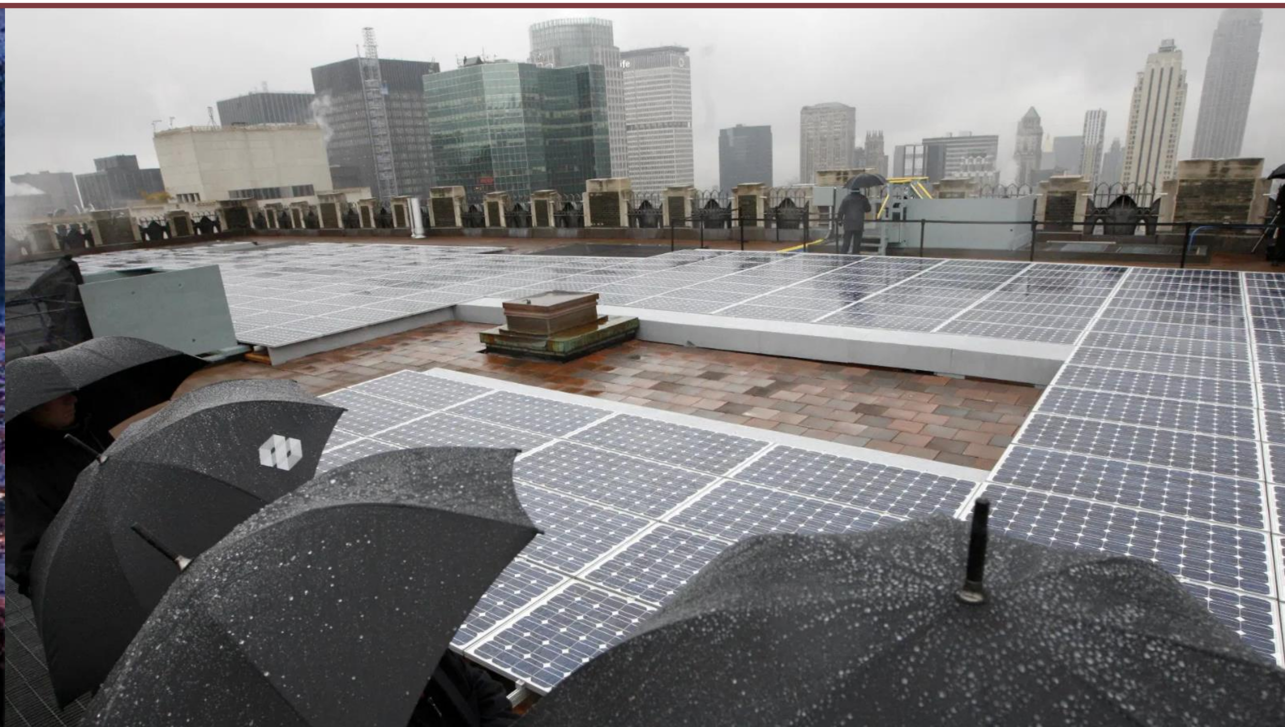
EnergyBank

Our Mission

Catalyse grid decarbonization with a disruptive energy storage technology.



EnergyBank Team

Tim Hawkey: CEO: Mech Eng., entrepreneurship, energy, automation & manufacturing background. EHF Fellow.

Dr Rhys Foster: Electrical and Software Lead: Storage technology and energy markets veteran. (Grid connected Li-ion pioneer – 2010 onwards)

Jordan Hooper: Fabrication Lead: Offshore oil and gas construction.

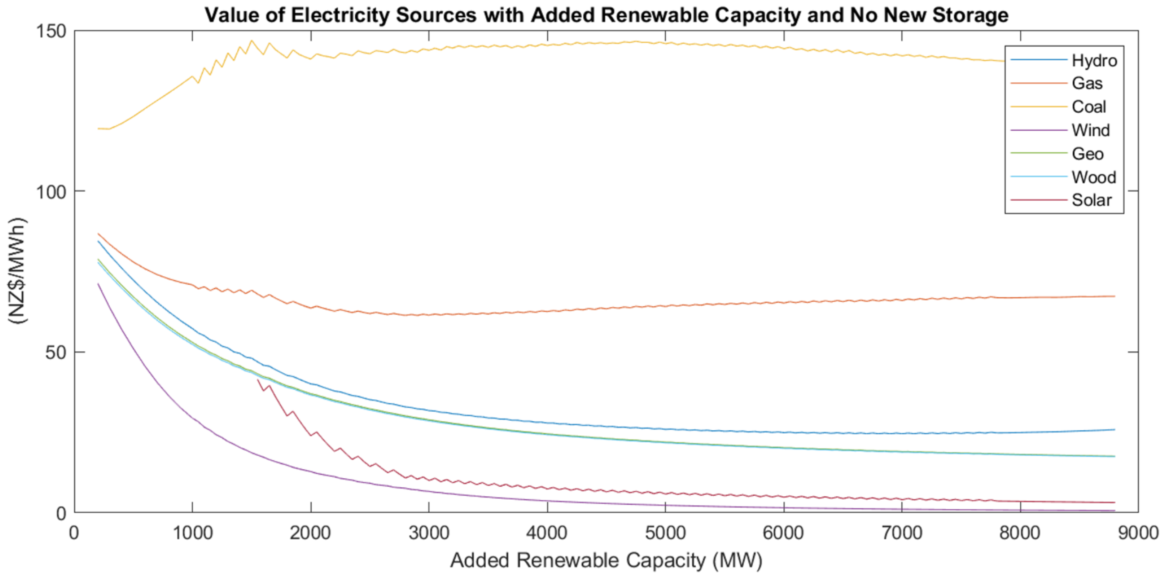
Problem

Fossil Energy:

- Contributes ~59% greenhouse effect.
- Currently fundamental to prosperity.

Renewables Uneconomic At Scale:

- Limitations with timing supply.
- Creating volatile markets, collapsing renewable prices.



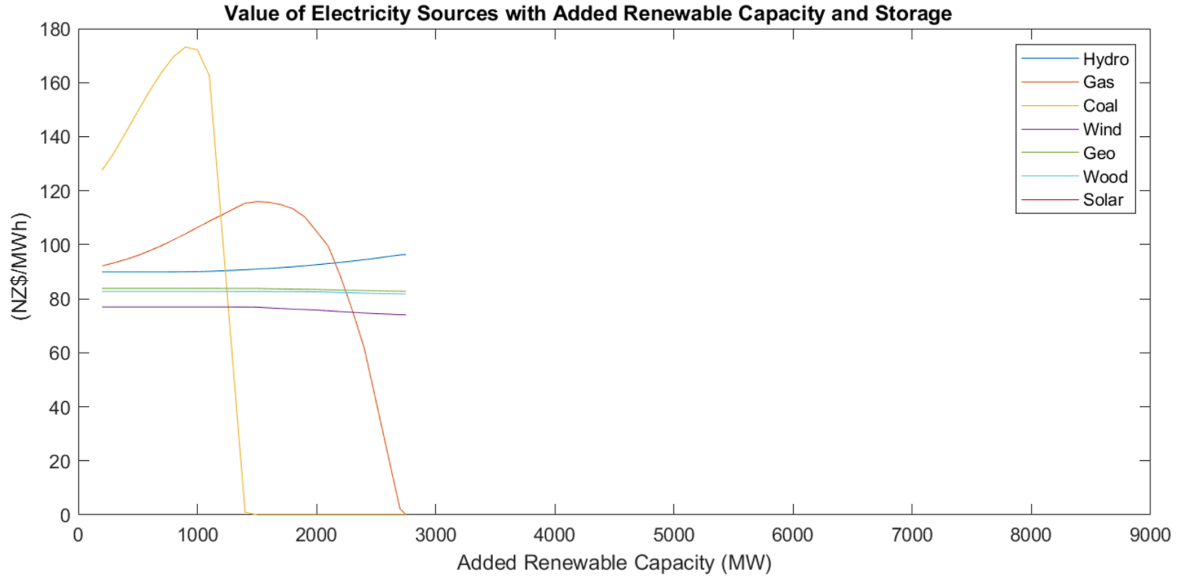
Solution

EnergyBank Will:

- Provide energy storage as a service.
- At significantly larger scale and lower cost than currently available.

This enables temporal arbitrage:

- Shifting of renewable energy so that timing of supply is controlled.
- Increasing demand for renewable electricity while undercutting fossil fuels.

