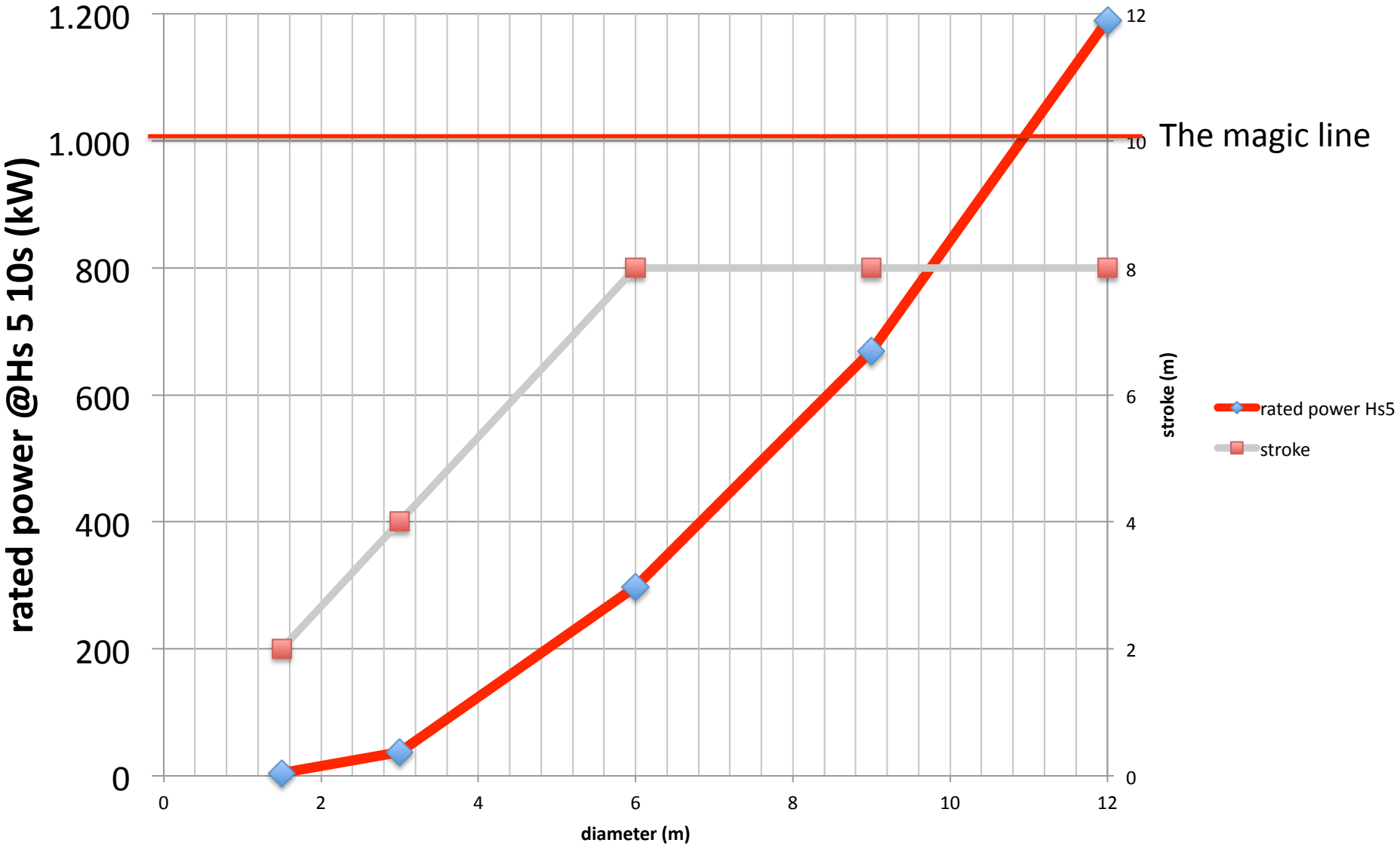




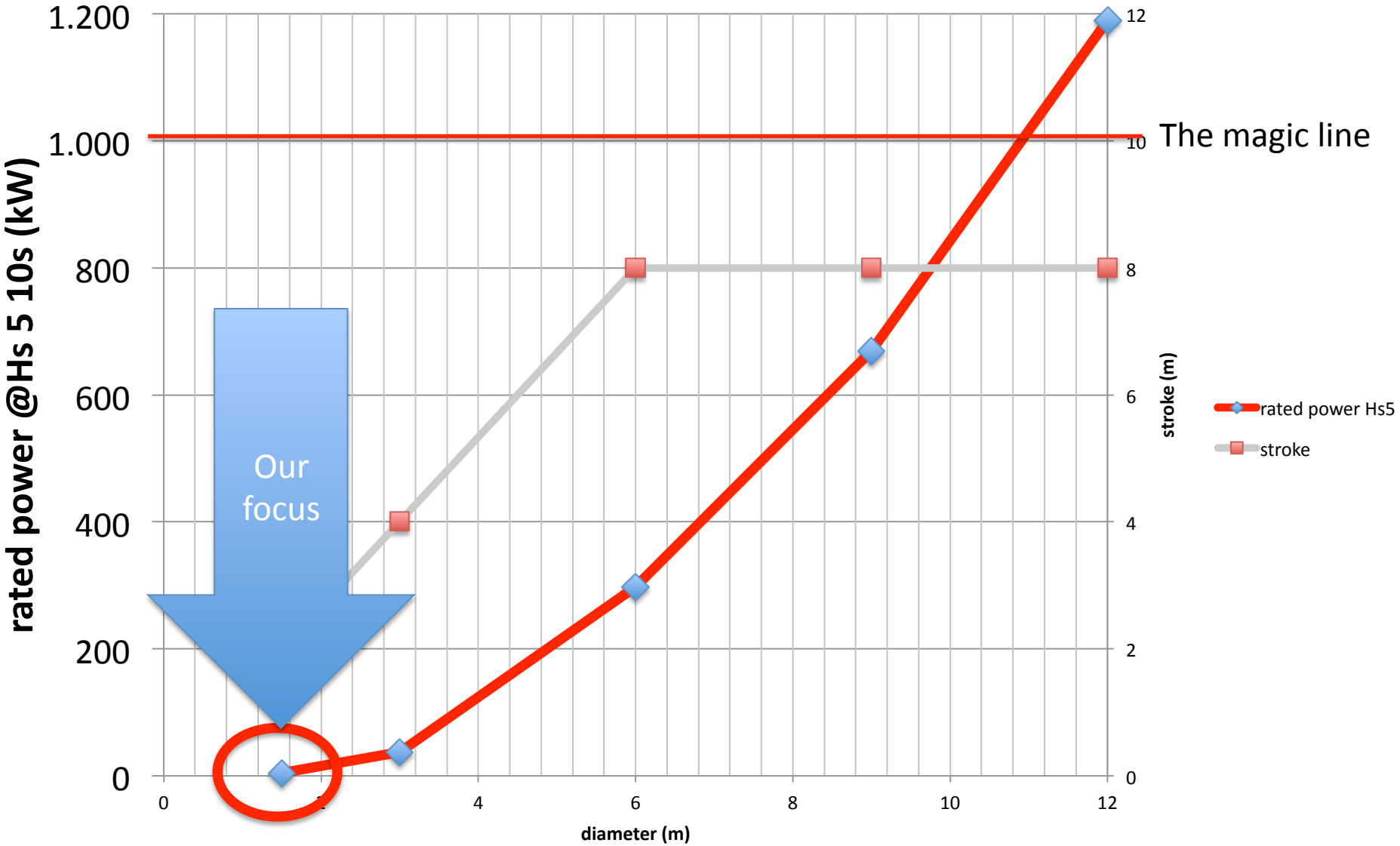


The system works as a damped mass spring system. The ais inside acts as a spring the turbine as a damper

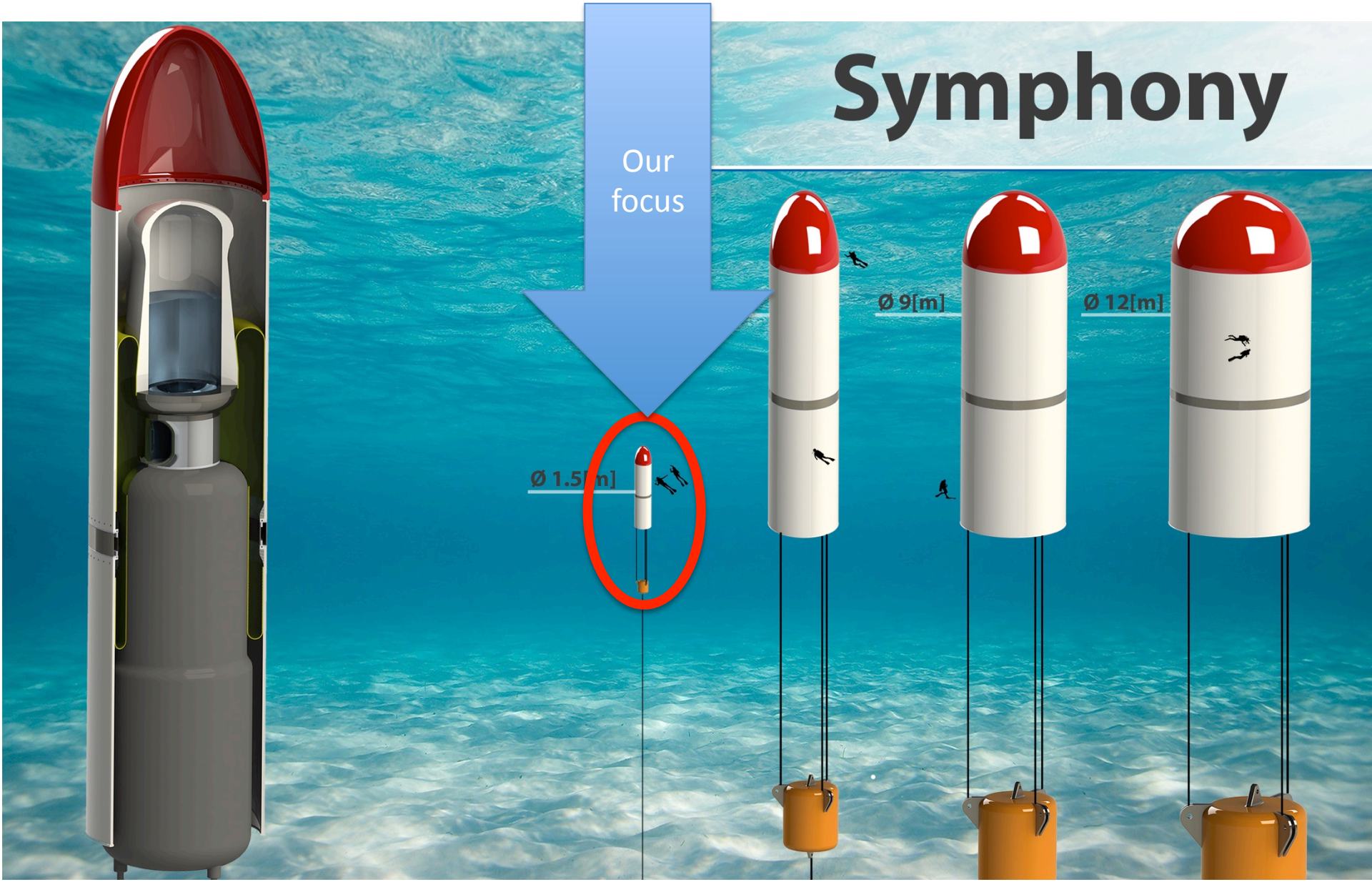
Symphony wave power output.



THINK SMALL !!! & de-risk before develop.



