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EMship Advanced Design

Master Thesis:

A Life Cycle Cost Analysis of Marine Scrubber Technologies

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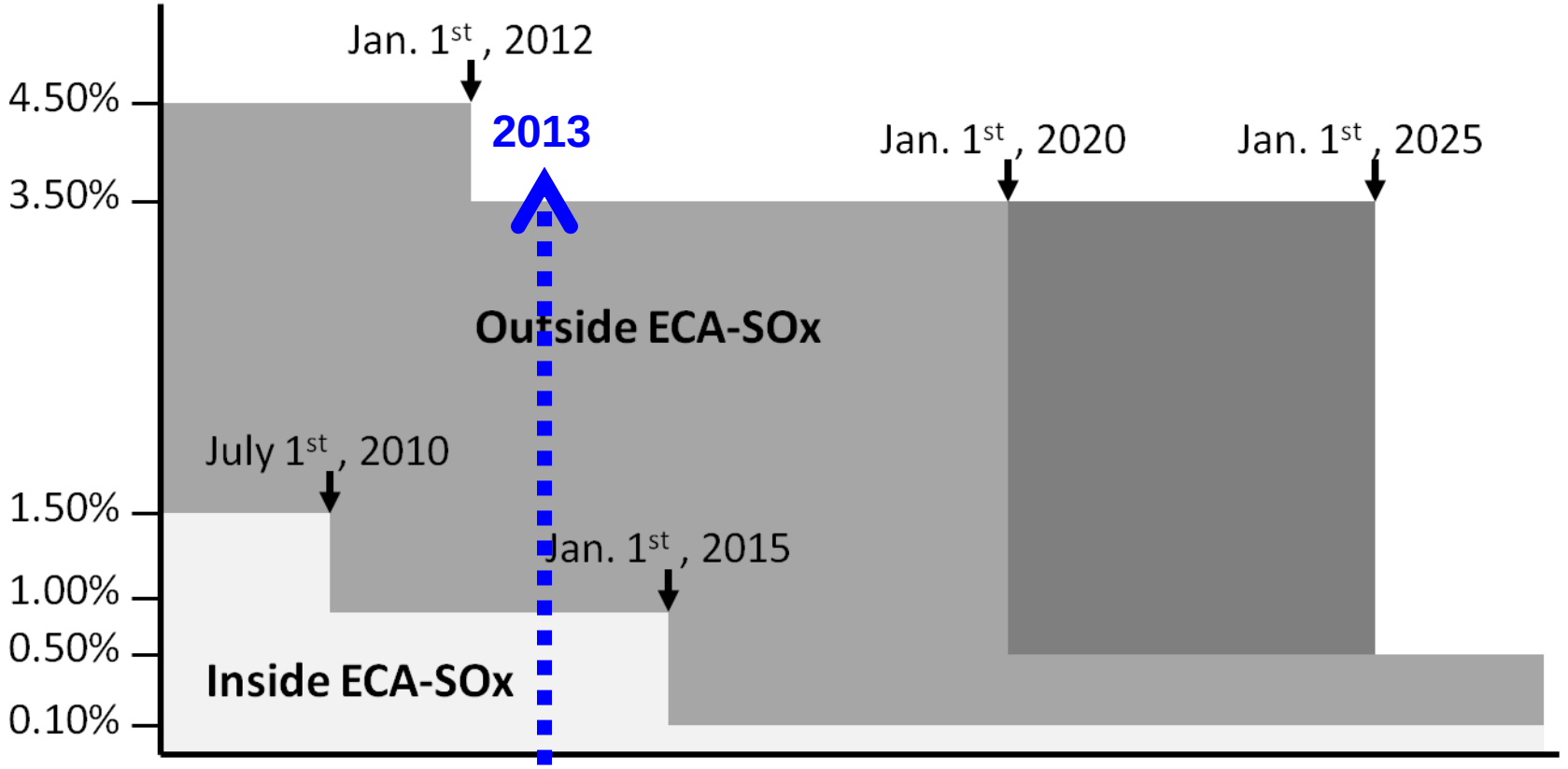
Company of Internship: Lloyd's Register