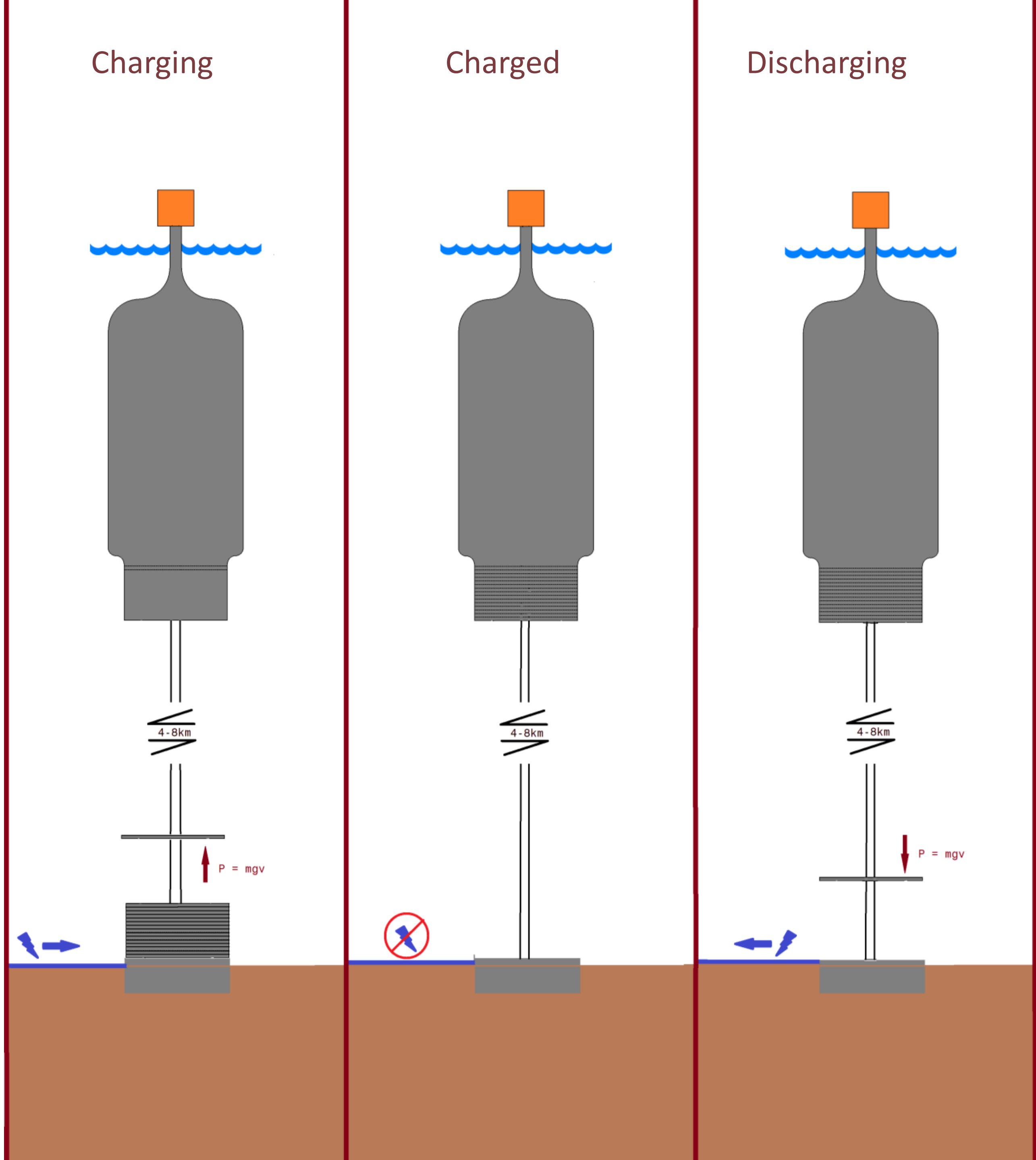


Technology

Deep ocean gravitational energy storage:

$$\Delta E_p = \sum m\, g \Delta h$$

- Mass produced floating units ($16-80m/ea)
- Each storing 1-10GWh/unit @ $7-14/kWh
- Due to the impact of very deep water (>4km), large Δh allows EnergyBank system to be <1/10th the cost of competitors

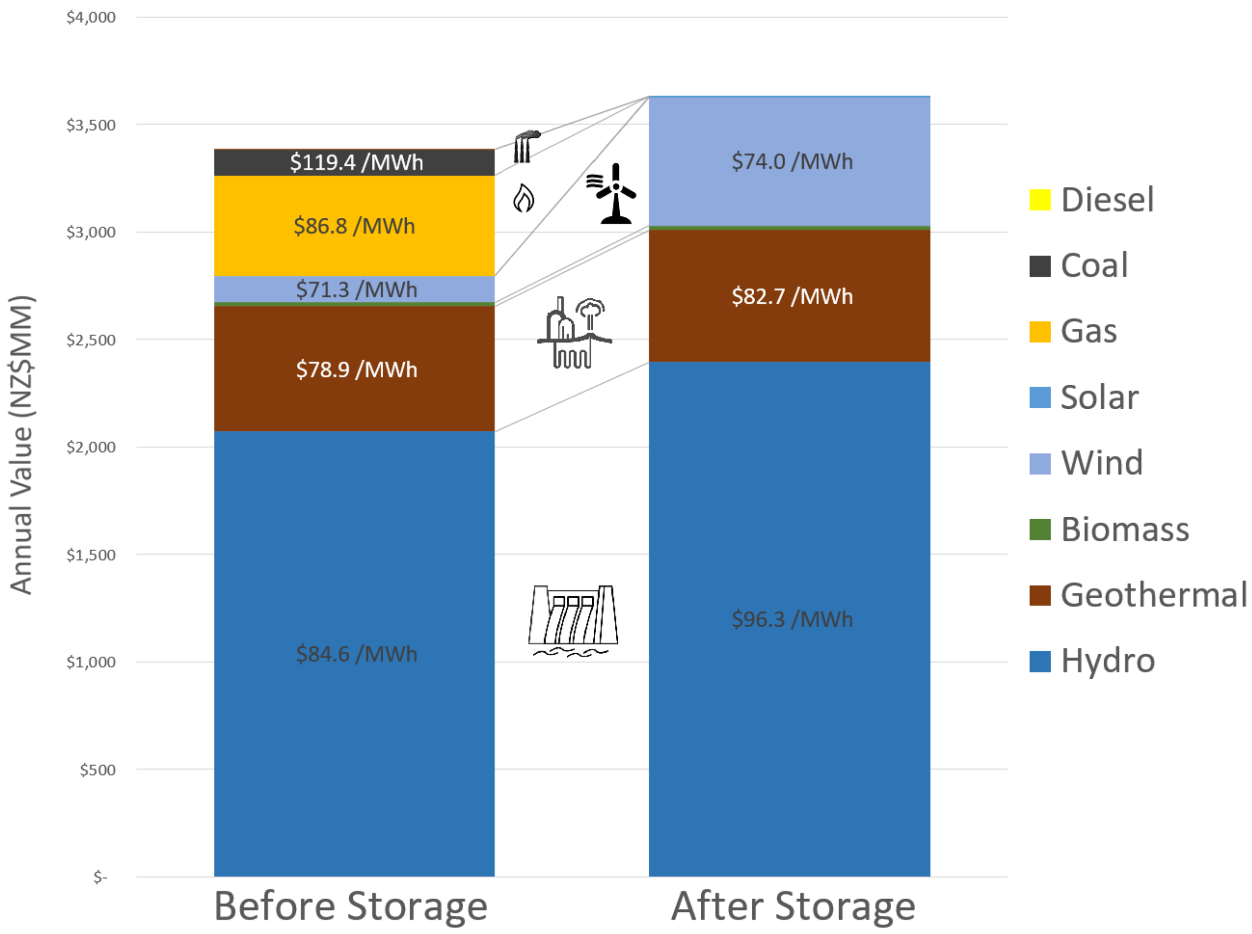


Value Proposition

EnergyBank plant in NZ market:

- Temporal arbitrage (~$40M/yr).
- Increases in value of renewable generation (~$208M/yr).
- >80% reduction in electricity related CO_2 emissions.
- LOI's for simple capacity lease provides visibility to $225M/y value capture in NZ. (Appendix A)