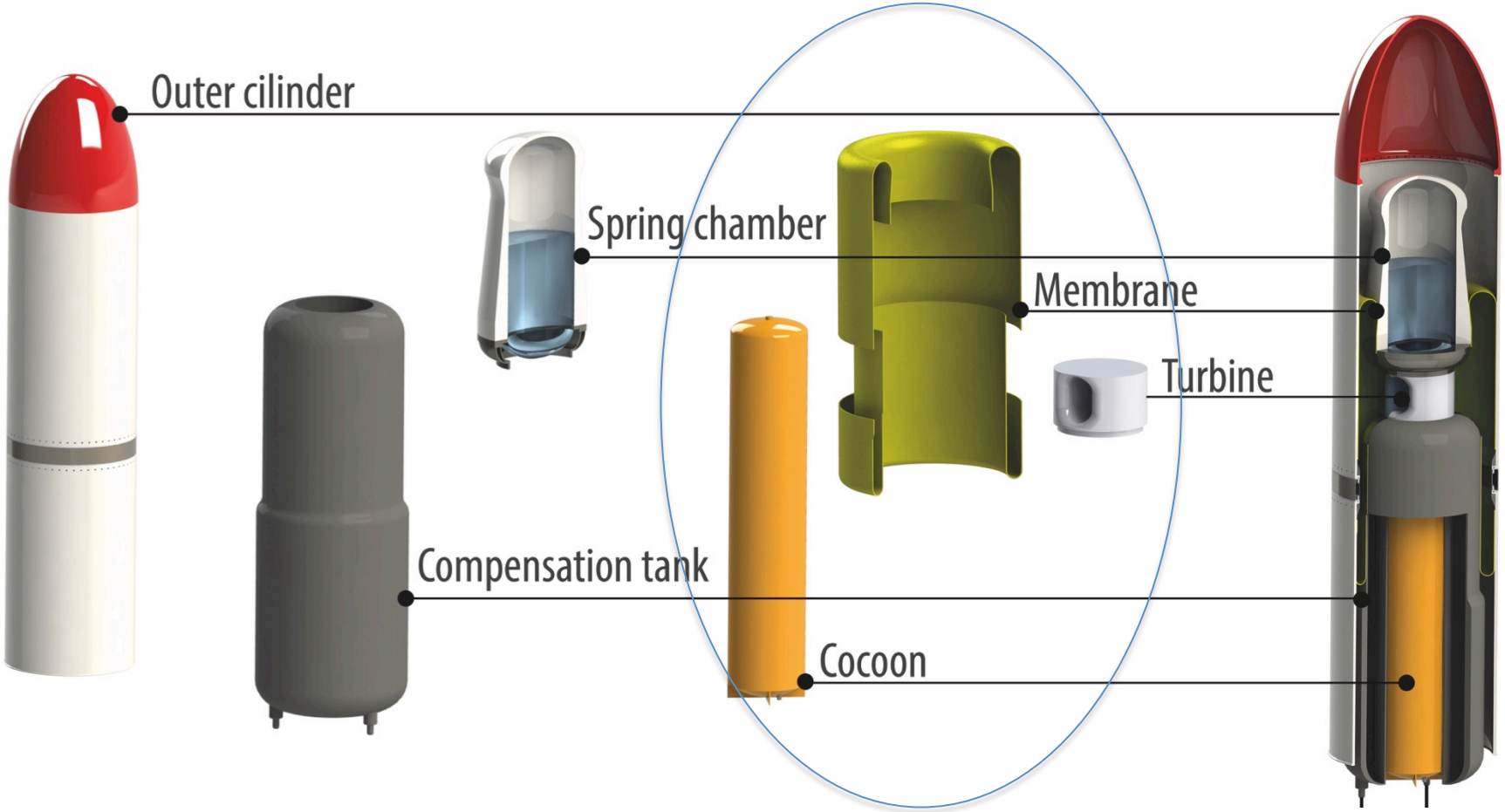
Symphony



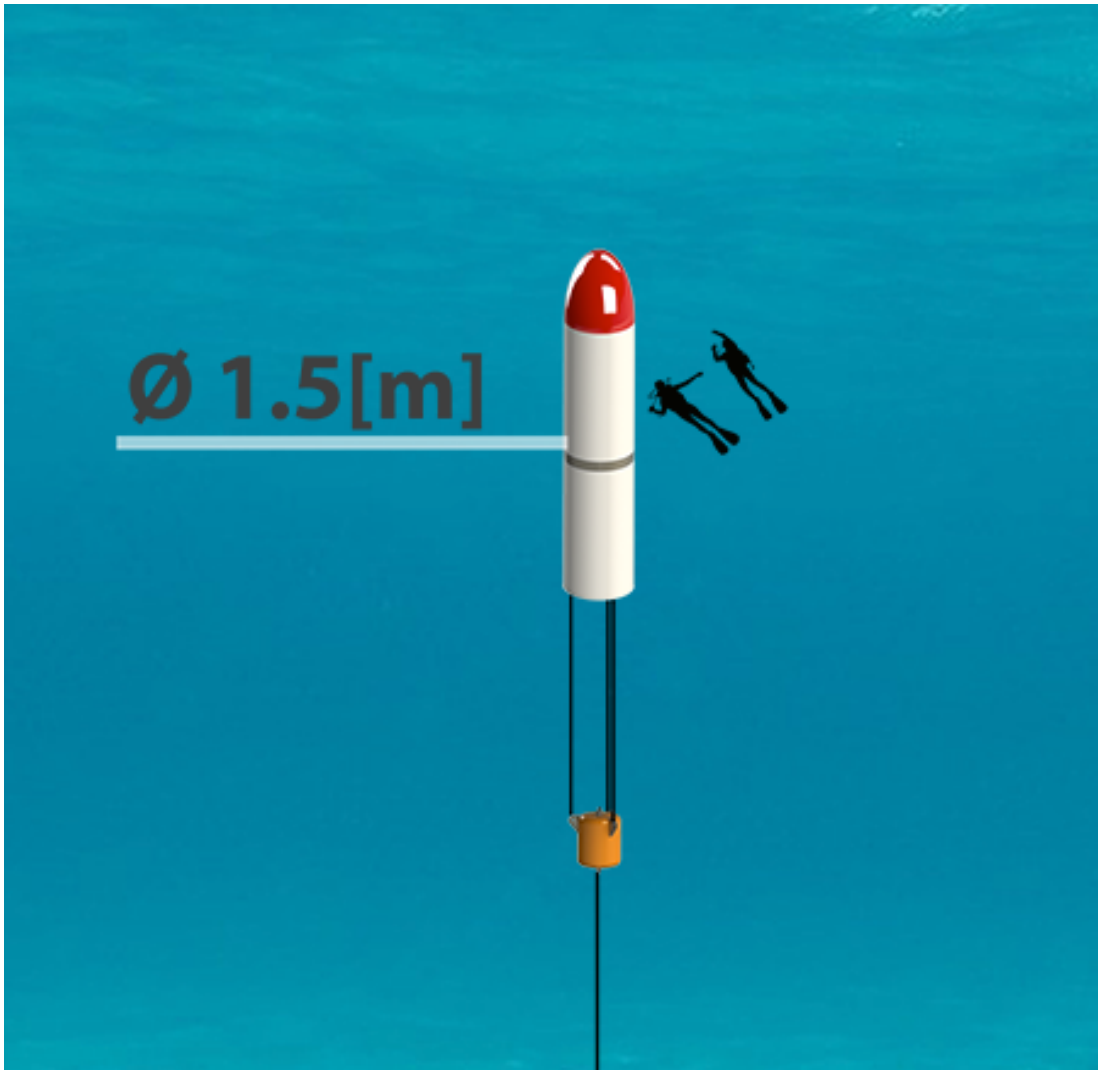
EU wetfeet program

Development needed on key components

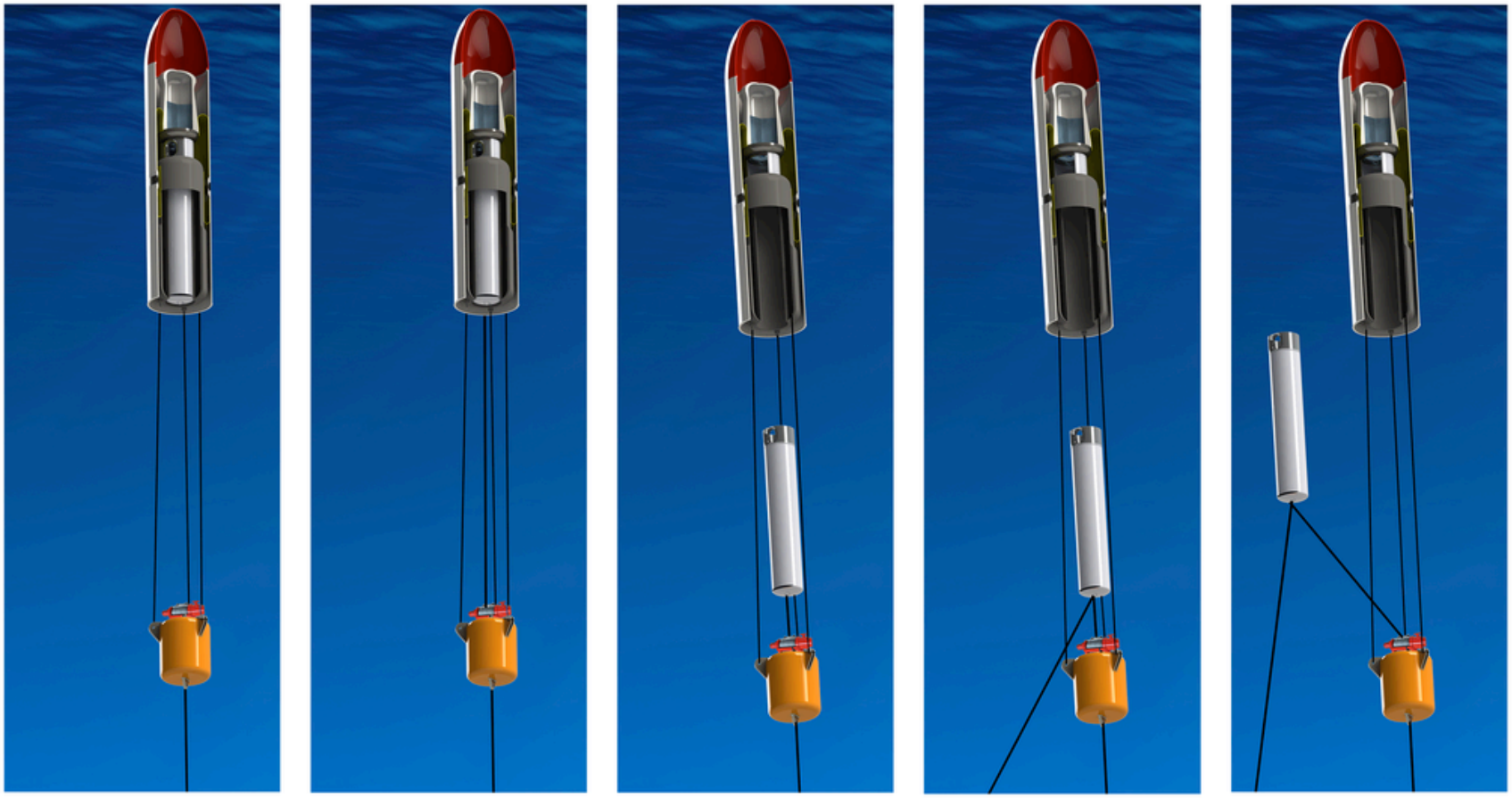
R&D project developing technology



Our focus



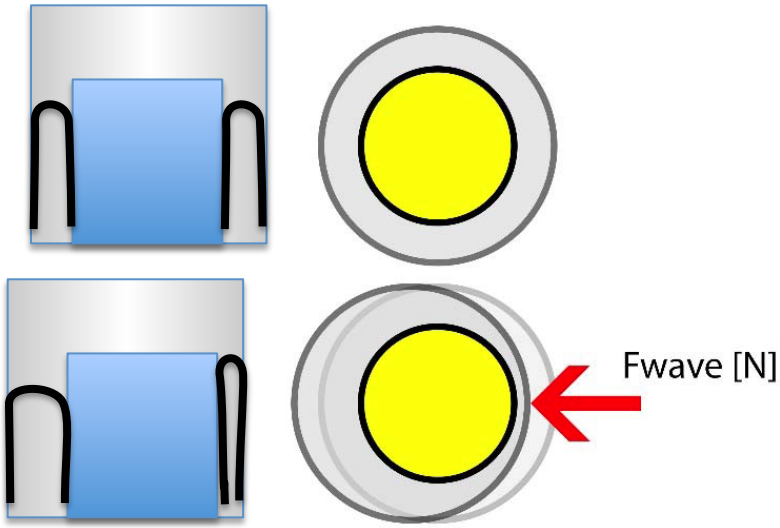
Cocoon design



Work done

Membrane performance as a bearing

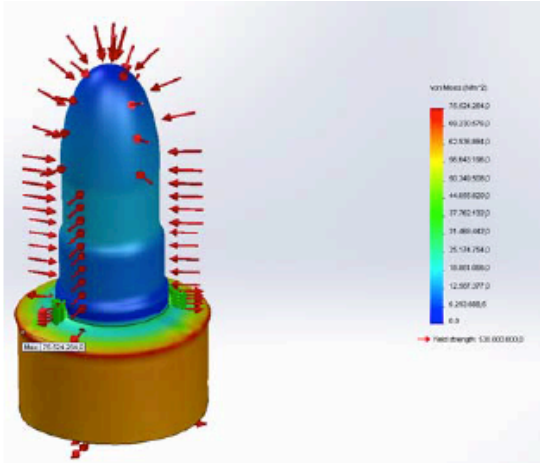
Thesis by Hans van Noorloos
University of applied science Inholland

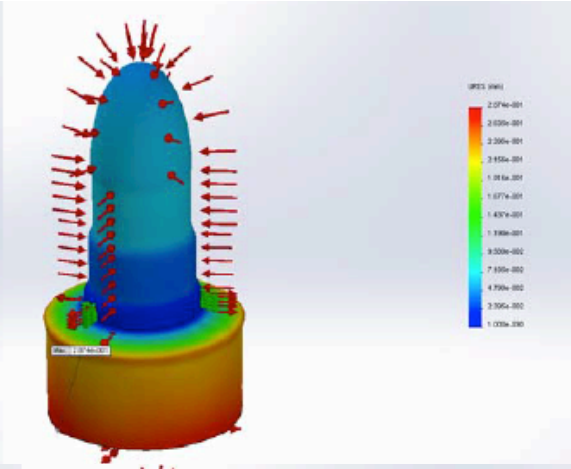


Maximum displacement during operation: Seastate: Hs=5[m] Period time band : 10-20[s]	10 [mm]
Maximum displacement during severe weather conditions: Seastate: Hs=10[m] Period time band : 12.5-25 [s]	12.5[mm]
to move the cylinder 0,01 meter 26 [kN] is needed	K= 2,7MN/m
the membranes own frequency is about	5 hertz.