MARPOL Annex VI

- SOx emission regulation



2015 : 1.00%S → **0.10**%S (Emission Control Area)

2020*: 3.50%S → 0.50%S (Global)

Emission Control Areas (ECAs)

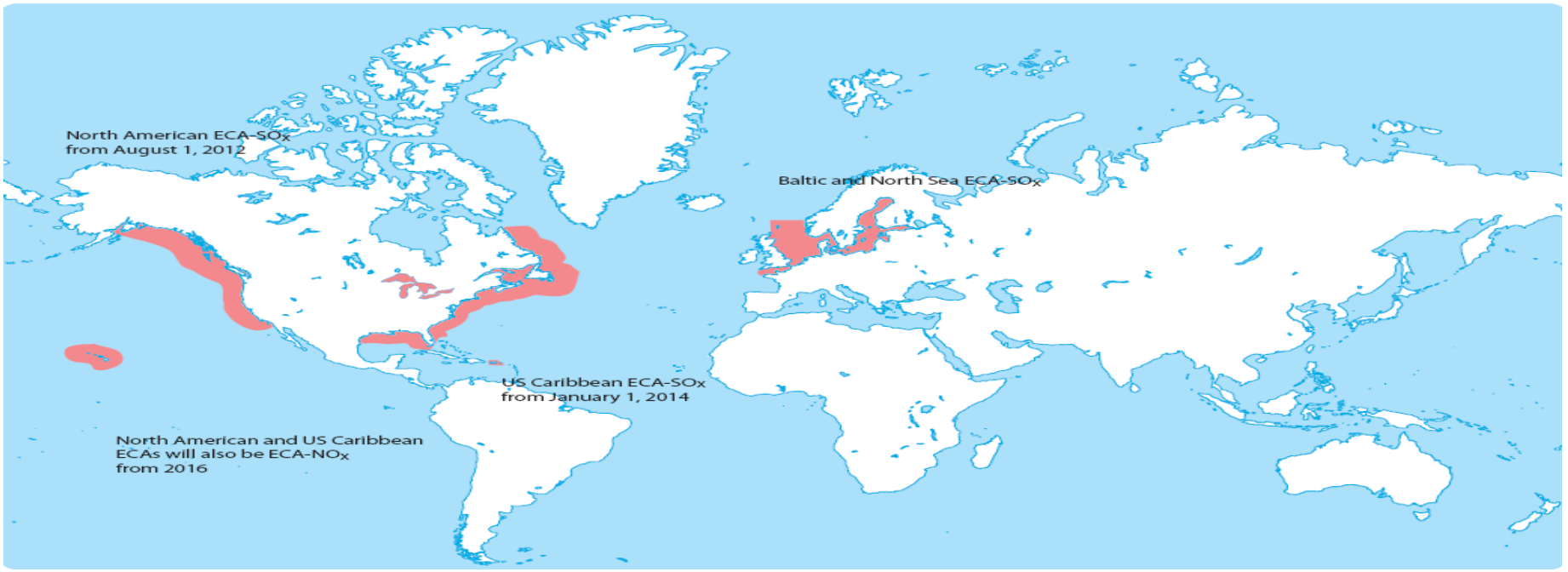
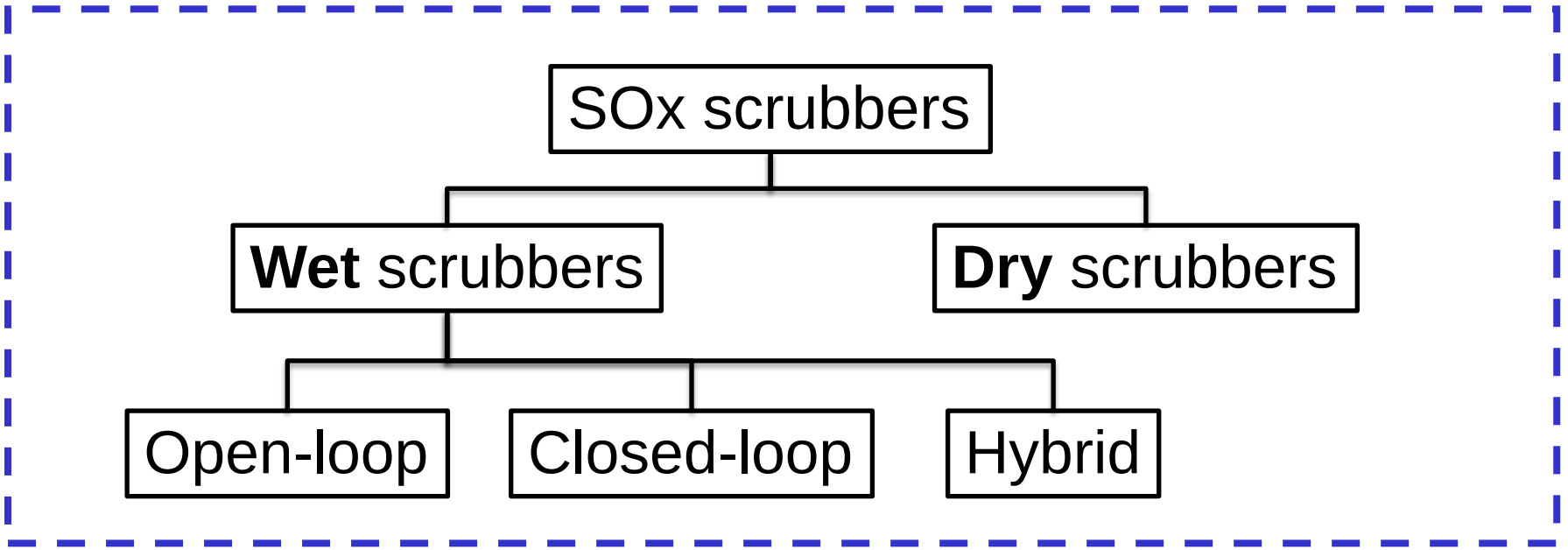