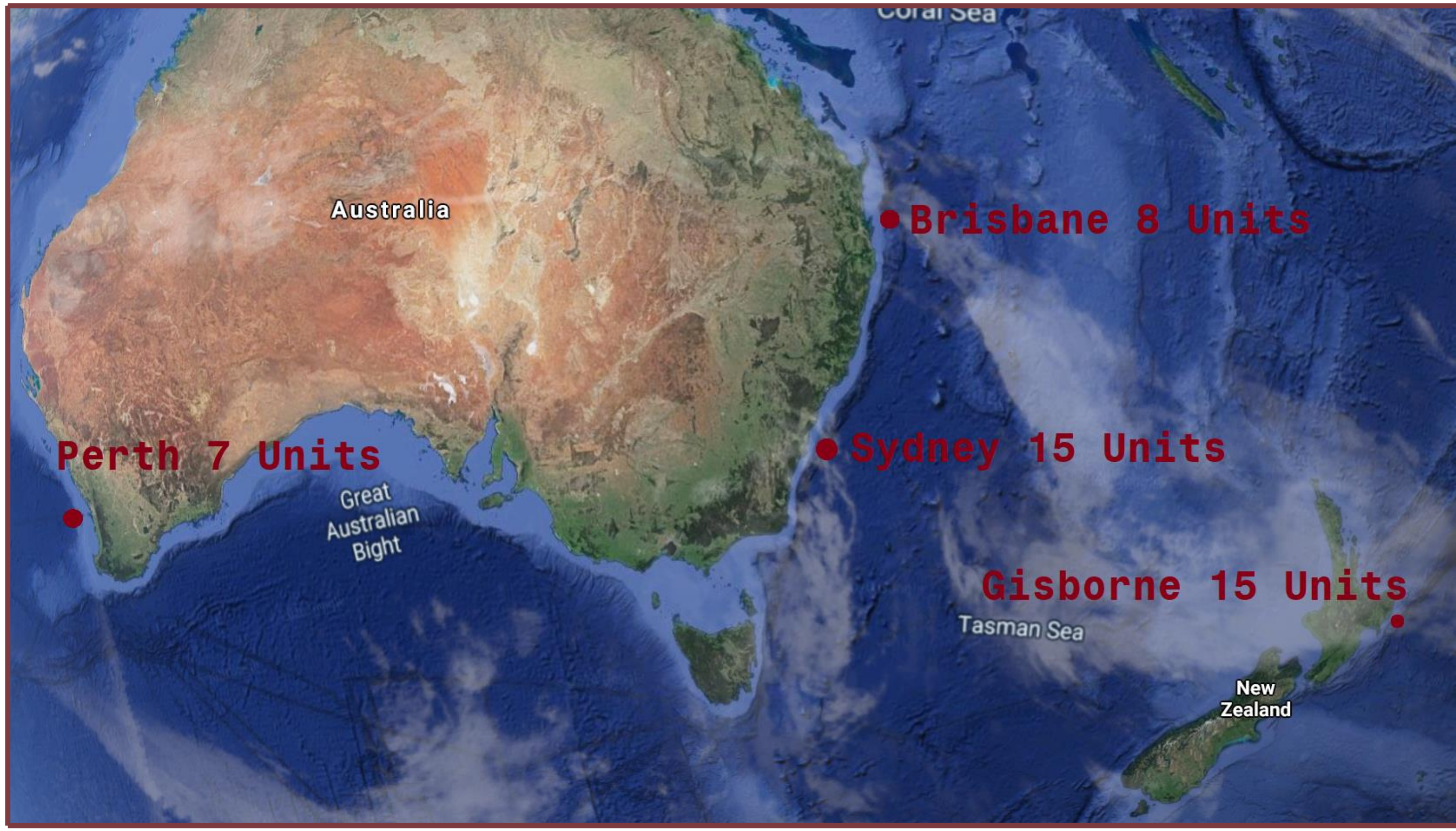
NZ Electricity System
Value Stack Before and After Storage



Market

Target Market 2030:

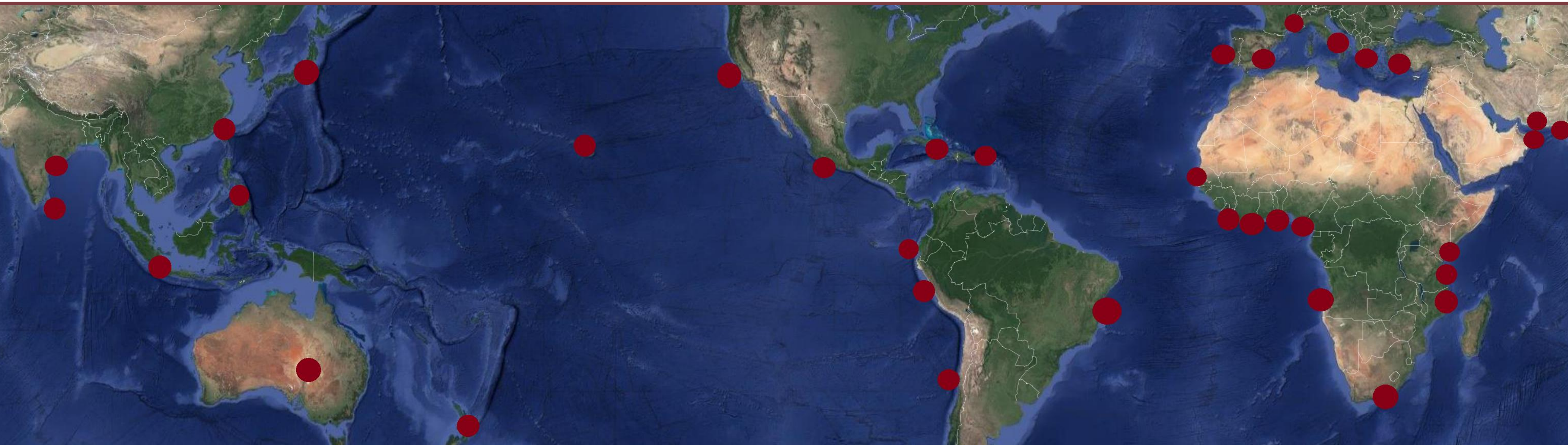
	2030
Countries	2
Population	30m
Storage Capacity	390GWh
Units (5GWh+)	45
Revenue Potential	NZ$3.51b



Market

Global Target Market:

	2030	2050
Countries	2	42
Population	30m	3,200m
Storage Capacity	390GWh	22,075GWh
Units (5GWh+)	45	3650
Revenue Potential	NZ$3.51b	NZ$198.67b



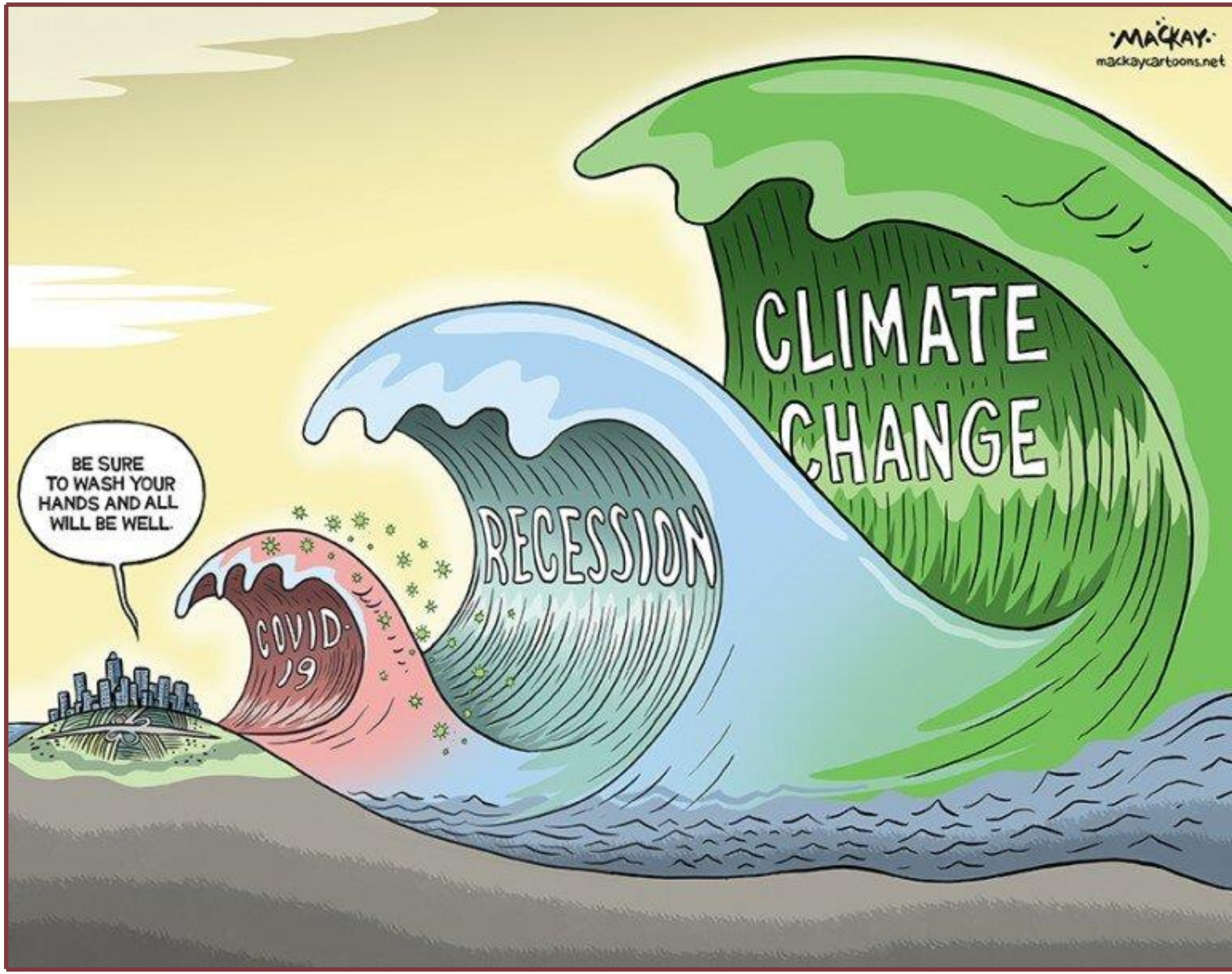
Why Now?