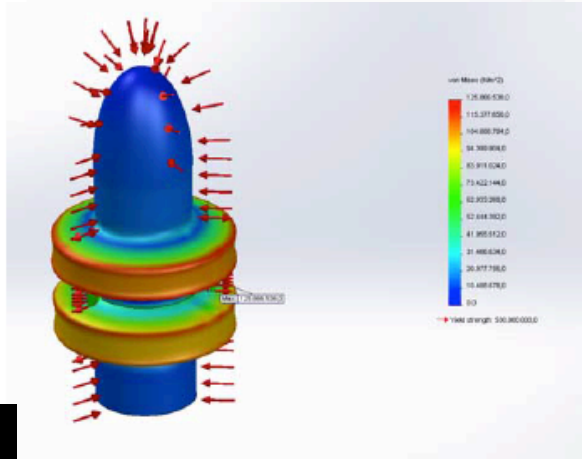
Structural analysis

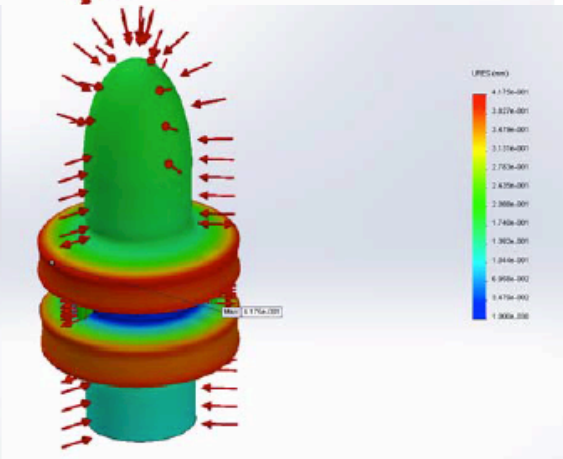
Top position





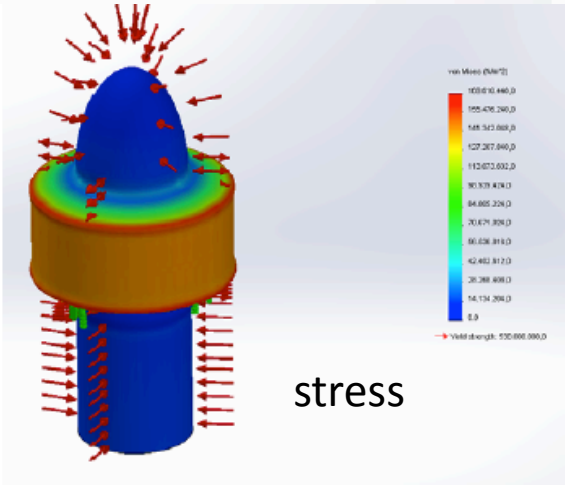
Middle position



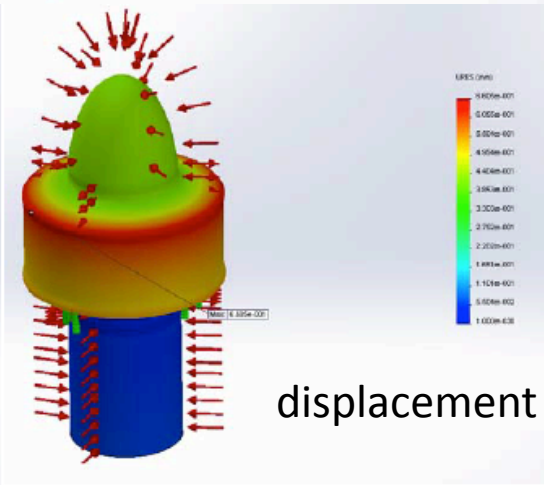


Nominal pressure of the interior is 15bar. This gives extensive forces on the construction

lower position



stress

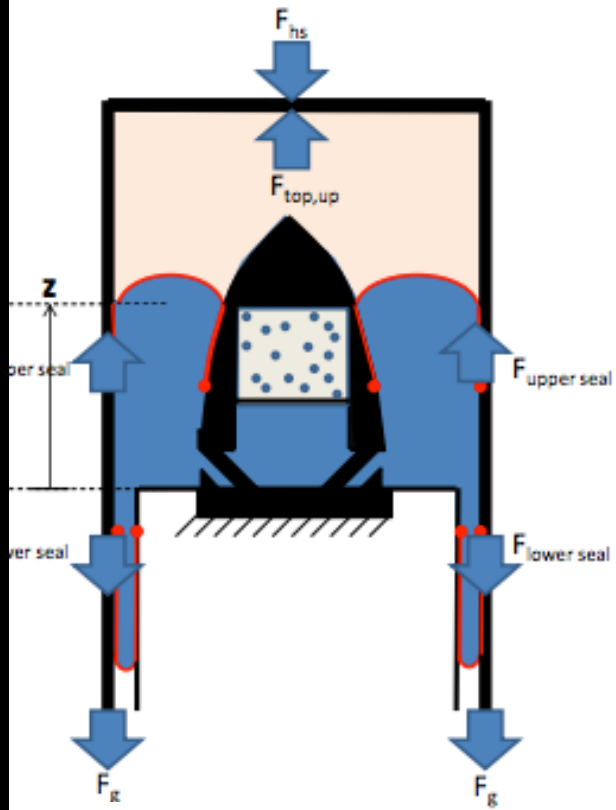


displacement

Work done

Thesis Aart Kooiman
Technical university Twente

Assisted by Miguel Prado pHd student TU-Delft



F_{hs} – Hydrostatic force
F_g – Gravitational force
$F_{top,up}$ – Upward force of top volume
$F_{upper\ seal}$ – Forces on the upper seal
$F_{lower\ seal}$ – Forces on the lower seal

3.3.1 Wall geometry

The geometry of the wall that will result in a spring with the prescribed spring characteristics is displayed in figure 3.7. Note that the values on the y-axis are half the stroke of the floater, due to the lever effect (paragraph 3.2). The maximum difference in diameter is 9.2 cm.

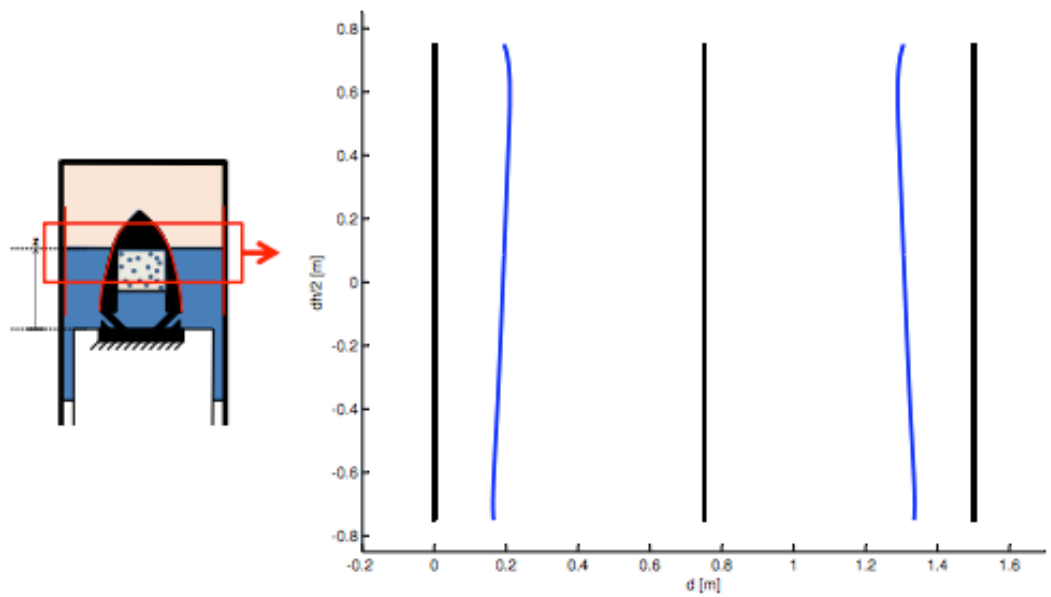


Figure 3.7: Wall shape of SWP that will result in a linear spring

For the geometry of the membrane shape a patent application is filed

Results from shaping the membrane

The spring has become linear for one specific frequency.
For other frequencies it is almost linear.

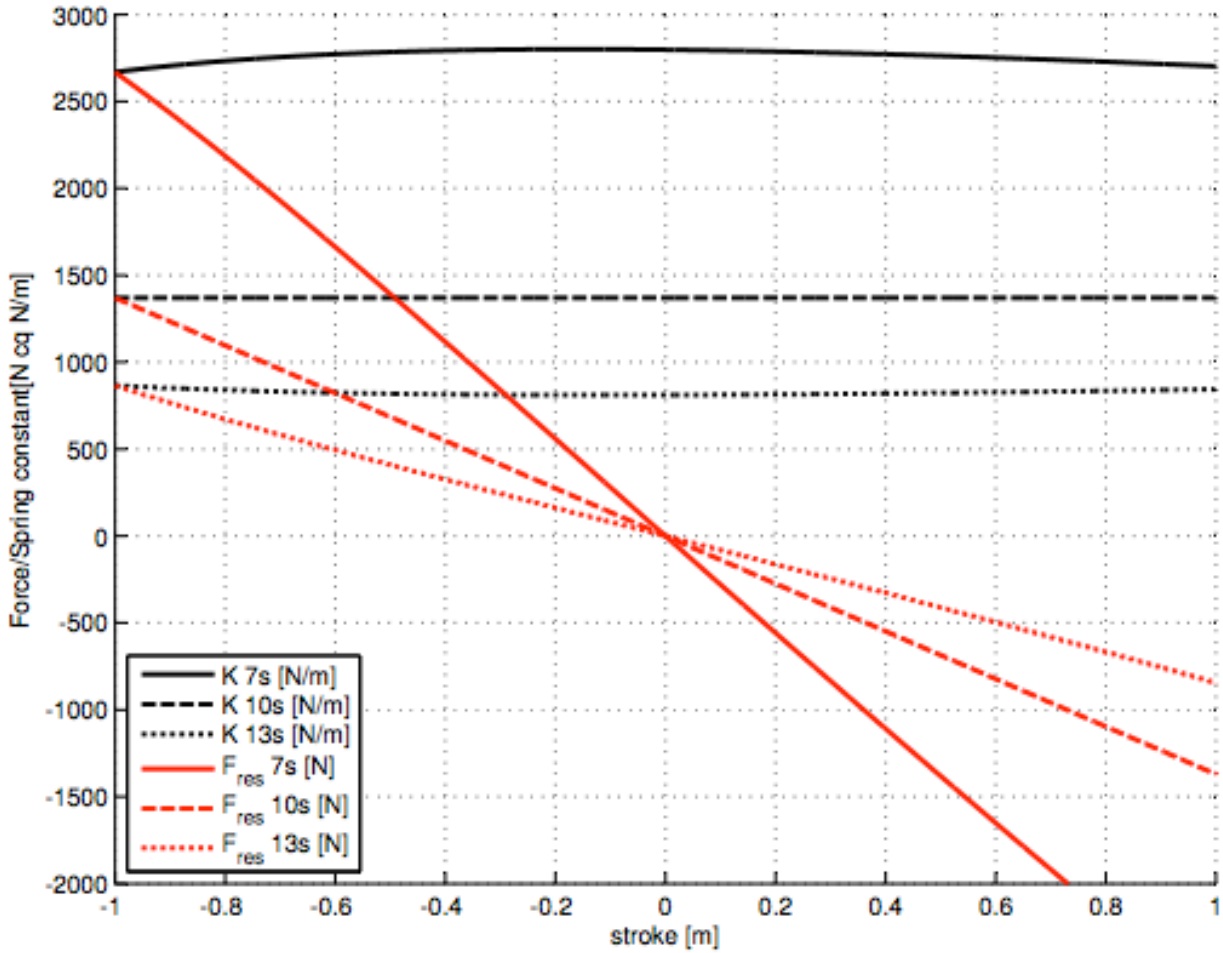


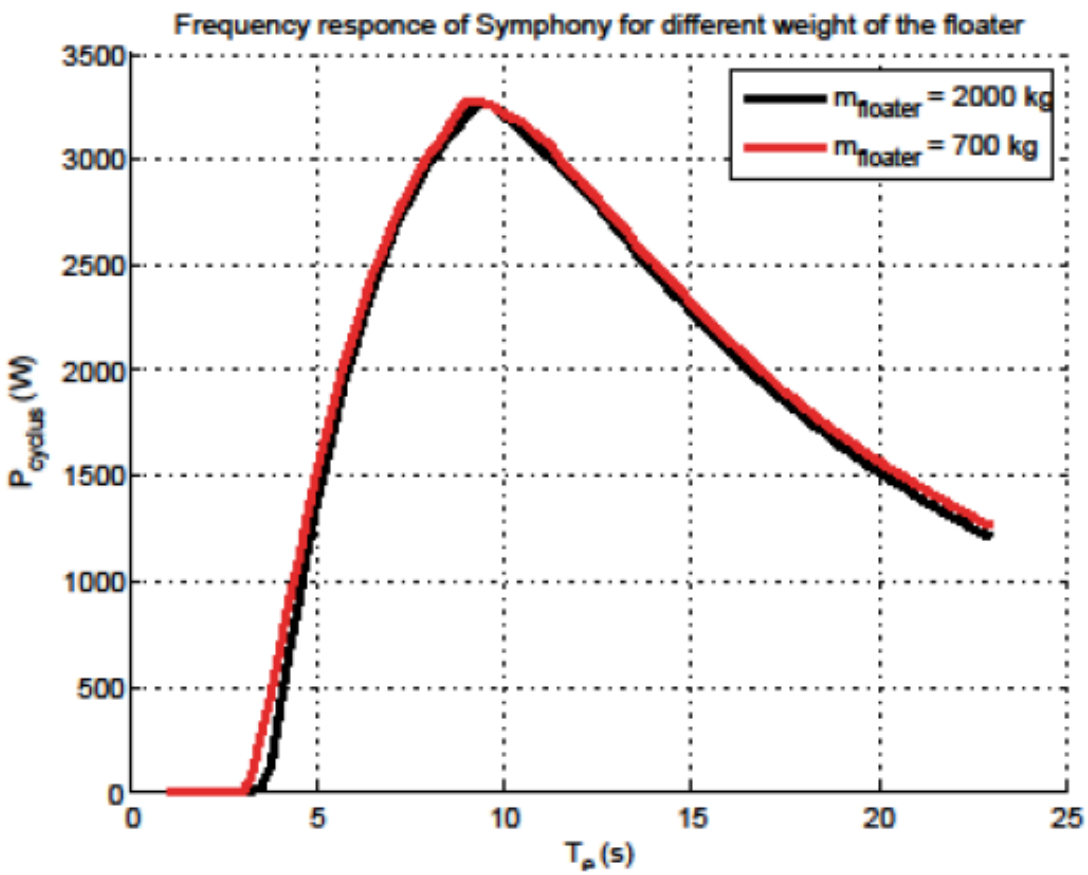
Figure 3.10: Resultant force and spring characteristics after tuning for the energy period

Difference in mass floater

The bodeplot is constructed for both floaters, resulting in the following bodeplot.

The system behaves as a wide banded resonator.
Partially this is because it is relative small to the waves.
Larger systems will have a different behavior

At a 0.2 m wave the system already moves over its full 2 m stroke



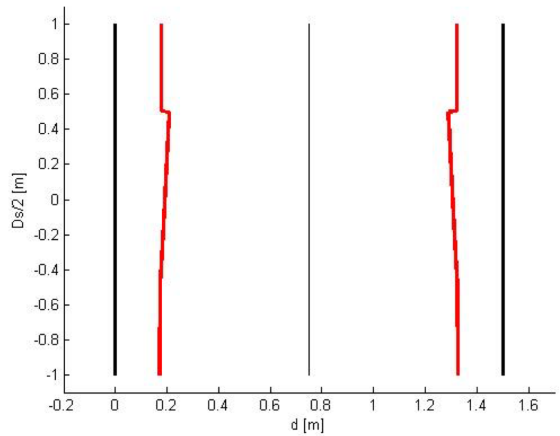
Figuur 3: bodeplot for different weights

Work done

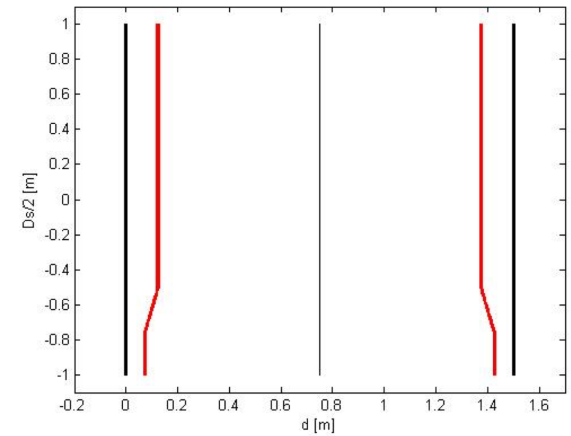
The work is not finished yet, but changing the shape at the end of the membrane has a huge effect for stopping the motion.