*image courtesy of Lloyd's Register

- **Current ECA-SOx**
  the Baltic and the North Sea, North American
- **Future ECA-SOx**
  2014 US Caribbean

Overview of Scrubber system

SOx



2015 0.10% ECA
2020 0.50% Global

Heavy Fuel Oil (HFO) 591 USD/MT [Rotterdam]
Marine Gas Oil (MGO) 925 USD/MT [Rotterdam]

Price spread:
334 USD/MT
(257 €/MT)

Wet Scrubber (1/3)

Seawater Open-loop

- Pros: seawater scrubbing (no chemical needed)
- Cons: wash water discharge, alkalinity limit

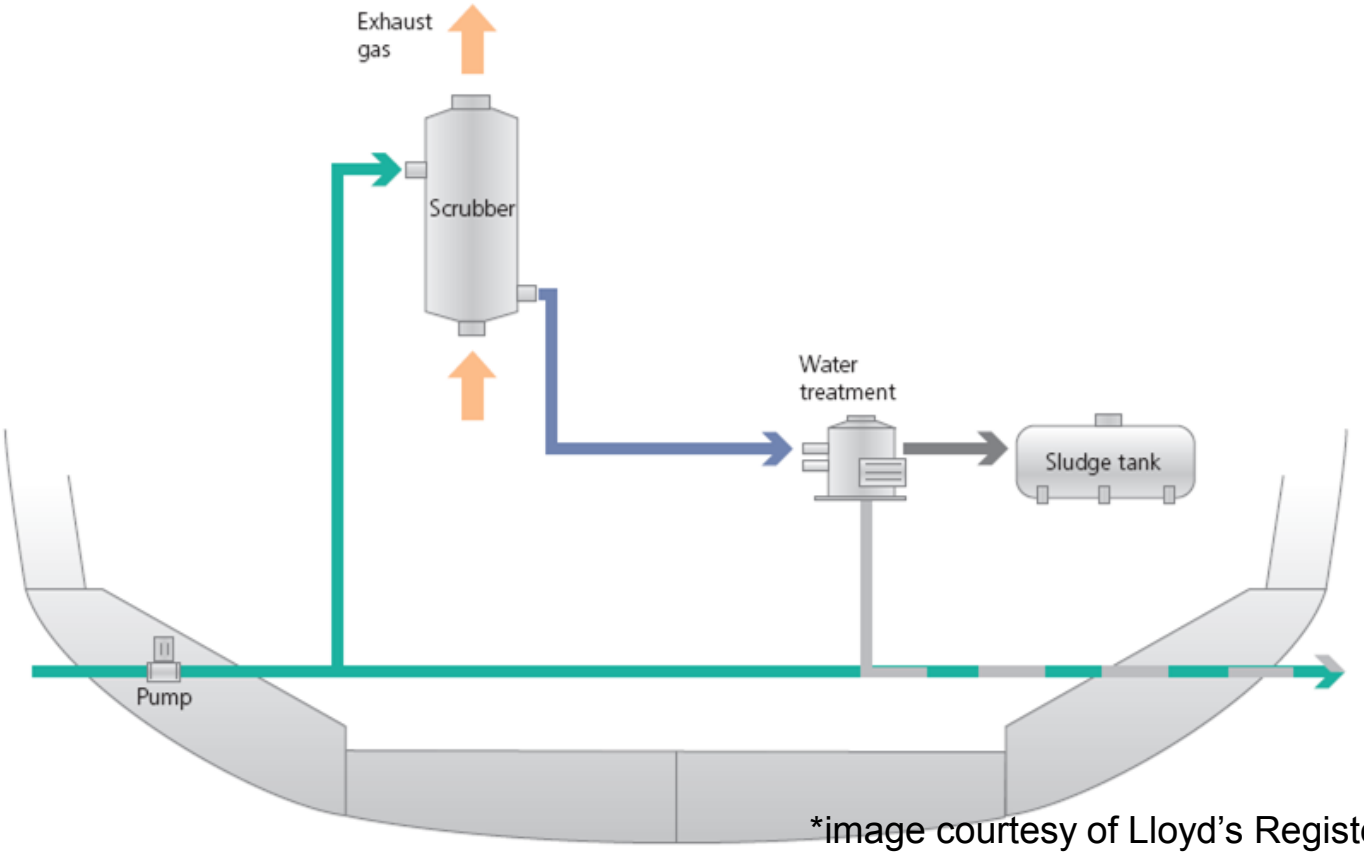


*image courtesy of Lloyd's Register

Wet Scrubber (2/3)