Confluence of:

- Technology
- Economics
- Social Impetus

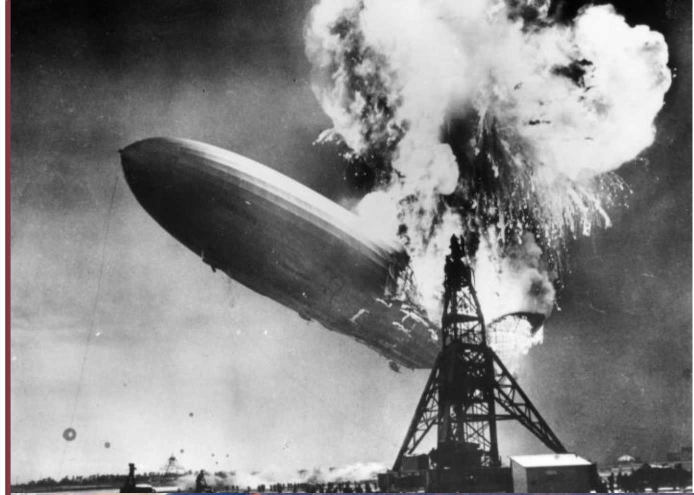
Results in:

- Big Opportunity



Competition

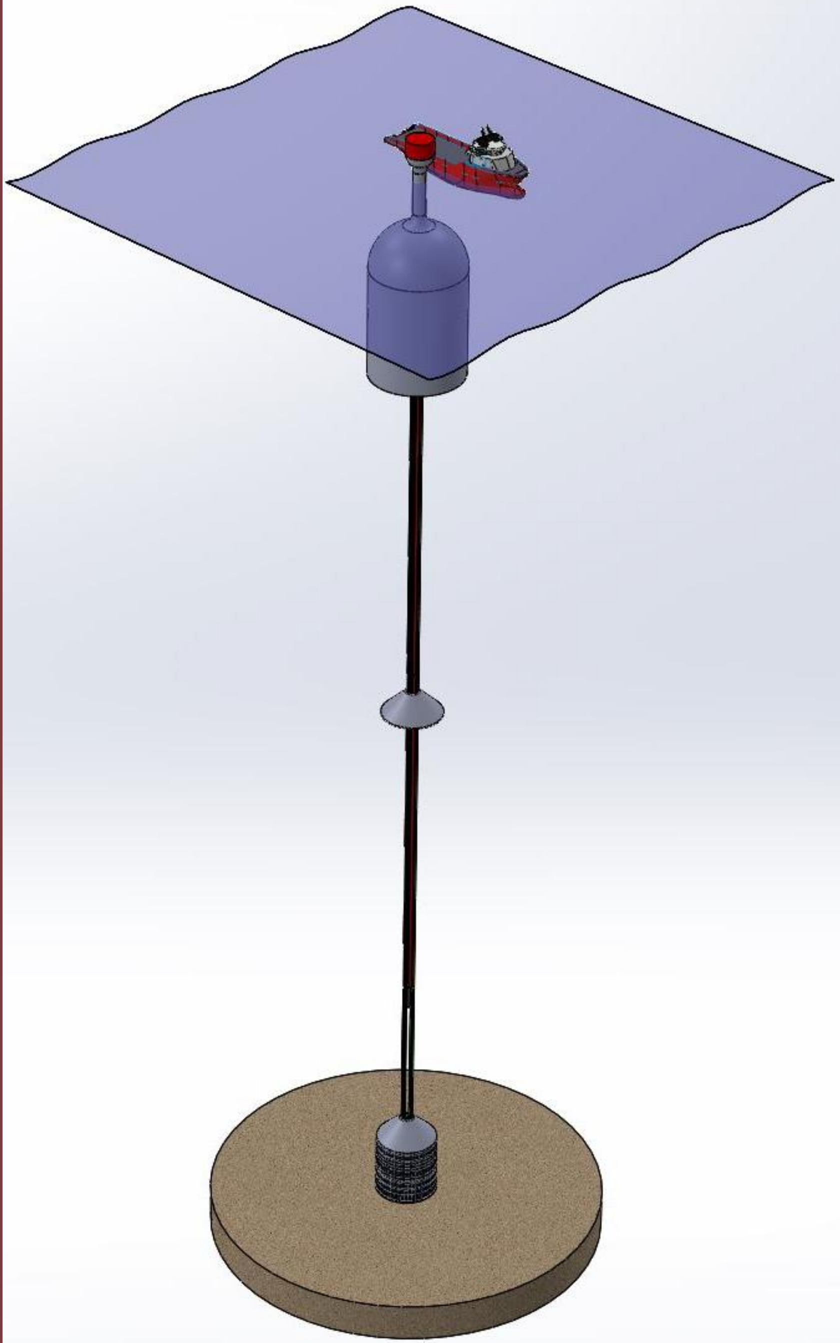
	Compressed Air	Chemical Batteries	Flywheel	Hydrogen	Pumped Hydro	Thermal	EnergyBank
Lifetime Cost	GOOD	BAD	BAD	GOOD	GOOD	OK	GOOD
Efficiency	BAD	GOOD	GOOD	BAD	GOOD	OK	GOOD
Responsiveness	OK	GOOD	GOOD	GOOD	OK	OK	OK
Scalability	BAD	BAD	BAD	OK	OK	OK	GOOD
Risk/Danger	OK	OK	OK	BAD	BAD	BAD	GOOD
Environment	GOOD	BAD	GOOD	OK	BAD	OK	GOOD



Competition

Competitive Differentiation:

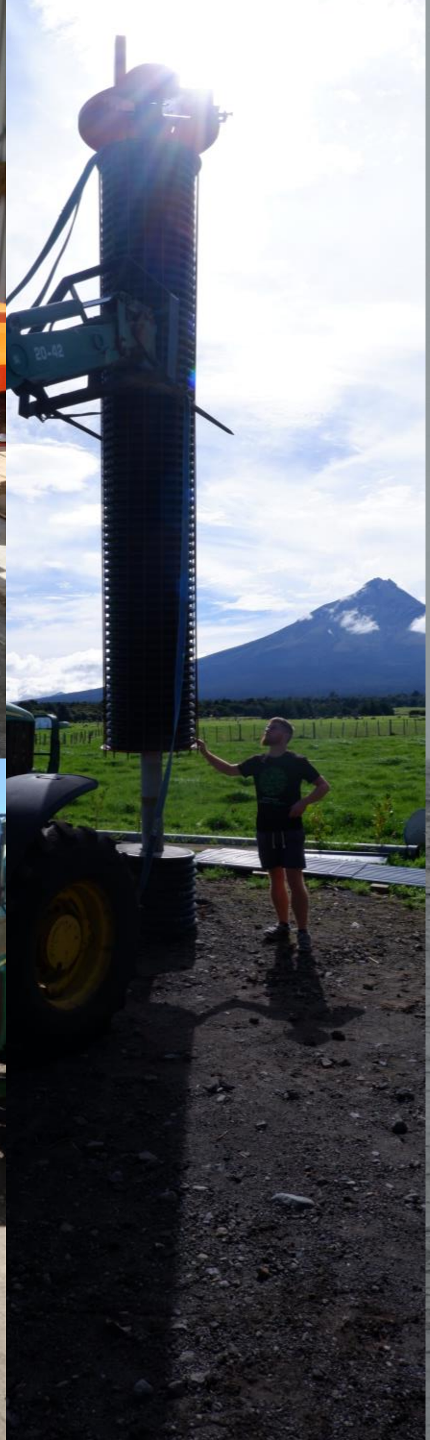
- Unitized, Modular and Scalable
- Efficient
- Economic
- No Land Use
- Little Public Risk
- Environmentally Benign
- Persistent
- Synergistic with offshore wind