Situatie 2

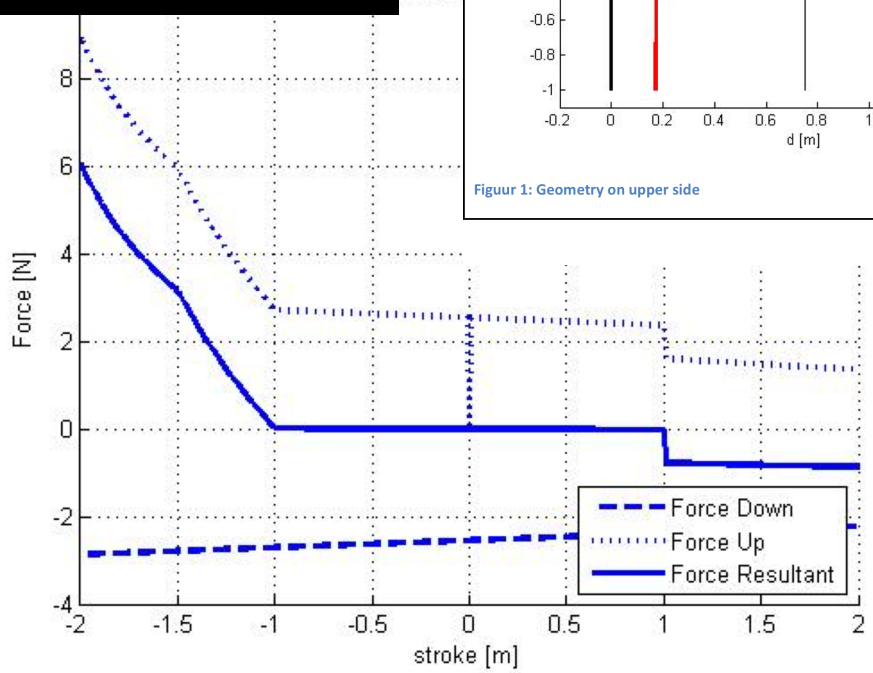
Maximale rem aan de bovenkant en geleidelijke vernauwing aan de onderkant.



Figuur 1: Geometry on upper side



Figuur 2: geometry on lower side



Simulation off the brakes

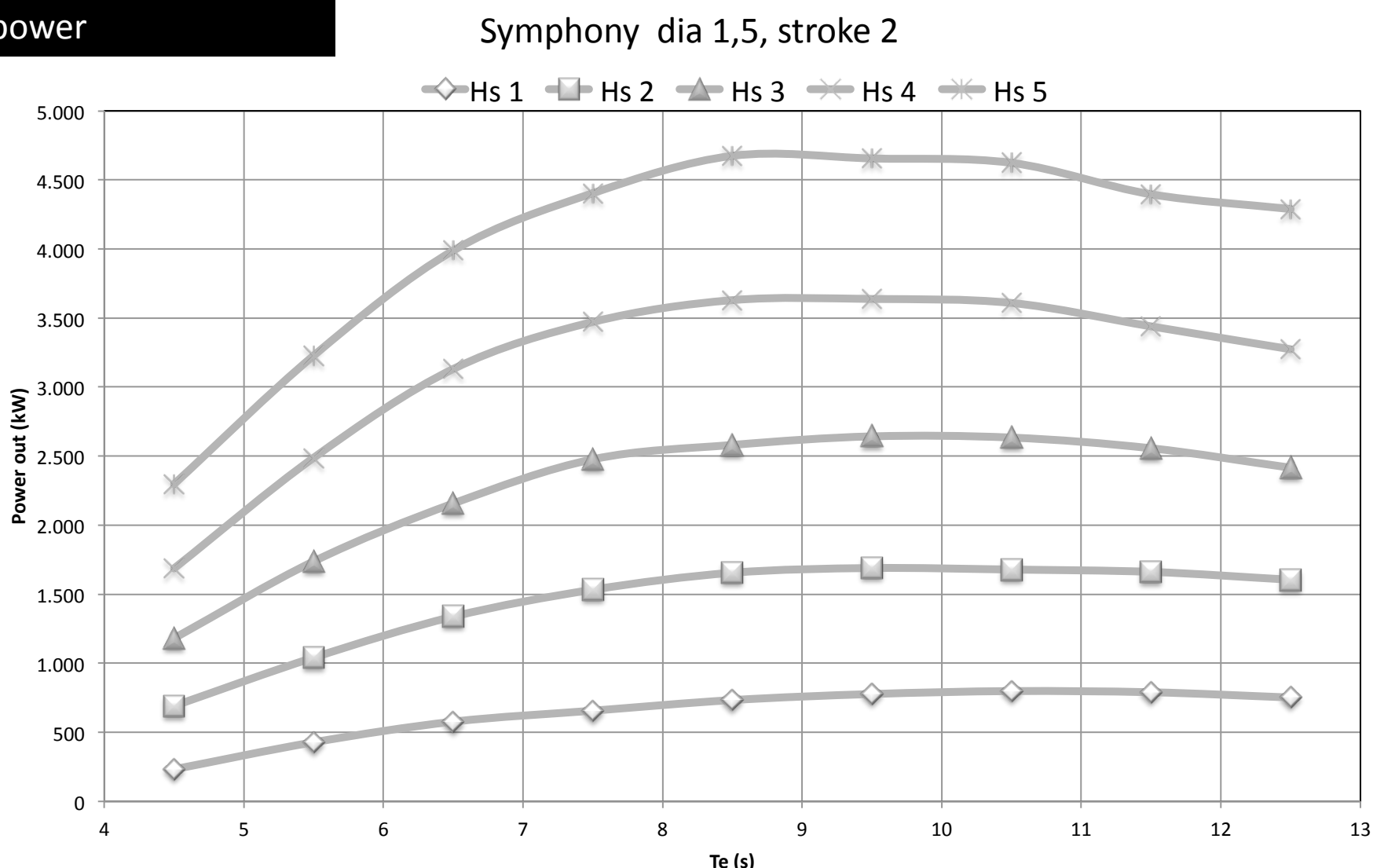
Results:

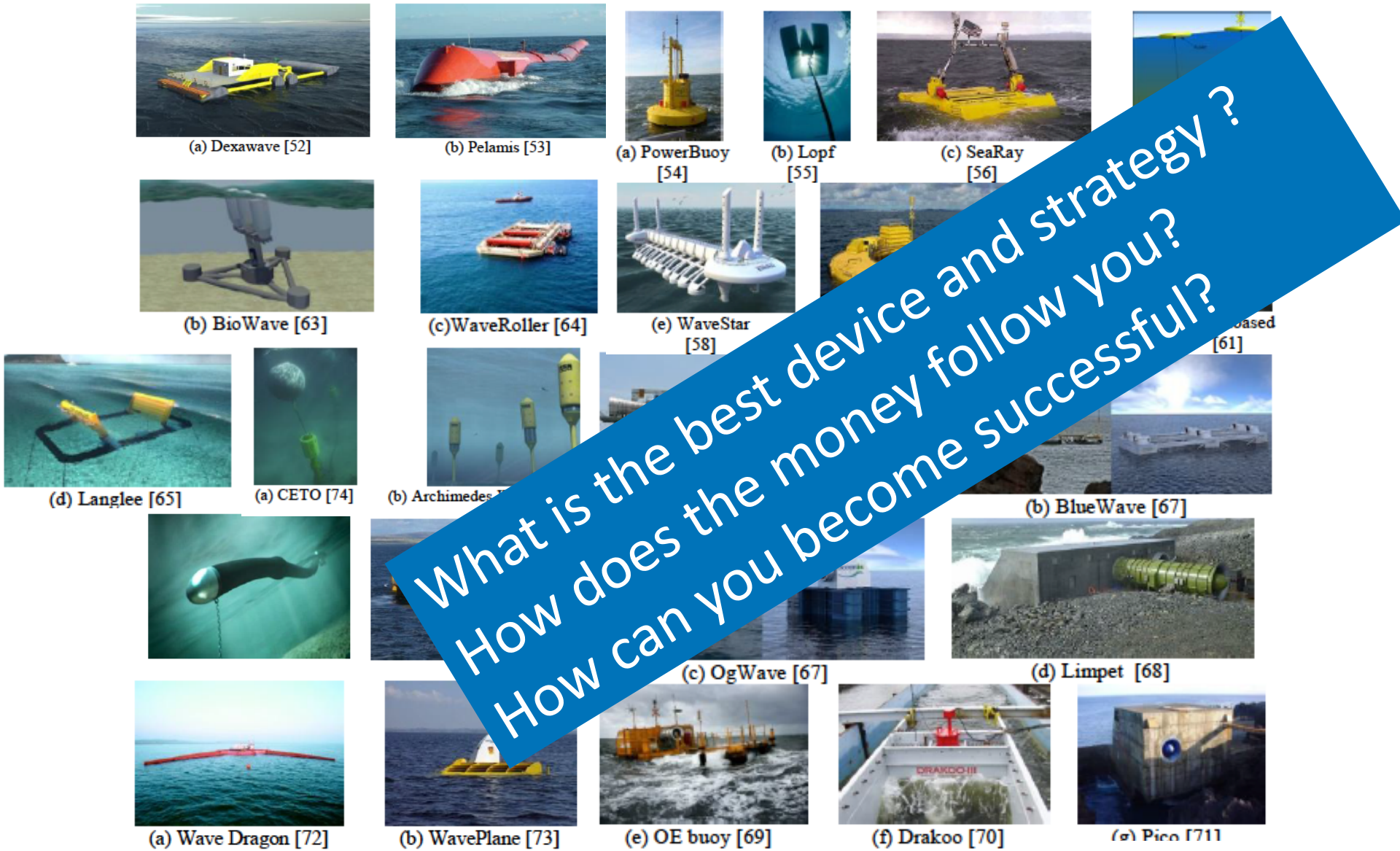
	Max distance in 3600s run with Hs 5 without PTO
Up	1.71 m
Down	- 1.47 m

Work done

Power diagram for the small device. Larger devices will go up to < 1 MW of power

POWER DIAGRAM





What is the best device and strategy ?
How does the money follow you?
How can you become successful?

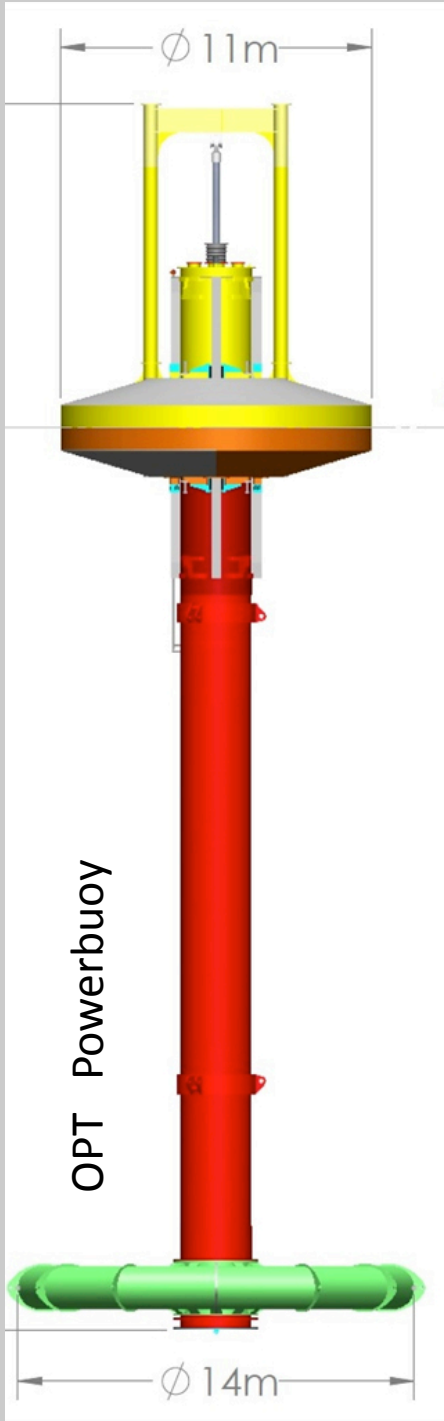
Recent Advances in the Development of Wave Energy Converters

Kaan Koca[#1], Andreas Kortenhaus[#2], Hocine Oumeraci[#3], Barbara Zanuttigh[*4], Elisa Angelelli[*5], Matteo Cantu[°6], Roberto Suffredini [°7], Giulia Franceschi [°8]

(a) Oyster 800 [62]

(e) SurgeWEC [66]

Technology performance versus TRL



OPT Powerbuoy

Metric	Defines	Directly associated with
TRL	how ready a technology is	commercial ability of the technology
TPL	how well a technology performs	economic ability of the technology

Table 1: Fundamental understanding and definition of TRL and TPL.