Freshwater Closed-loop

- Pros: zero discharge mode, removal efficiency
- Cons: NaOH dosing, fresh water

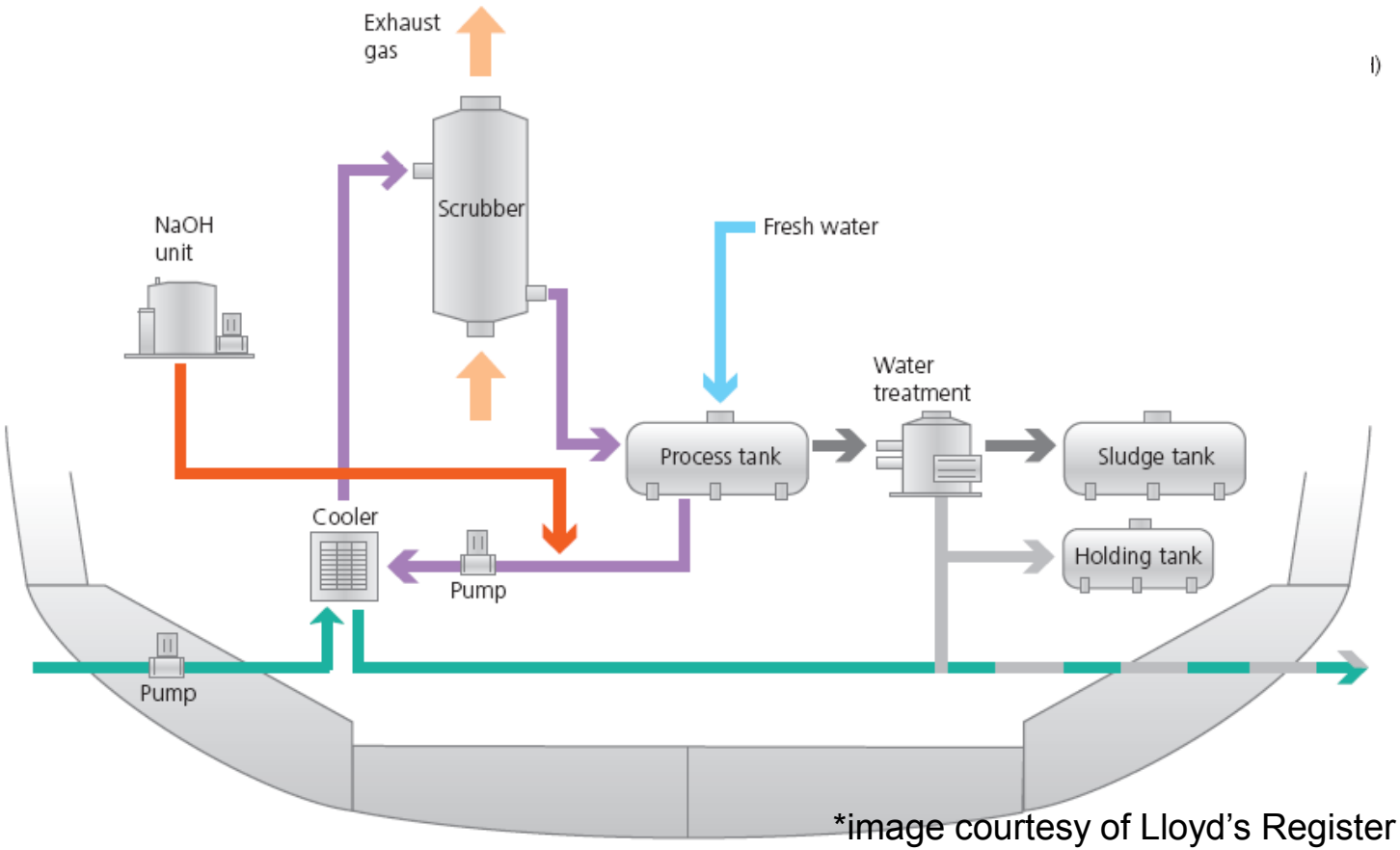


*image courtesy of Lloyd's Register

Wet Scrubber (3/3)

Hybrid (Open/Closed-loop)