Technical Progress

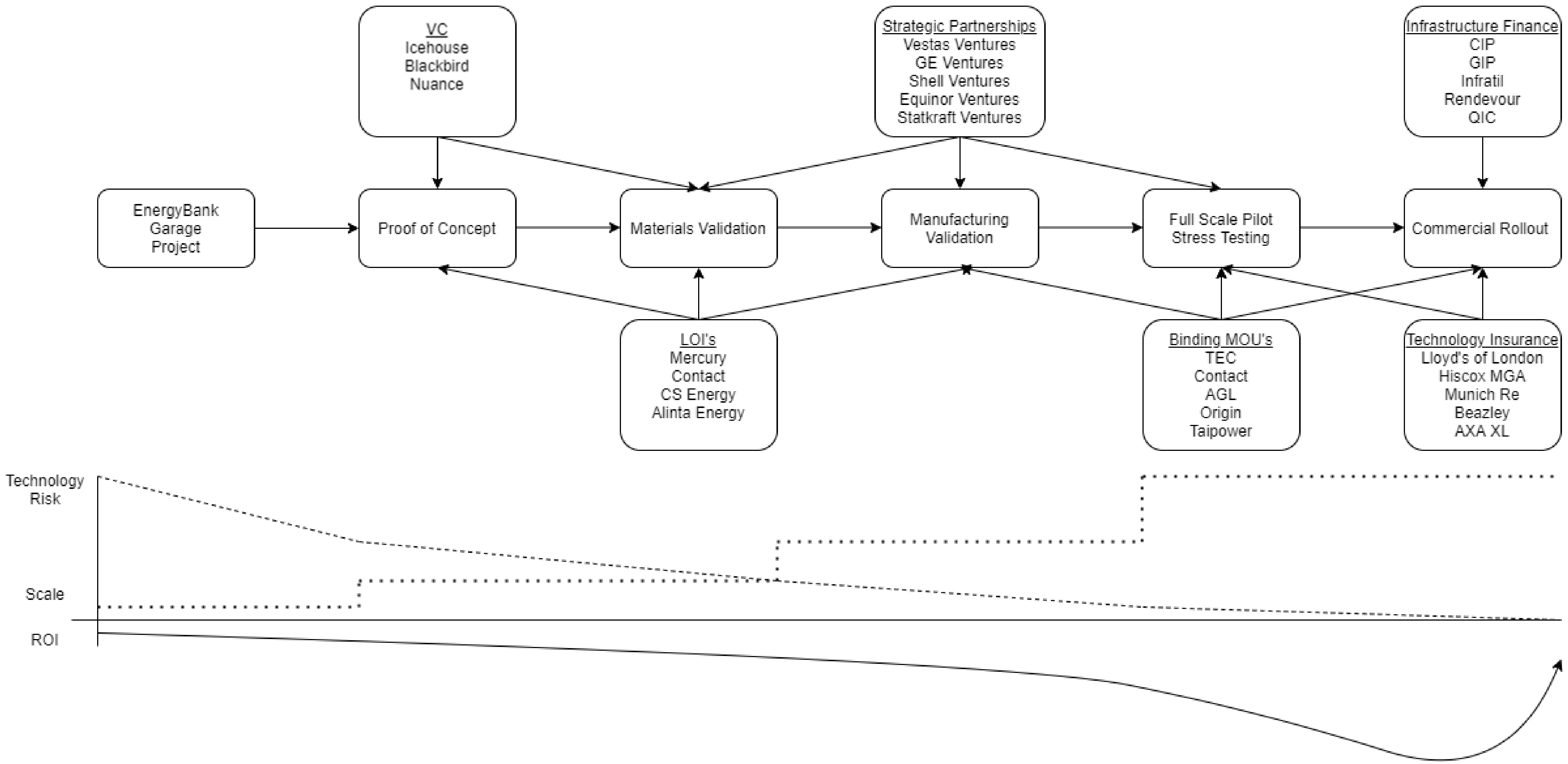
- 10 kW/h unit float/stability tests completed
- Regen winch design successfully tested/iterated
- Long term water tests next



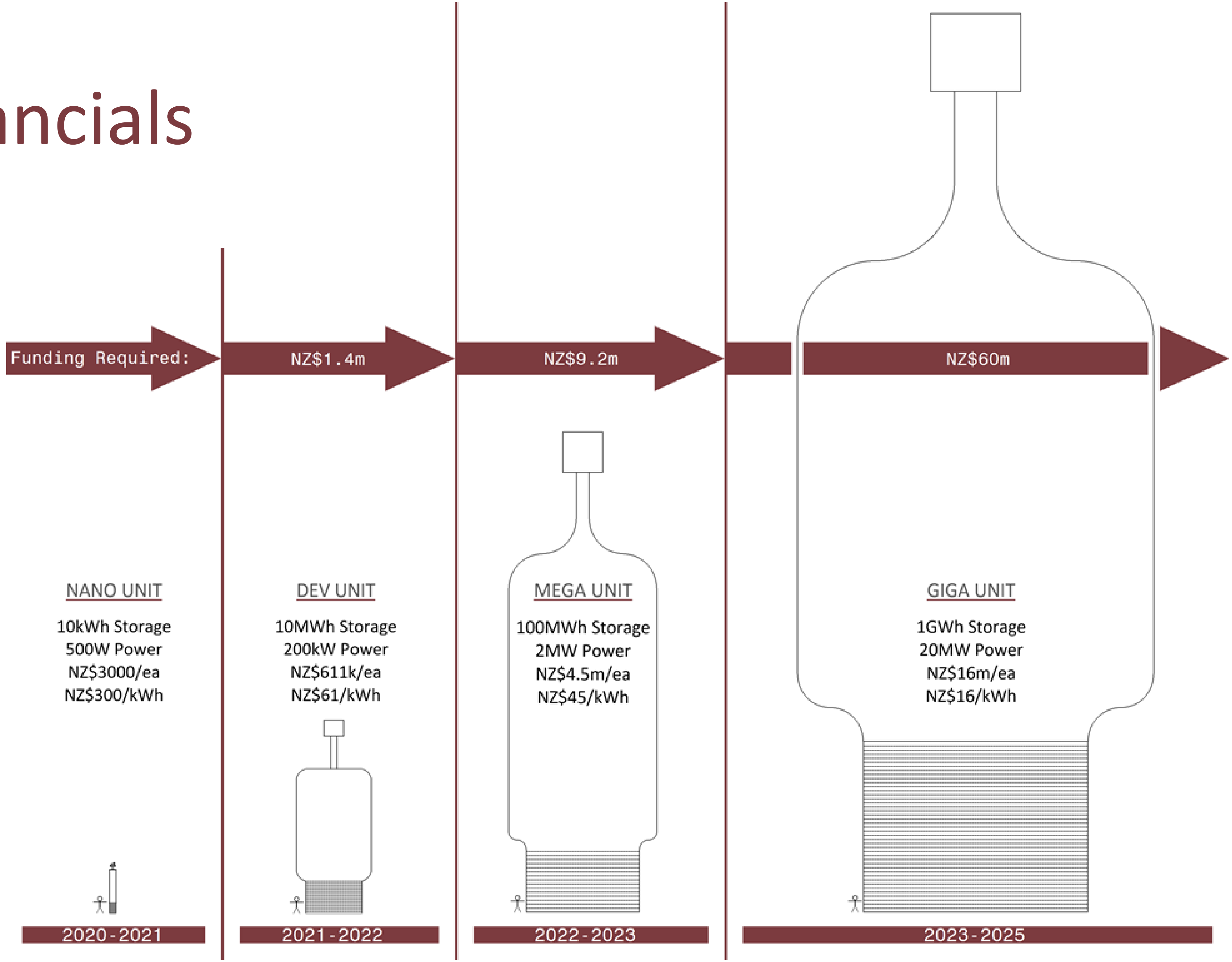




Path to Market



Financials

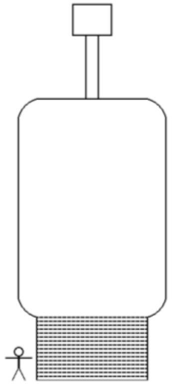

Funding Required:
NZ$1.4m
NZ$9.2m
NZ$60m
NANO UNIT
10kWh Storage
500W Power
NZ$3000/ea
NZ$300/kWh
DEV UNIT
10MWh Storage
200kW Power
NZ$611k/ea
NZ$61/kWh
MEGA UNIT
100MWh Storage
2MW Power
NZ$4.5m/ea
NZ$45/kWh
GIGA UNIT
1GWh Storage
20MW Power
NZ$16m/ea
NZ$16/kWh
2020-2021
2021-2022
2022-2023
2023-2025