4th International Conference on Ocean Energy, 17 October, Dublin

WEC Technology Readiness and Performance Matrix – finding the best research technology development trajectory

J. Weber[1]

[1] Wavebob Ltd,
H3, Maynooth Business Campus,
Maynooth, Co. Kildare, Ireland,
E-mail: Jochem.Weber@Wavebob.com

https://www.dropbox.com/s/b64vpbju9tkucu6/TLP_TRL%20paper.%20.pdf?dl=0

Pelamis OPD

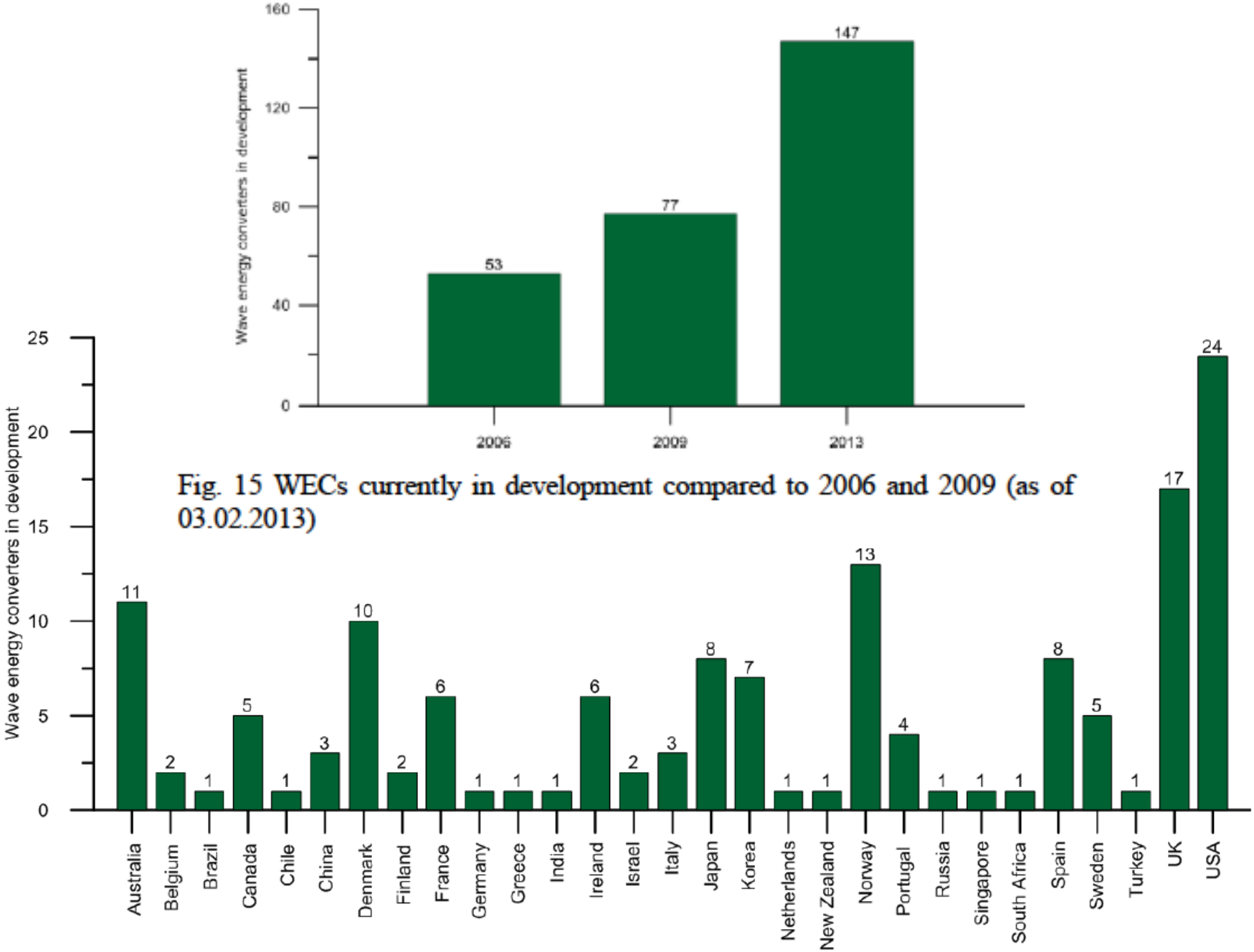
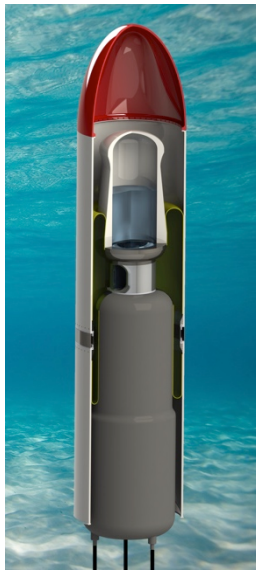


Fig. 15 WECs currently in development compared to 2006 and 2009 (as of 03.02.2013)



Symphony wave power

TRL levels

2010

Increased costs, better design understanding

Image	Stage	TRL	State of the development	Stage Gates
	Stage 1: Proof of concept Scale guide: 1:25 – 100 (Small)	1	Confirmation of operation	Performance review / Technical analysis; Return; Exit; Go
		2	Performance	
		3	Device Optimization	
	Stage 2: Validation and design model Scale guide: 1:10 – 25 (Medium)	4	Sub-system assessment	Performance review / Design analysis; Return; Go
	Stage 3: Process model Scale guide: 1:2 – 5 (Large)	5	Sub-assembly bench tests	Performance review / Components analysis; Return; Exit; Go
		6	Full-scale prototype in sea	
	Stage 4: Prototype model Scale guide: 1:1 – 2 (Prototype)	7	Solo, sheltered, grid emulator	Performance review / Operations analysis; Return; Go
		8	Solo, exposed grid	
	Stage 5: Demonstration Scale guide: 1:1 (Full)	9	Multi-device array	Performance review / Economic analysis; Return; Commercial Readiness

Recent Advances in the Development of Wave Energy Converters

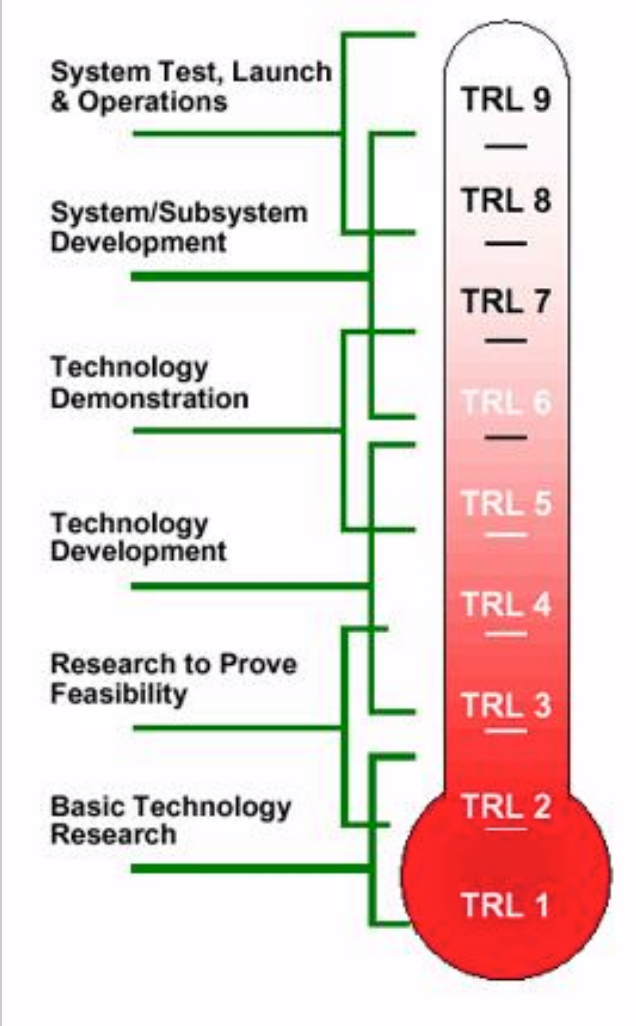
Kaan Koca[#1], Andreas Kortenhaus[#2], Hocine Oumeraci[#3], Barbara Zanuttigh[*4], Elisa Angelelli[*5], Matteo Cantu[°6], Roberto Suffredini [°7], Giulia Franceschi [°8]

AWS has been a huge learning experience from this the new concept is derived, that will have to prove itself

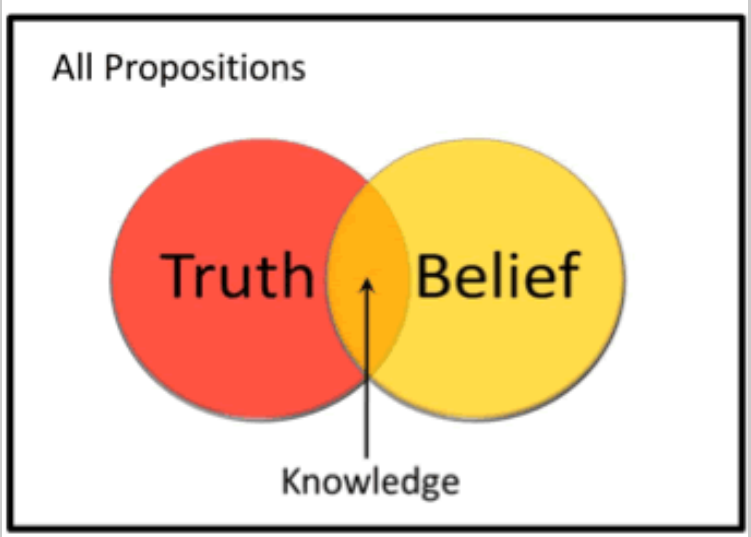
What we cannot see, does not exist.

Technology readiness levels, and risk decrease

NASA - ESA



perception



Technical Performance Levels

TPL	Category		TPL Characteristics
	L	Characteristics	
9	high	Technology is economically viable and competitive as a renewable energy form	Competitive with other energy sources without special support mechanism
8			Competitive with other energy sources given sustainable support mechanism
7			Competitive with other renewable energy sources given favourable support mechanism
6	medium	Technology features some characteristics for potential economic viability under distinctive market and operational conditions. Technological or conceptual improvements may be required.	Majority of key performance characteristics & cost drivers satisfy potential economical viability under distinctive and favourable market and operational conditions
5			In order to achieve economical viability under distinctive and favourable market and operational conditions some key technology implementation improvements are required.
4			In order to achieve economical viability under distinctive and favourable market and operational conditions some key technology implementation and fundamental conceptual improvements are required.
3	low	Technology is not economically viable	Minority of key performance characteristics & cost drivers do not satisfy potential economic viability
2			Some of key performance characteristics & cost drivers do not satisfy potential economic viability
1			Majority of key performance characteristics & cost drivers do not satisfy and present a barrier to potential economic viability

Idealistic.

Reconsider the value of TRL

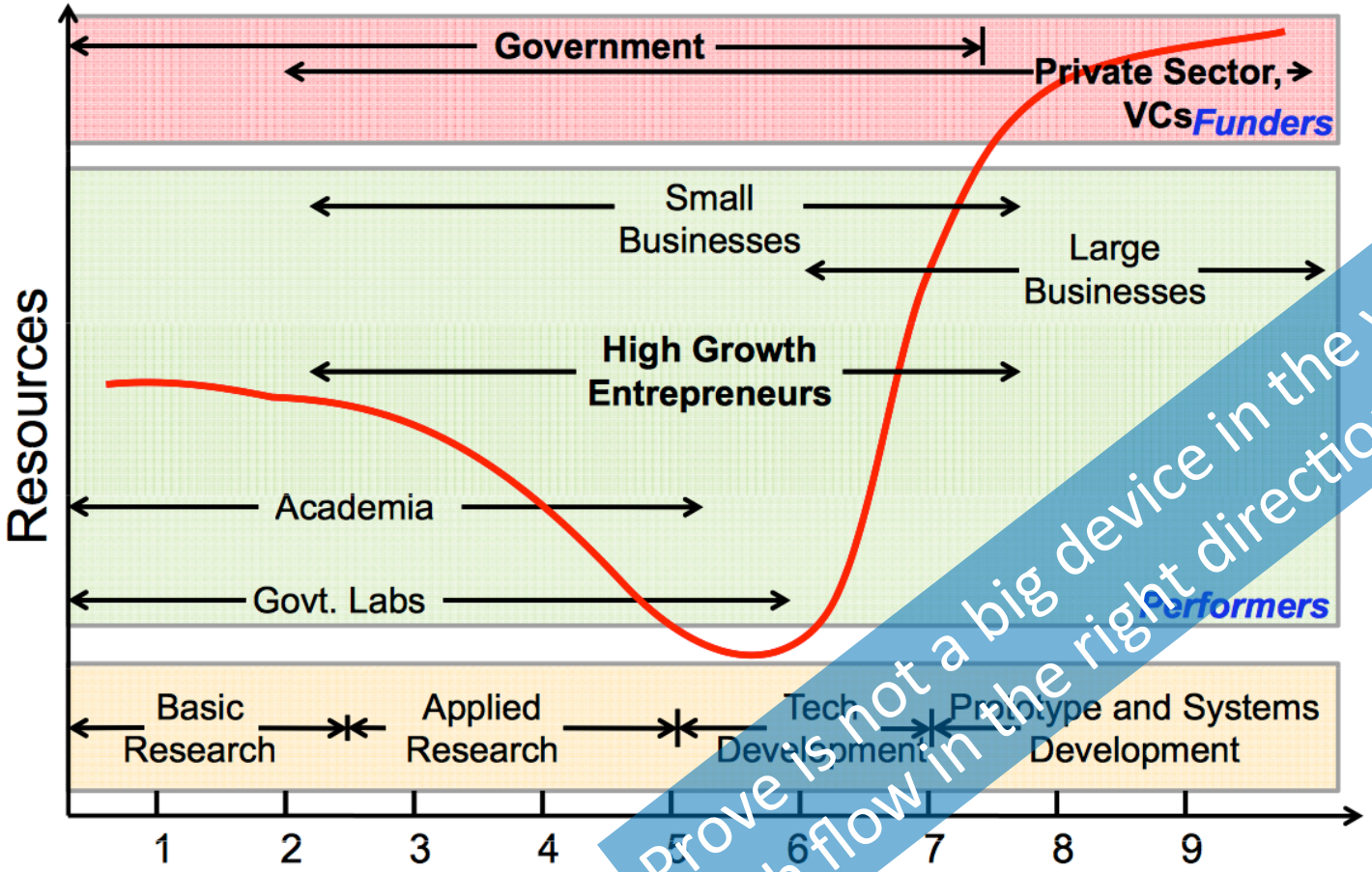
Technology readiness levels

introduce TPL

Technology performance levels

full scale doesn't mean it is economic viable.
.....and you do not want to be there if it is not

Reconsider the financing mechanism for new capital intensive technologies, like marine energy.