Deal

****DEAL COMPLETED****

We will:

- Secure further LOI's
- Develop Dev Unit



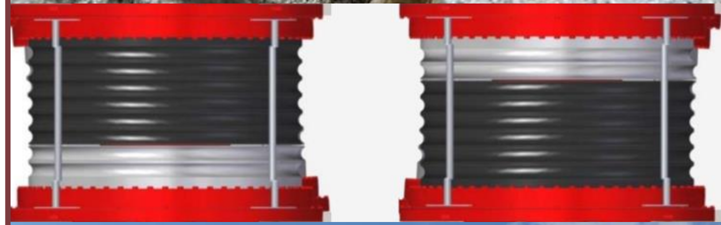
- 10MWh Storage
- 200kW Power
- NZ$611k/ea
- NZ$61/kWh

By:

- Setting up in decommissioned power station.
- Building buoy from fibre-glass reinforced concrete.
- Further developing a low-wear, traction winch system.
- Testing in deep-water marine environment.

Next round:

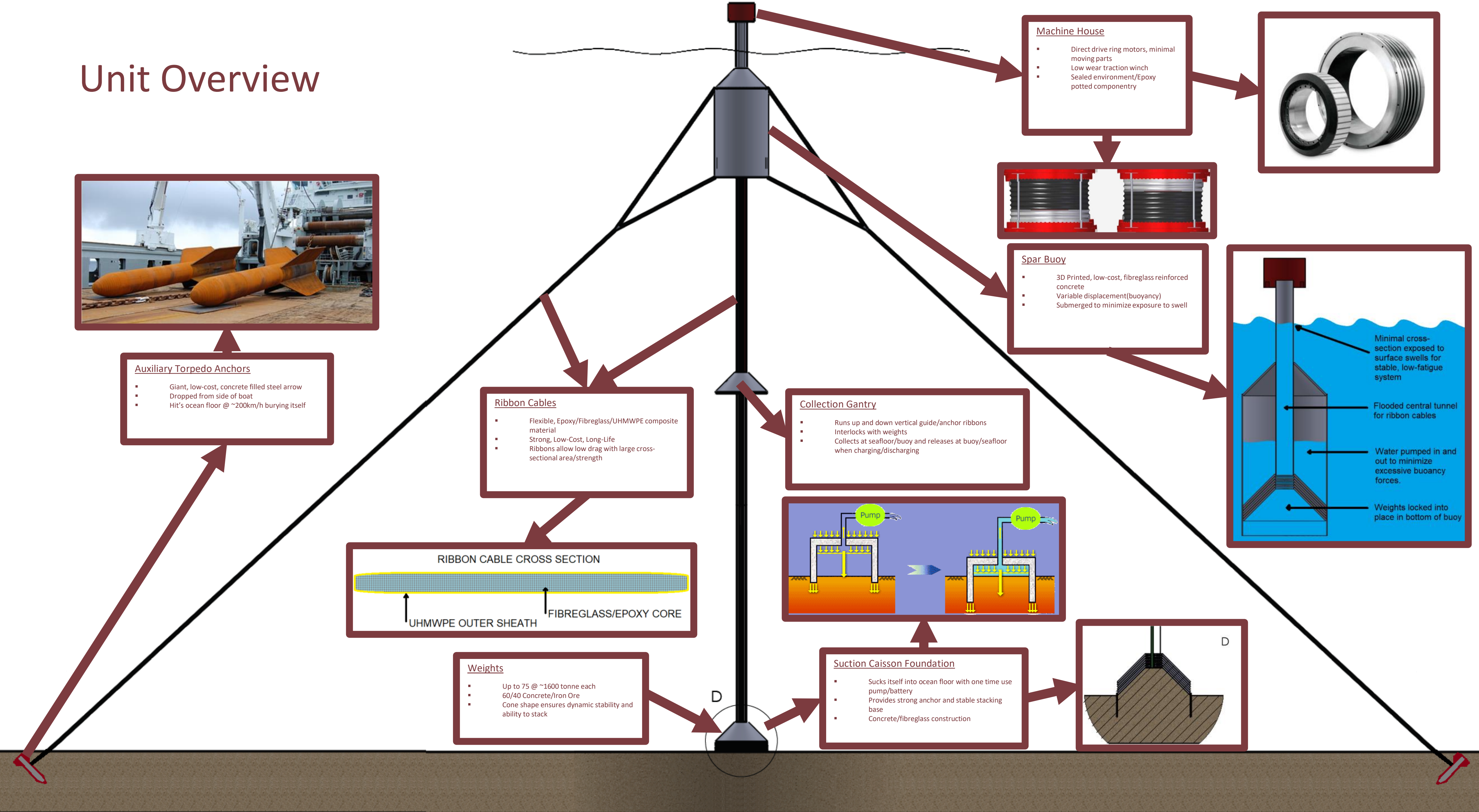
- Scale up, vertically integrate where prudent.
- Test mass manufacturing process at small scale.



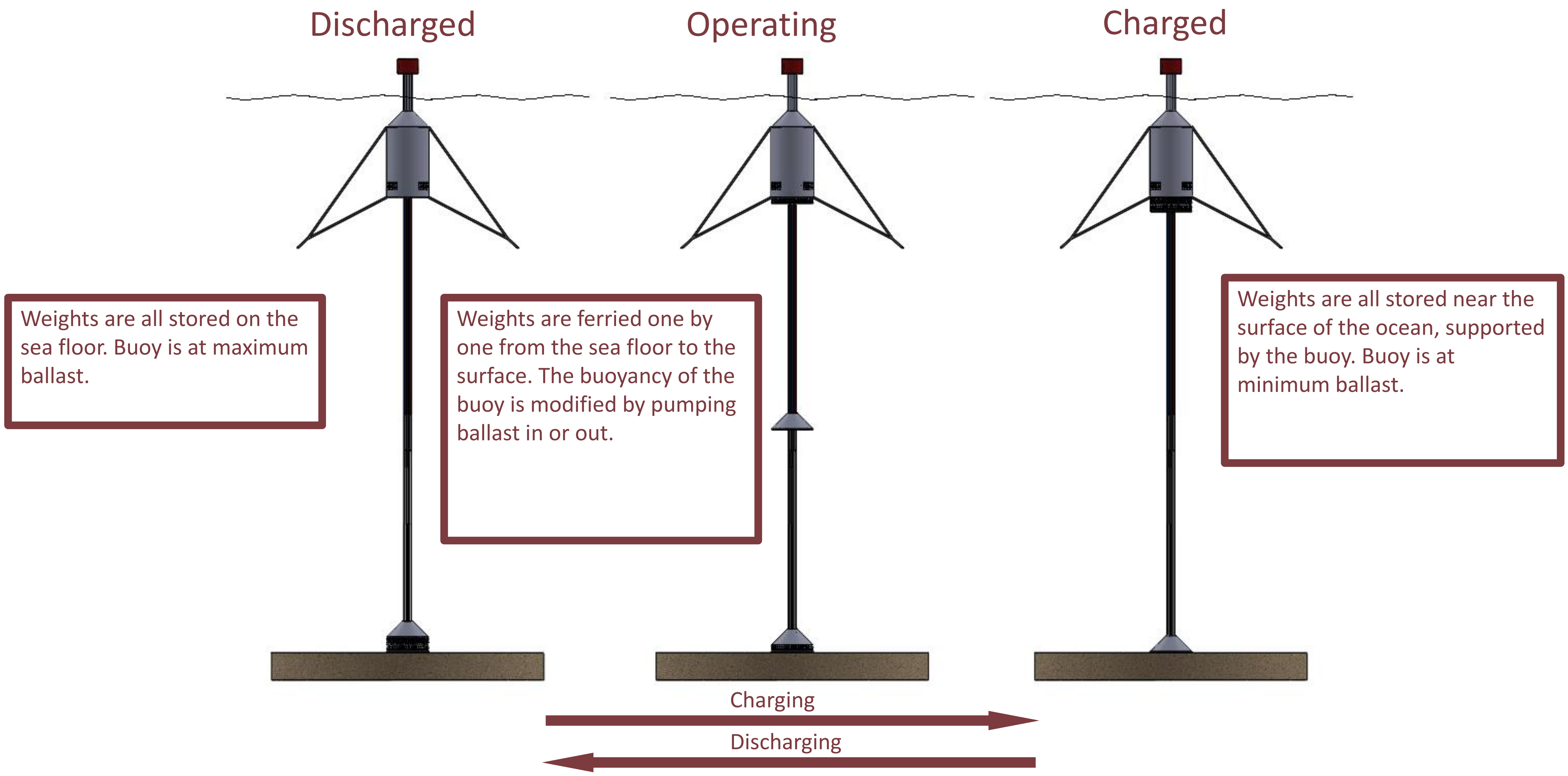
Appendix:

Concept structure & ocean forces overview

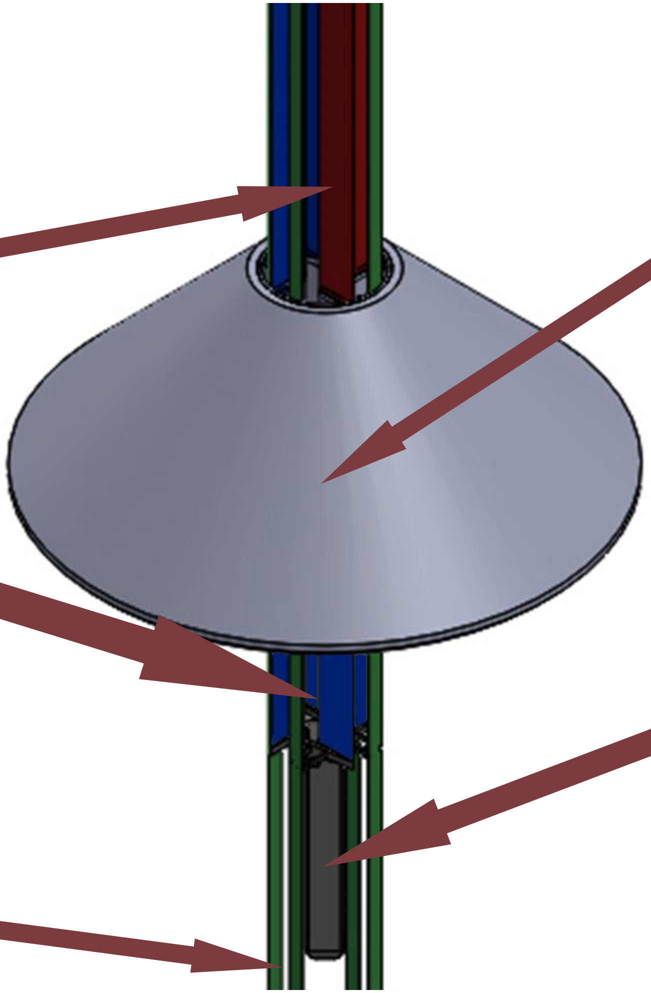
Unit Overview



Operation


Discharged
Operating
Charged
Weights are all stored on the sea floor. Buoy is at maximum ballast.
Weights are ferried one by one from the sea floor to the surface. The buoyancy of the buoy is modified by pumping ballast in or out.
Weights are all stored near the surface of the ocean, supported by the buoy. Buoy is at minimum ballast.
Charging
Discharging

Cable System



Lifting Cables

The lifting cables are shown in red (high tension end) and blue (low tension end). These cables run from the main weight around the traction winch and then back down to the counterweight. The lifting cables carry the force from the weights during lifting.

Tether Cables

The cables shown in green are the tether cables. These connect between the buoy and the foundation on the sea floor. These cables carry the positive buoyancy load from the buoy and act as guide for the weights to travel up and down.

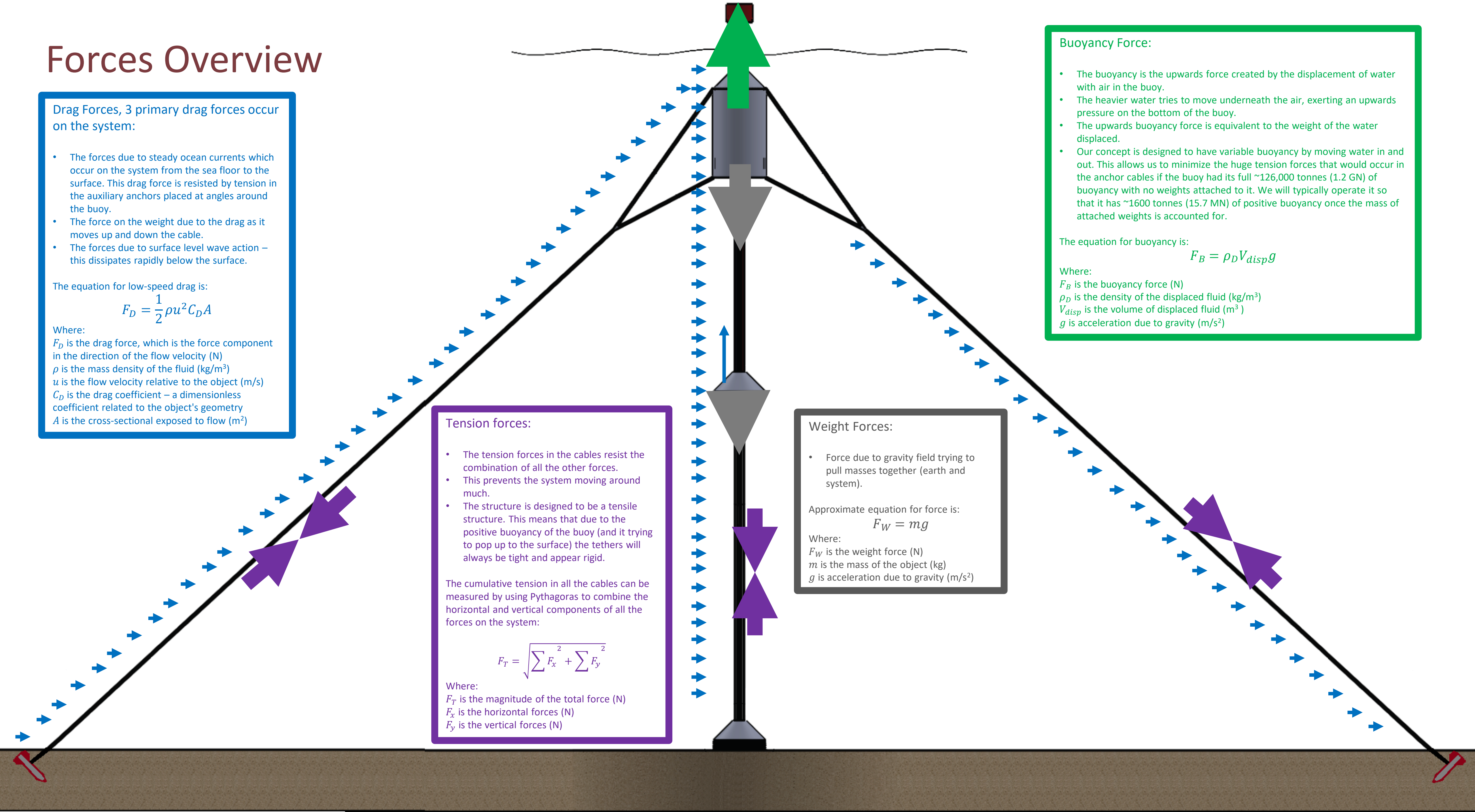
Main Weight

The main weights are manufactured from concrete densified with iron ore.

Counterweight

The counterweight is necessary for the traction winch to function, it keeps tension on the "loose" end of the winch. It will be ~1/60th the mass of the main weight and runs on guides through the centre of the tether cables.

Forces Overview



Drag Forces, 3 primary drag forces occur on the system:

- The forces due to steady ocean currents which occur on the system from the sea floor to the surface. This drag force is resisted by tension in the auxiliary anchors placed at angles around the buoy.
- The force on the weight due to the drag as it moves up and down the cable.
- The forces due to surface level wave action – this dissipates rapidly below the surface.