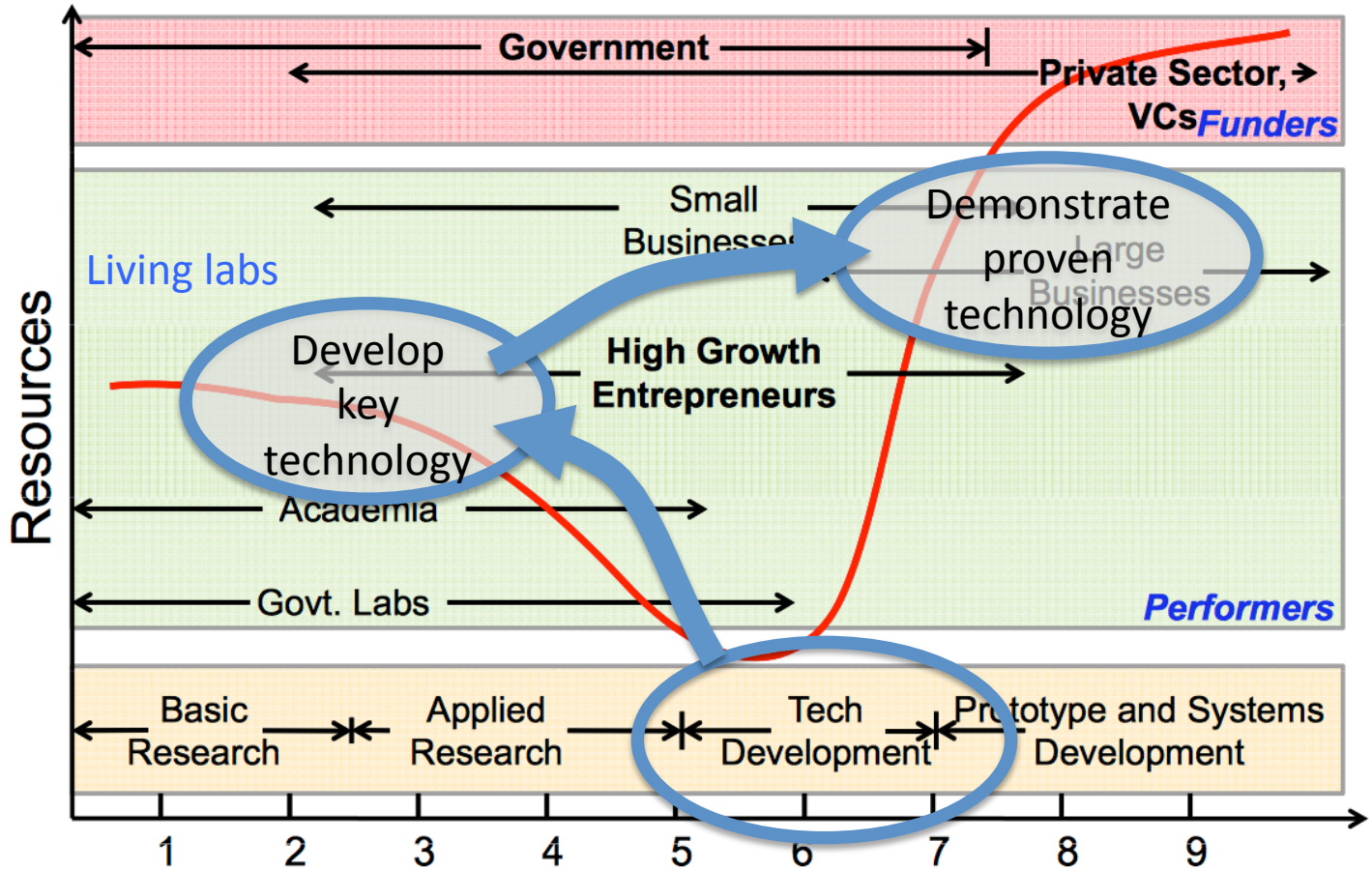


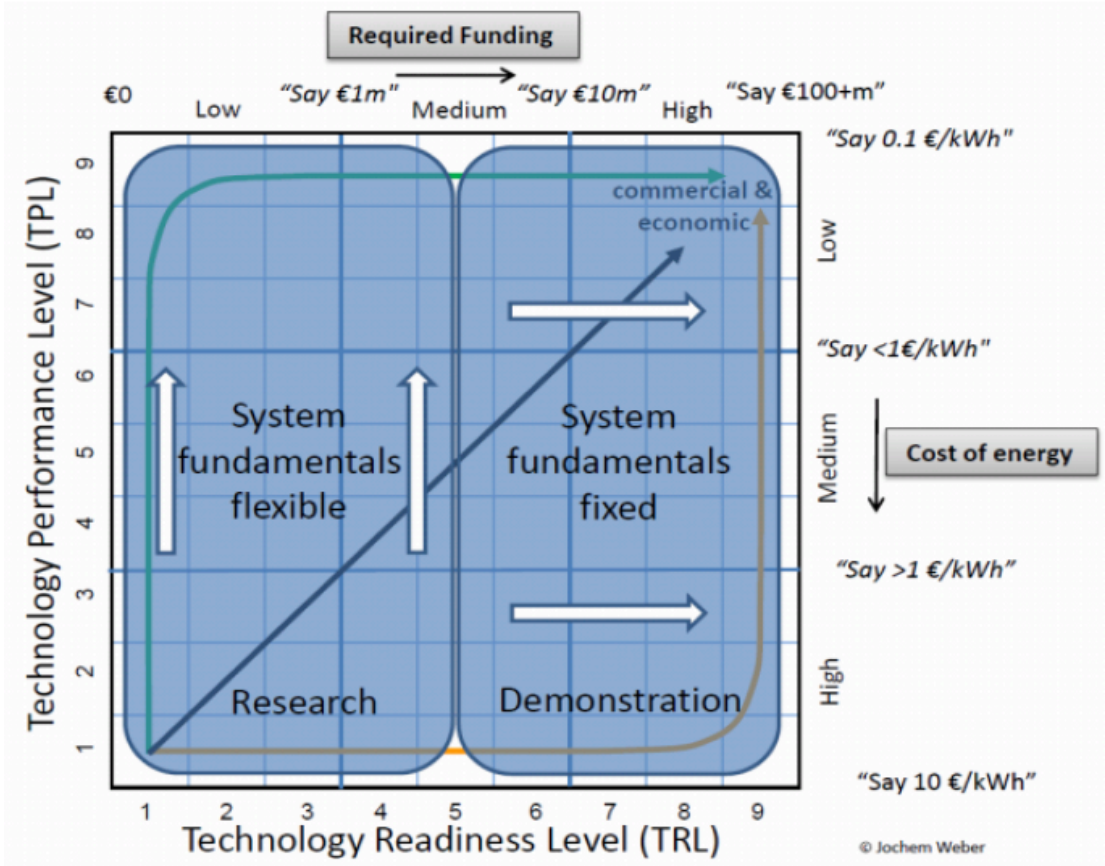
Prove is not a big device in the water. It is a cash flow in the right direction

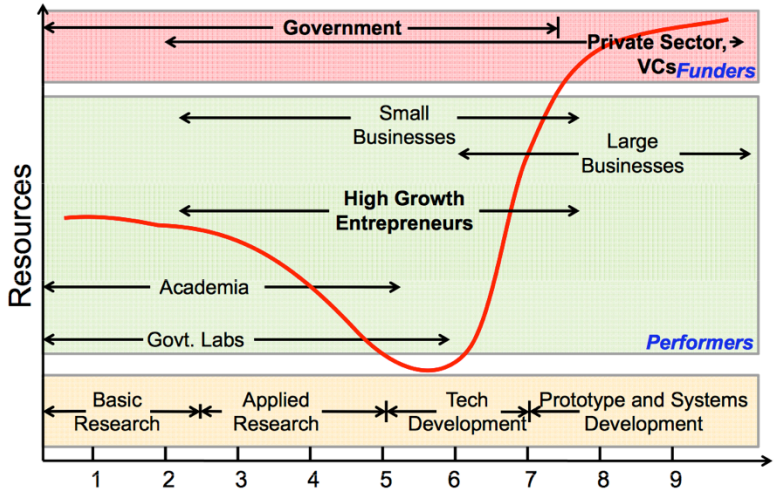
Strategy to bridge the funding gap;

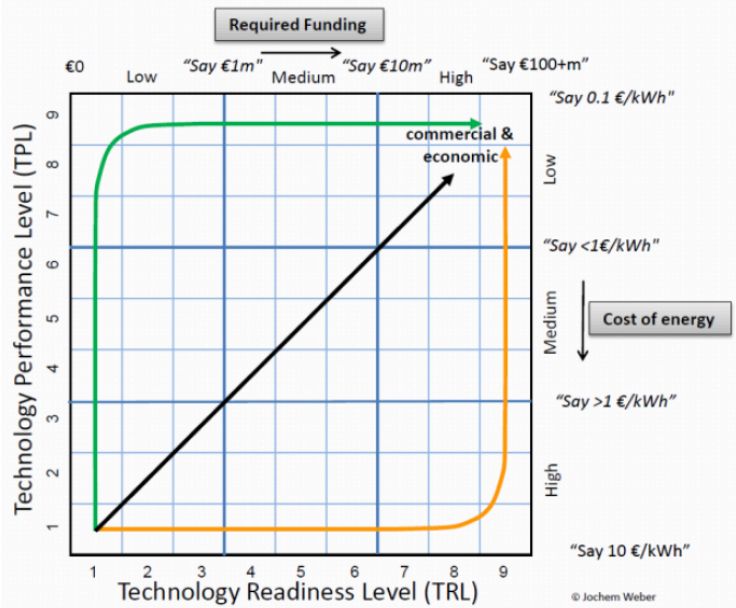
R&D funding, by developing key technology @ early stage & small scale demonstration.

Only demonstrate large system once spall system is extensively tested

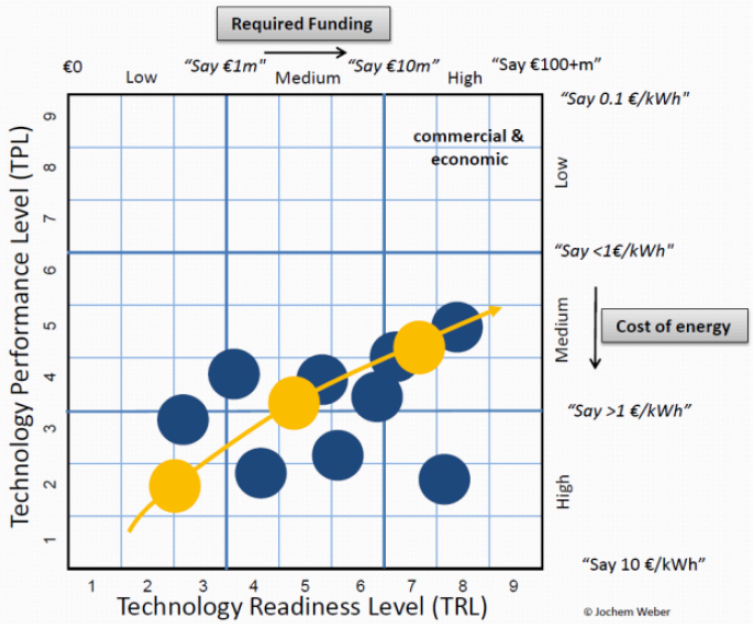



Required Funding
€0
Low
"Say €1m"
Medium
"Say €10m"
High
"Say €100+m"
"Say 0.1 €/kWh"
commercial &
economic
Low
"Say <1€/kWh"
System
fundamentals
flexible
System
fundamentals
fixed
Medium
Cost of energy
"Say >1 €/kWh"
Research
Demonstration
High
"Say 10 €/kWh"
Technology Performance Level (TPL)
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9
Technology Readiness Level (TRL)
© Jochem Weber

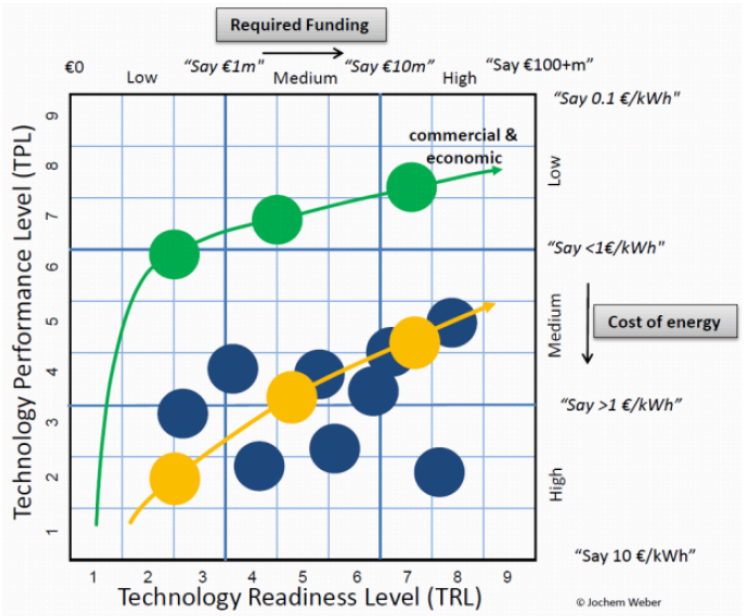

Government
Private Sector,
VCs
Funders
Small
Businesses
Large
Businesses
High Growth
Entrepreneurs
Academia
Govt. Labs
Performers
Resources
Basic
Research
Applied
Research
Tech
Development
Prototype and Systems
Development
1 2 3 4 5 6 7 8 9



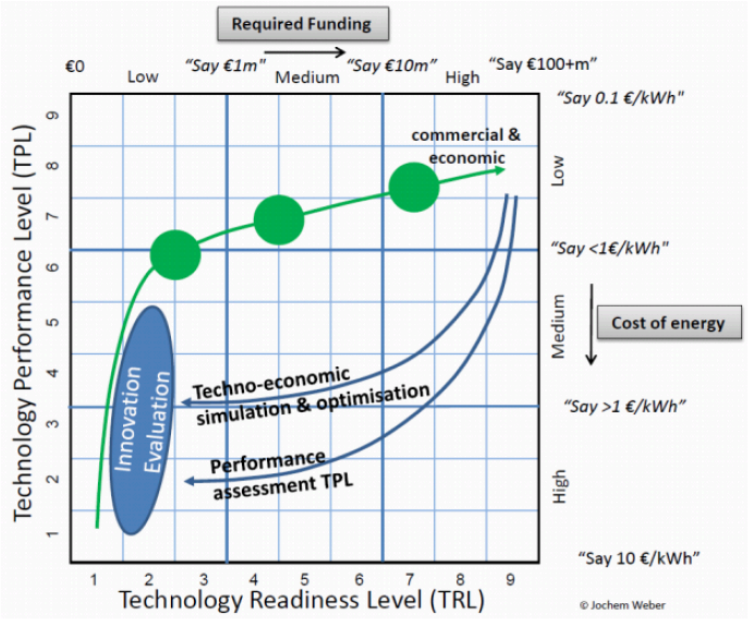
The choice is yours !!!