The equation for low-speed drag is:

$$F_D = \frac{1}{2}\rho u^2 C_D A$$

Where:
F_D is the drag force, which is the force component in the direction of the flow velocity (N)
ρ is the mass density of the fluid (kg/m^3)
u is the flow velocity relative to the object (m/s)
C_D is the drag coefficient – a dimensionless coefficient related to the object's geometry
A is the cross-sectional exposed to flow (m^2)

Tension forces:

- The tension forces in the cables resist the combination of all the other forces.
- This prevents the system moving around much.
- The structure is designed to be a tensile structure. This means that due to the positive buoyancy of the buoy (and it trying to pop up to the surface) the tethers will always be tight and appear rigid.

The cumulative tension in all the cables can be measured by using Pythagoras to combine the horizontal and vertical components of all the forces on the system:

$$F_T = \sqrt{\sum F_x^2 + \sum F_y^2}$$

Where:
F_T is the magnitude of the total force (N)
F_x is the horizontal forces (N)
F_y is the vertical forces (N)

Weight Forces:

- Force due to gravity field trying to pull masses together (earth and system).

Approximate equation for force is:

$$F_W = mg$$

Where:
F_W is the weight force (N)
m is the mass of the object (kg)
g is acceleration due to gravity (m/s^2)

Buoyancy Force:

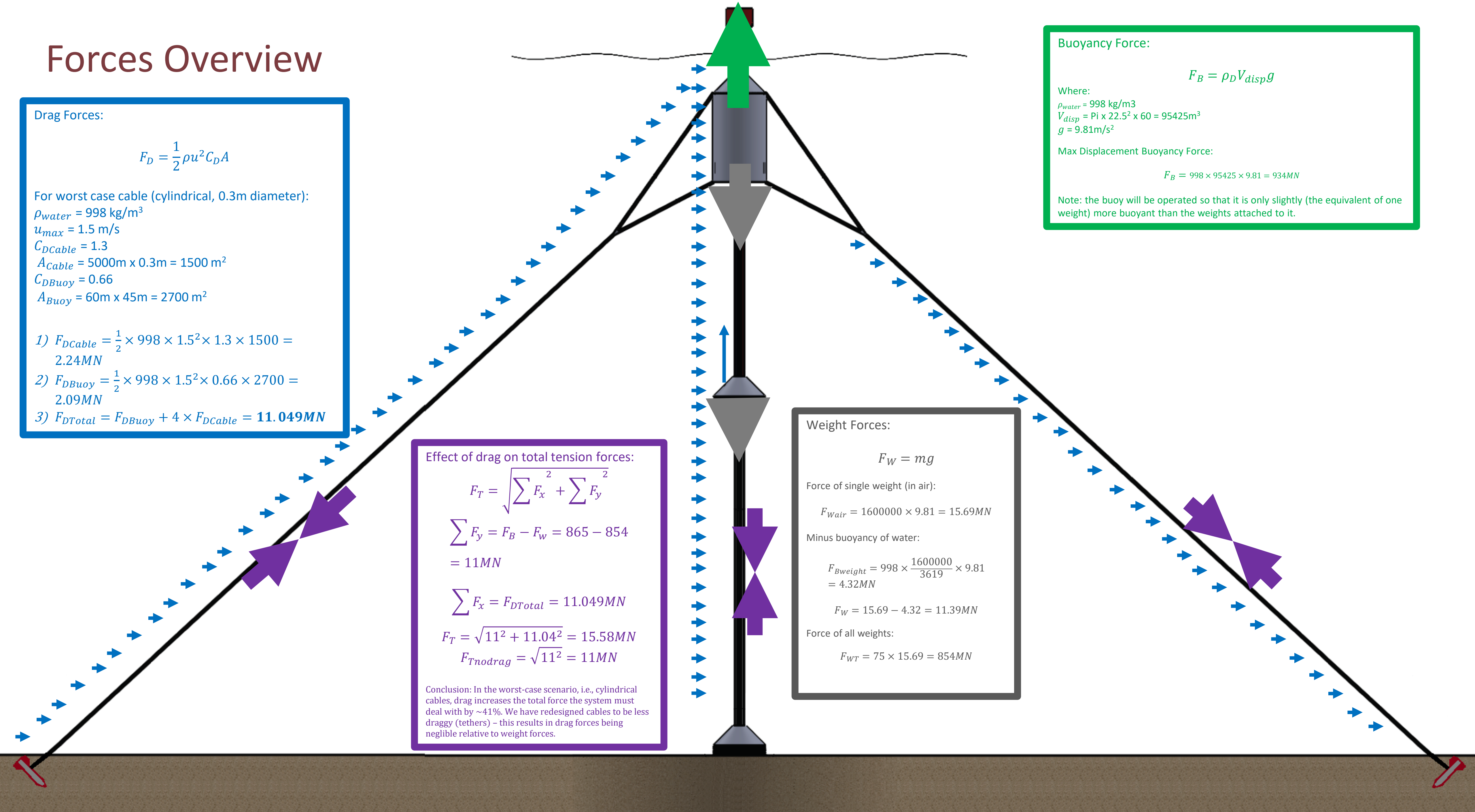
- The buoyancy is the upwards force created by the displacement of water with air in the buoy.
- The heavier water tries to move underneath the air, exerting an upwards pressure on the bottom of the buoy.
- The upwards buoyancy force is equivalent to the weight of the water displaced.
- Our concept is designed to have variable buoyancy by moving water in and out. This allows us to minimize the huge tension forces that would occur in the anchor cables if the buoy had its full ~126,000 tonnes (1.2 GN) of buoyancy with no weights attached to it. We will typically operate it so that it has ~1600 tonnes (15.7 MN) of positive buoyancy once the mass of attached weights is accounted for.

The equation for buoyancy is:

$$F_B = \rho_D V_{disp} g$$

Where:
F_B is the buoyancy force (N)
ρ_D is the density of the displaced fluid (kg/m^3)
V_{disp} is the volume of displaced fluid (m^3)
g is acceleration due to gravity (m/s^2)

Forces Overview



Drag Forces:

$$F_D = \frac{1}{2}\rho u^2 C_D A$$

For worst case cable (cylindrical, 0.3m diameter):

ρ_{water} = 998 kg/m^3
u_{max} = 1.5 m/s
C_{DCable} = 1.3
A_{Cable} = 5000m x 0.3m = 1500 m^2
C_{DBuoy} = 0.66
A_{Buoy} = 60m x 45m = 2700 m^2

1) $F_{DCable} = \frac{1}{2} \times 998 \times 1.5^2 \times 1.3 \times 1500 = 2.24MN$
2) $F_{DBuoy} = \frac{1}{2} \times 998 \times 1.5^2 \times 0.66 \times 2700 = 2.09MN$
3) $F_{DTotal} = F_{DBuoy} + 4 \times F_{DCable} = \mathbf{11.049MN}$

Effect of drag on total tension forces:

$$F_T = \sqrt{\sum F_x^{\,2} + \sum F_y^{\,2}}$$

$$\sum F_y = F_B - F_w = 865 - 854 = 11MN$$

$$\sum F_x = F_{DTotal} = 11.049MN$$

$$F_T = \sqrt{11^2 + 11.04^2} = 15.58MN$$

$$F_{Tnodrag} = \sqrt{11^2} = 11MN$$

Conclusion: In the worst-case scenario, i.e., cylindrical cables, drag increases the total force the system must deal with by ~41%. We have redesigned cables to be less draggy (tethers) – this results in drag forces being negligible relative to weight forces.

Weight Forces:

$$F_W = mg$$

Force of single weight (in air):

$$F_{Wair} = 1600000 \times 9.81 = 15.69MN$$

Minus buoyancy of water:

$$F_{Bweight} = 998 \times \frac{1600000}{3619} \times 9.81 = 4.32MN$$

$$F_W = 15.69 - 4.32 = 11.39MN$$

Force of all weights:

$$F_{WT} = 75 \times 15.69 = 854MN$$

Buoyancy Force:

$$F_B = \rho_D V_{disp} g$$

Where:
ρ_{water} = 998 kg/m3
V_{disp} = Pi x 22.5^2 x 60 = 95425m^3
g = 9.81m/s^2

Max Displacement Buoyancy Force:

$$F_B = 998 \times 95425 \times 9.81 = 934MN$$

Note: the buoy will be operated so that it is only slightly (the equivalent of one weight) more buoyant than the weights attached to it.