practice

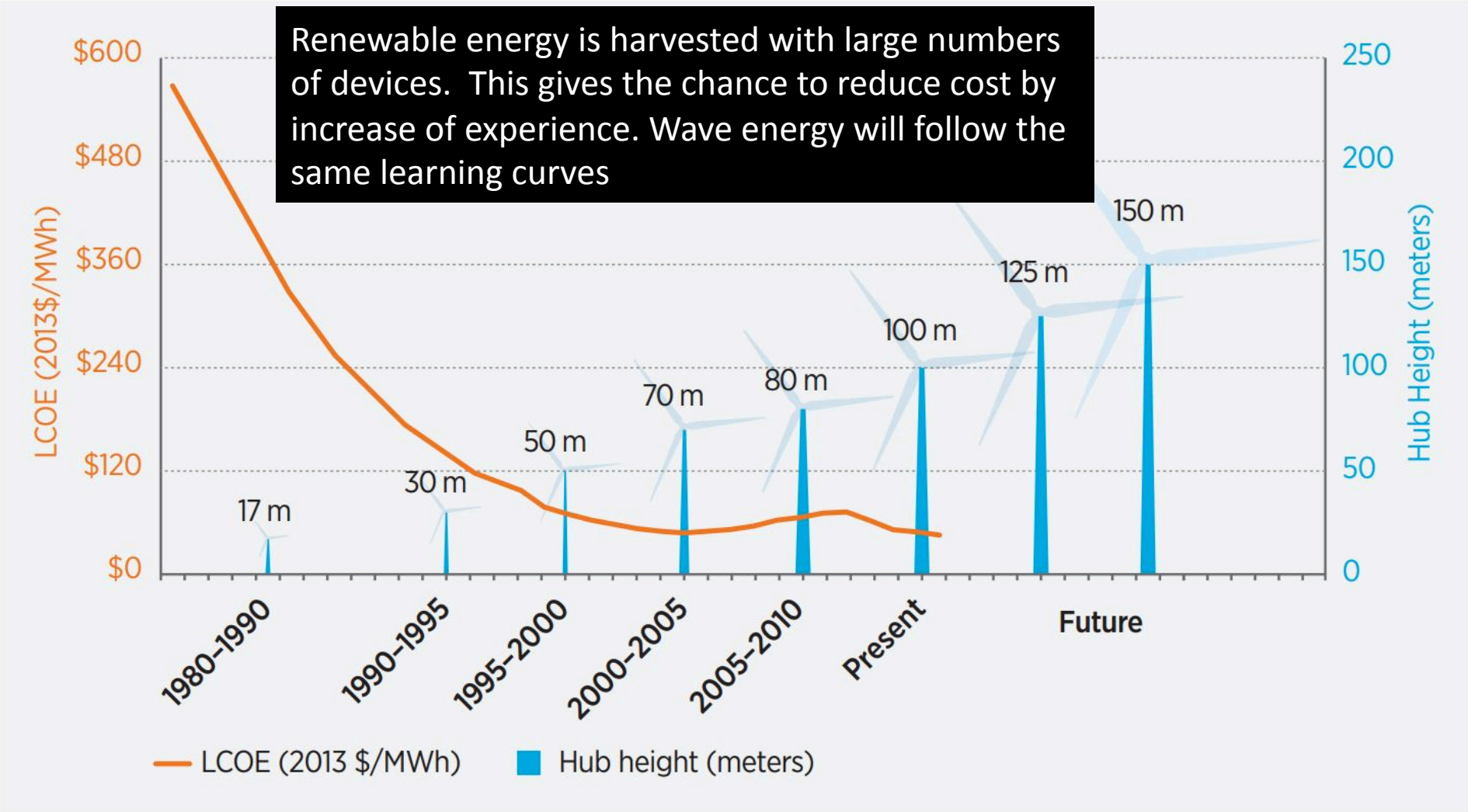


Improving by early stage technology development



Including (general) experience

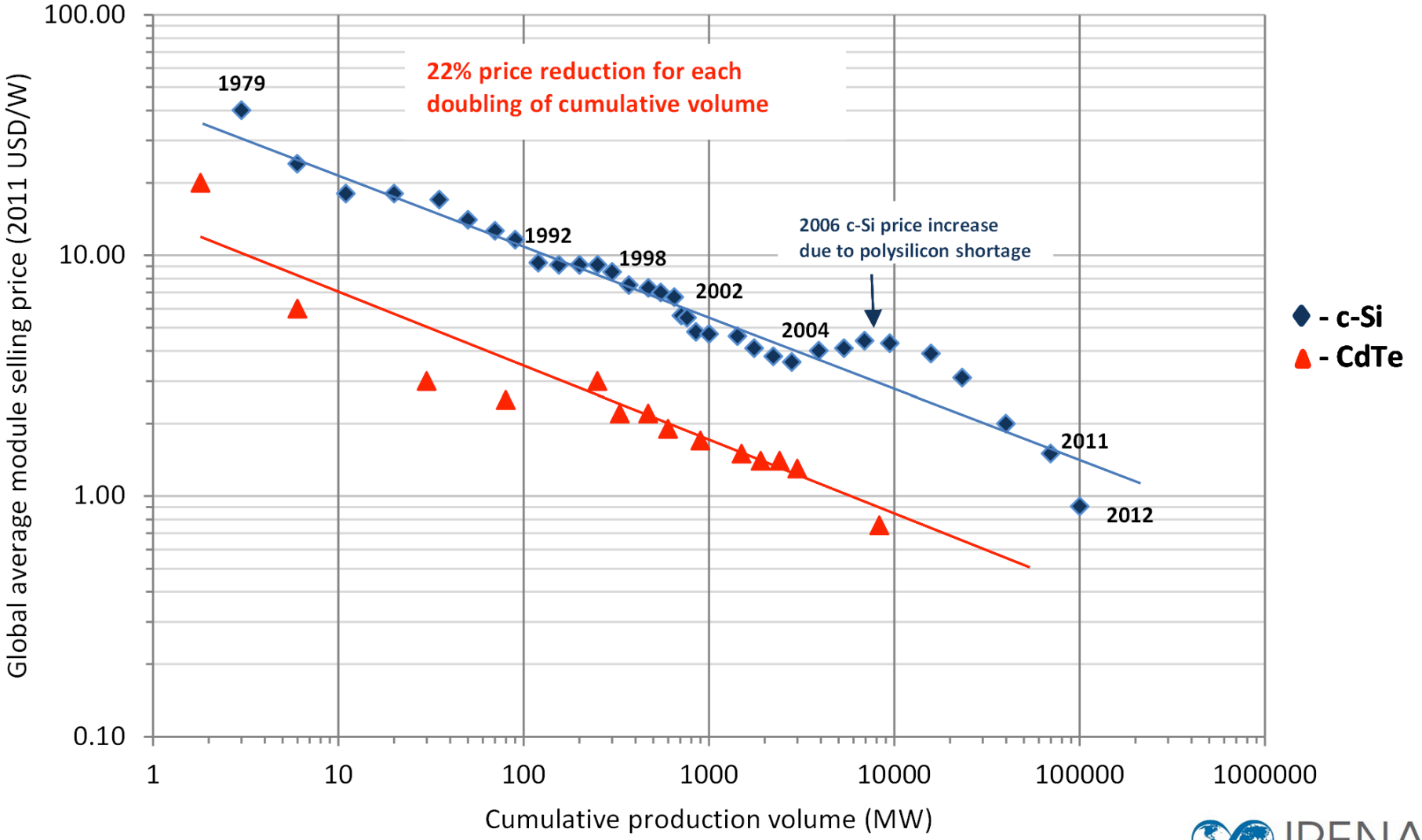
Scale-up of wind technology has supported cost reductions.



Note: LCOE is estimated in good to excellent wind resource sites (typically those with average wind speeds of 7.5 m/s or higher), excluding the federal production tax credit. Hub heights reflect typical turbine model size for the time period.

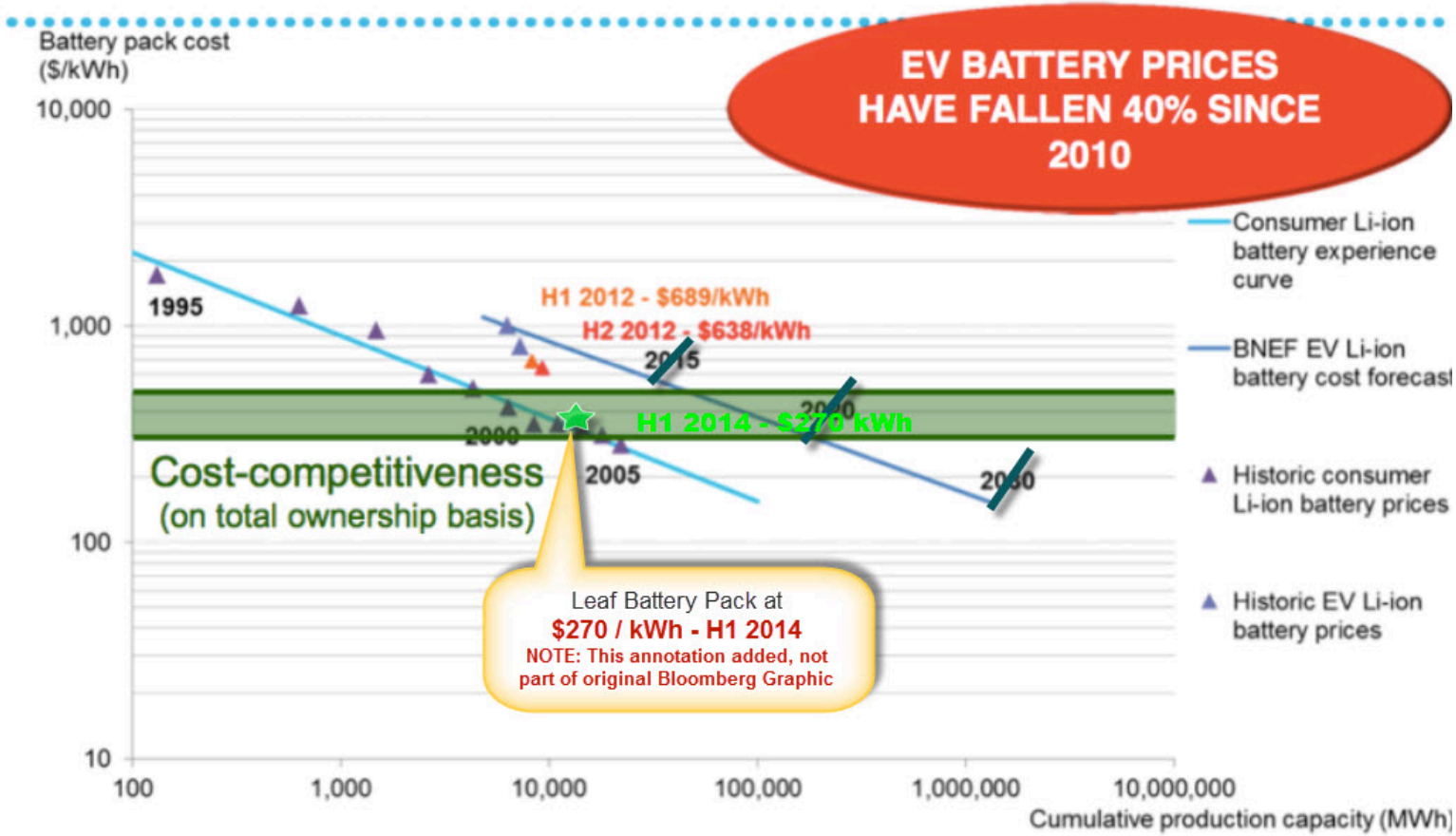
Figure ES.2-5. Wind technology scale-up trends and the levelized cost of electricity

22% learning curve solar panels

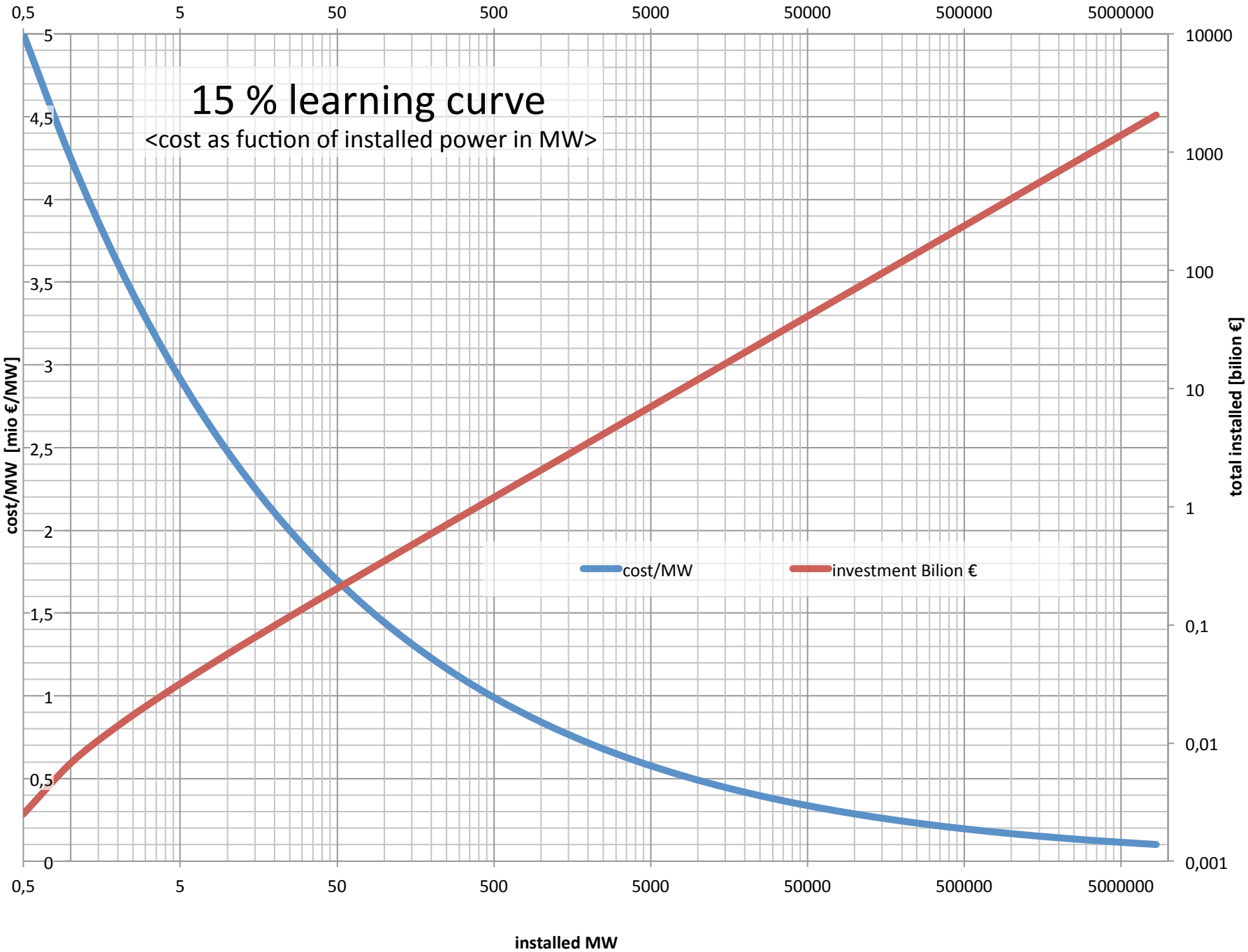


IRENA
International Renewable Energy Agency

LITHIUM-ION BATTERY EXPERIENCE CURVE



Source: Battery University, MIIT, IIT, Bloomberg New Energy Finance


15 % learning curve
<cost as fuction of installed power in MW>
cost/MW [mio €/MW]
total installed [bilion €]
installed MW
cost/MW
investment Bilion €
0,5
5
50
500
5000
50000
500000
5000000
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
0,001
0,01
0,1
1
10
100
1000
10000

Support programs, how to participate ?

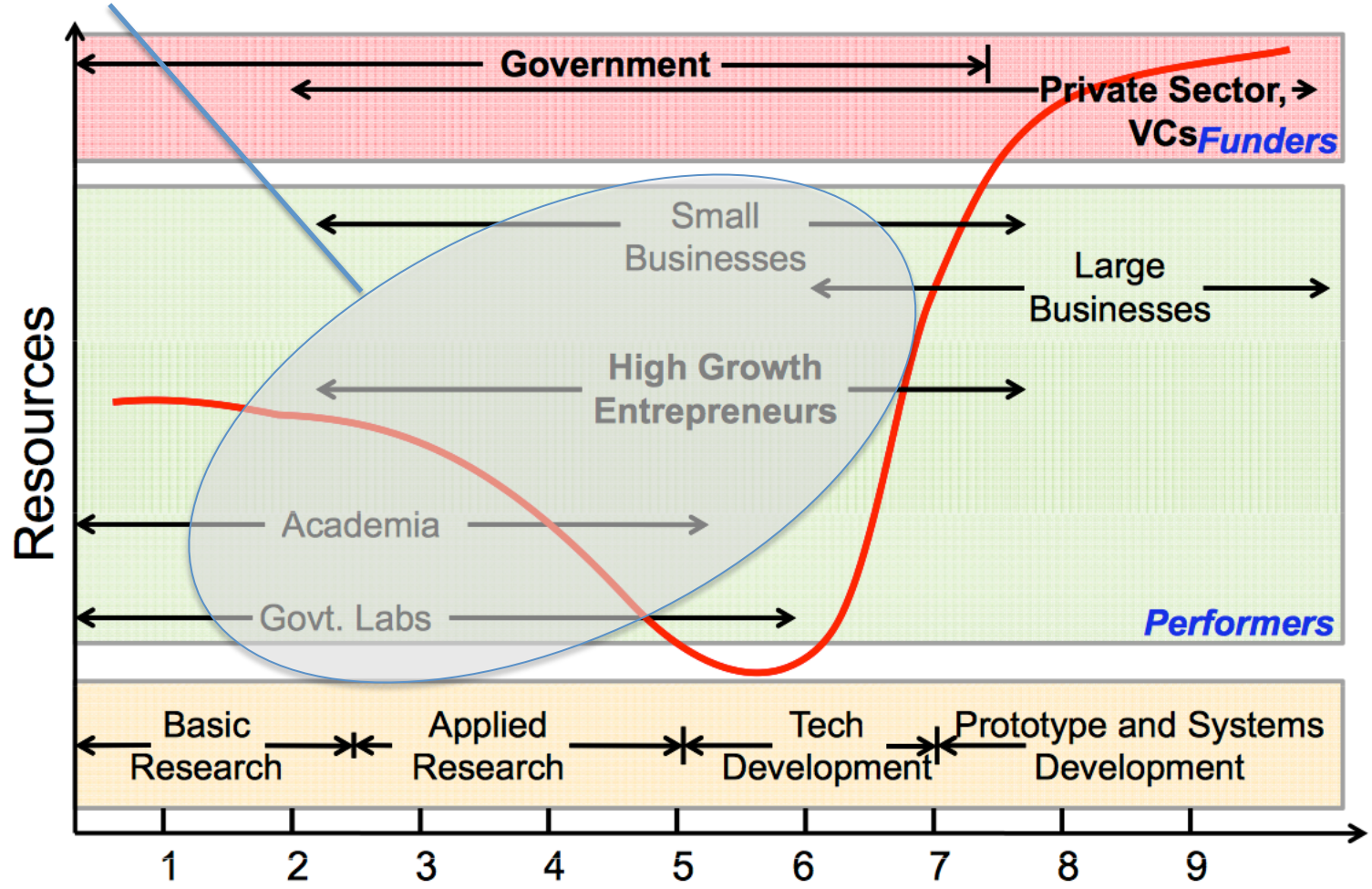
Only cooperation within the triple helix will make the development possible

- Build small.
- Test components, systems and array's.
  - Several years
  - Scale up with CO2 support mechanism.
- Low cost Lean organization with support off
  - Universities and Universities for applied science
    - Phd.
    - Thesis
    - Research programs
  - Institutes (ECN)
    - Implementation.
    - Financers support
  - Branch organization.
    - Oil and gas.
    - Shipbuilding.
    - OEM

Public
Private
Partnerships

How to participate?

Join forces



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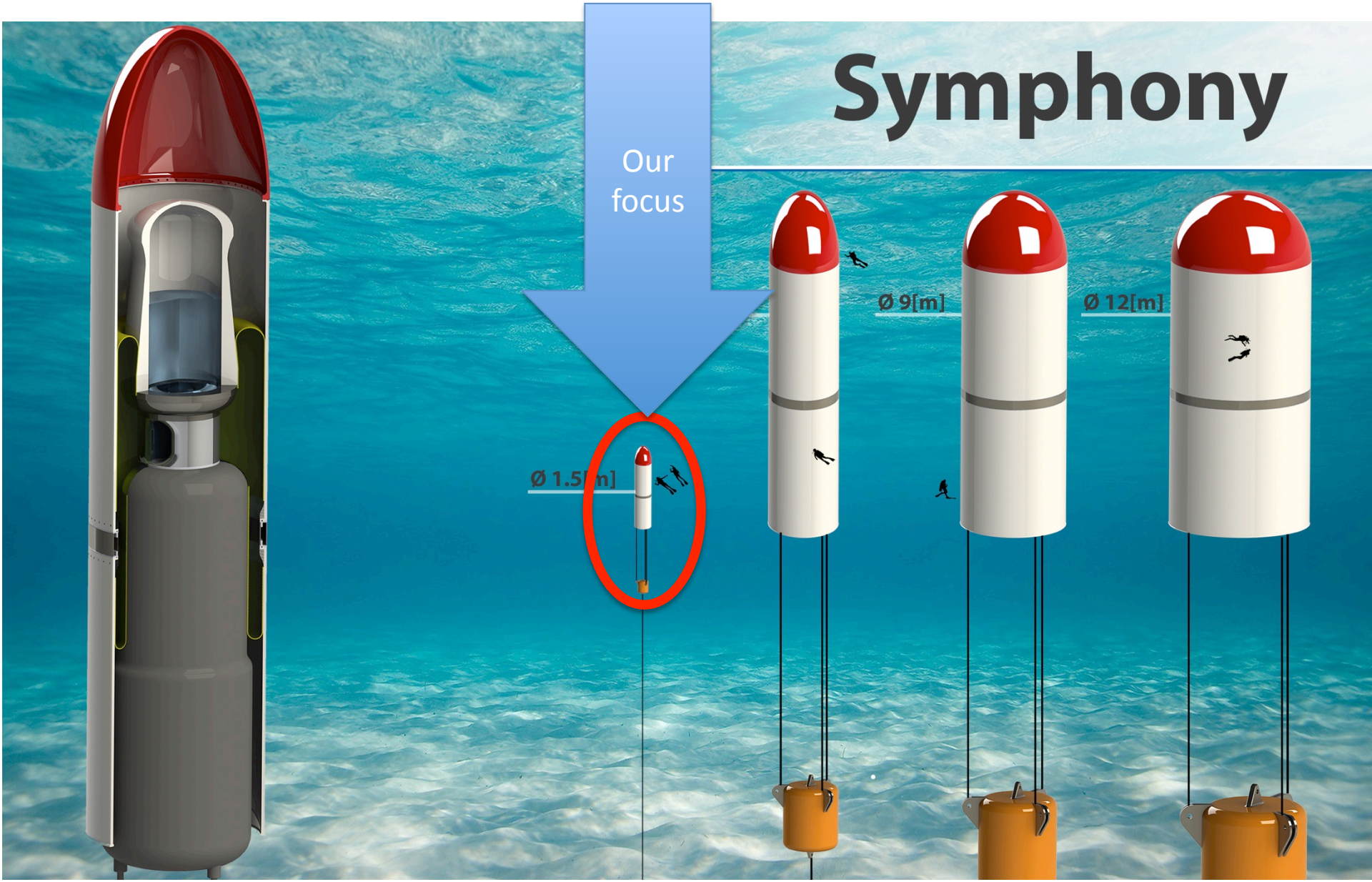

Future work

- Design and build (2016)
  - Membrane
  - Turbine
  - Control cocoon.
- Design and build and test anchoring
  - Scale model at Edinburgh university.
- Design build and test prototype (1,5m – 40kW)
  - @ Sinus harbor Portugal and/or Netherlands??
- Research on PTO for up scaling.
- Research on array and grid control.
- Development of niche applications.
- Time domain model validation.

Contact.

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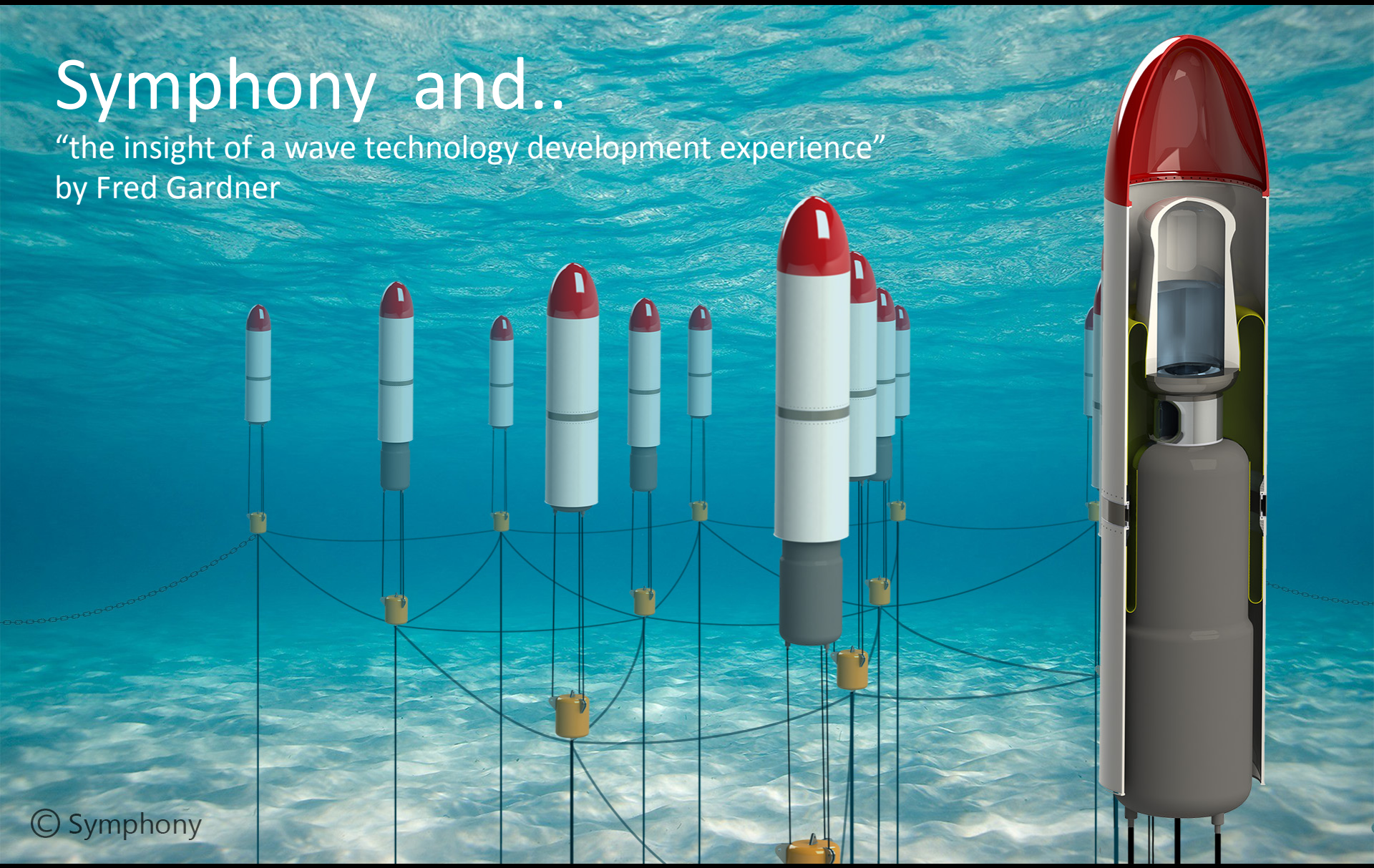
- Teamwork.nl

- or Henk Pollinder @ TU – Delft.

Symphony and..

"the insight of a wave technology development experience"

by Fred Gardner



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