- Pros: mode switching
- Cons: complex system

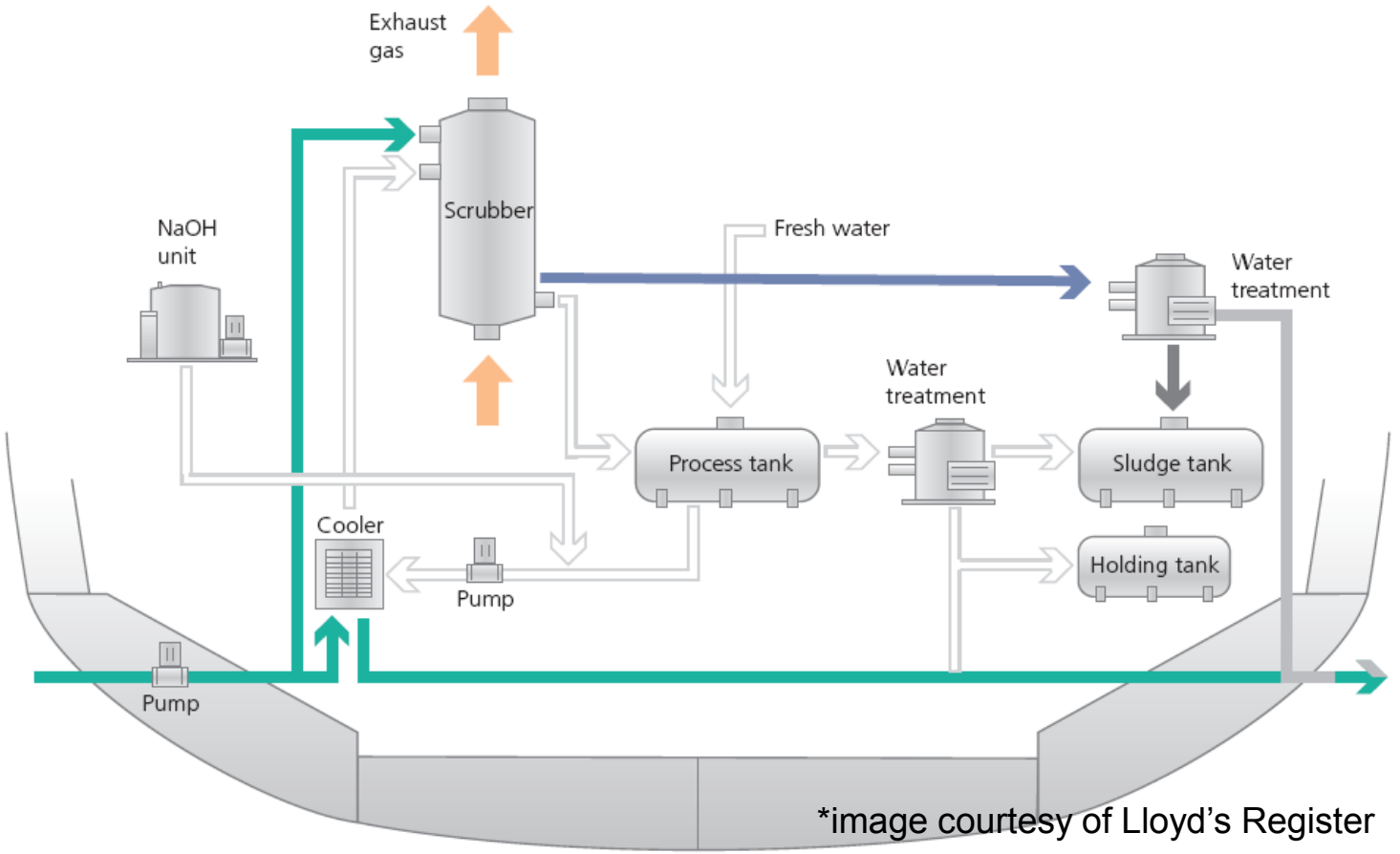
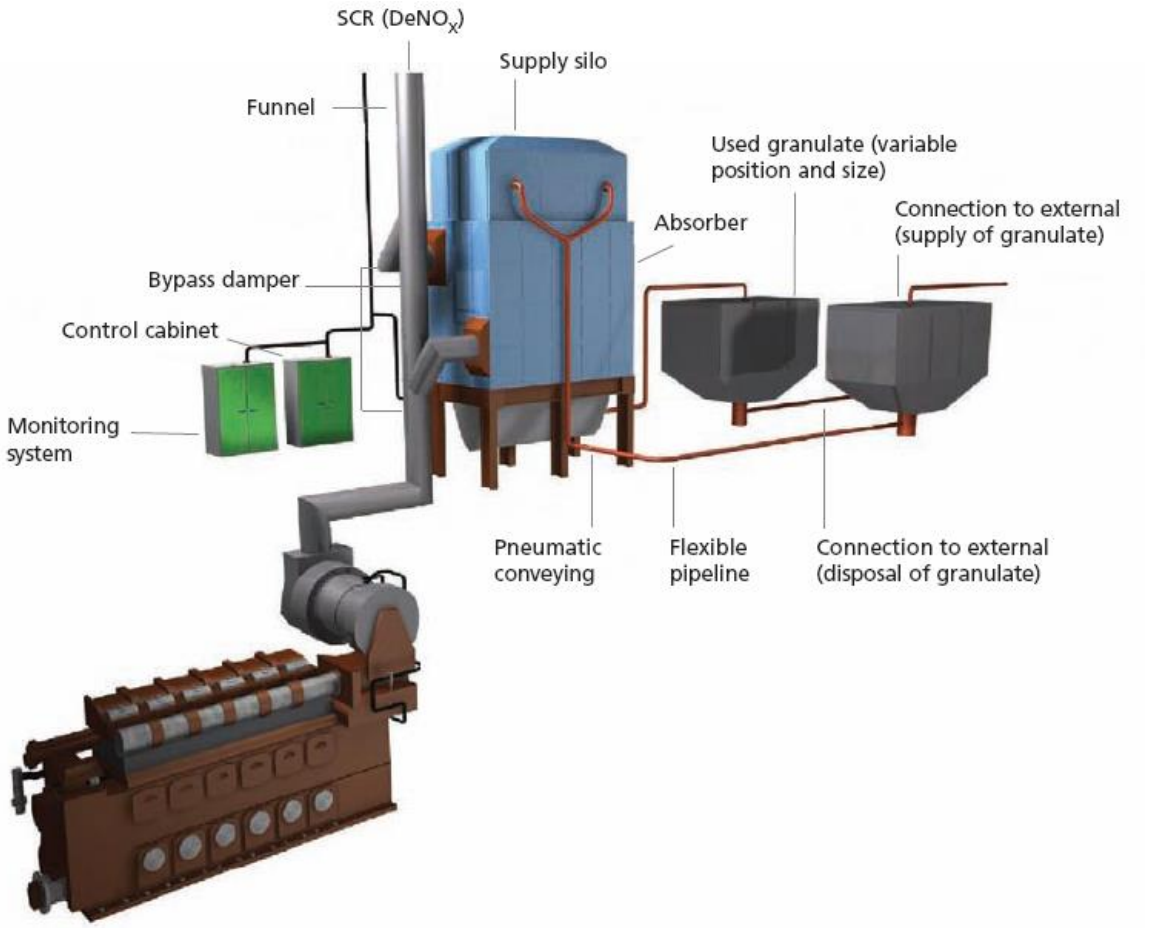


*image courtesy of Lloyd's Register

Dry Scrubber

- Pros: dry scrubbing - $Ca(OH)_2$, no temperature drop
- Cons: bulky scrubber unit



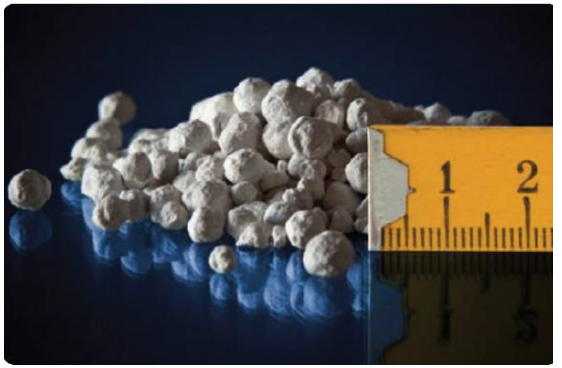
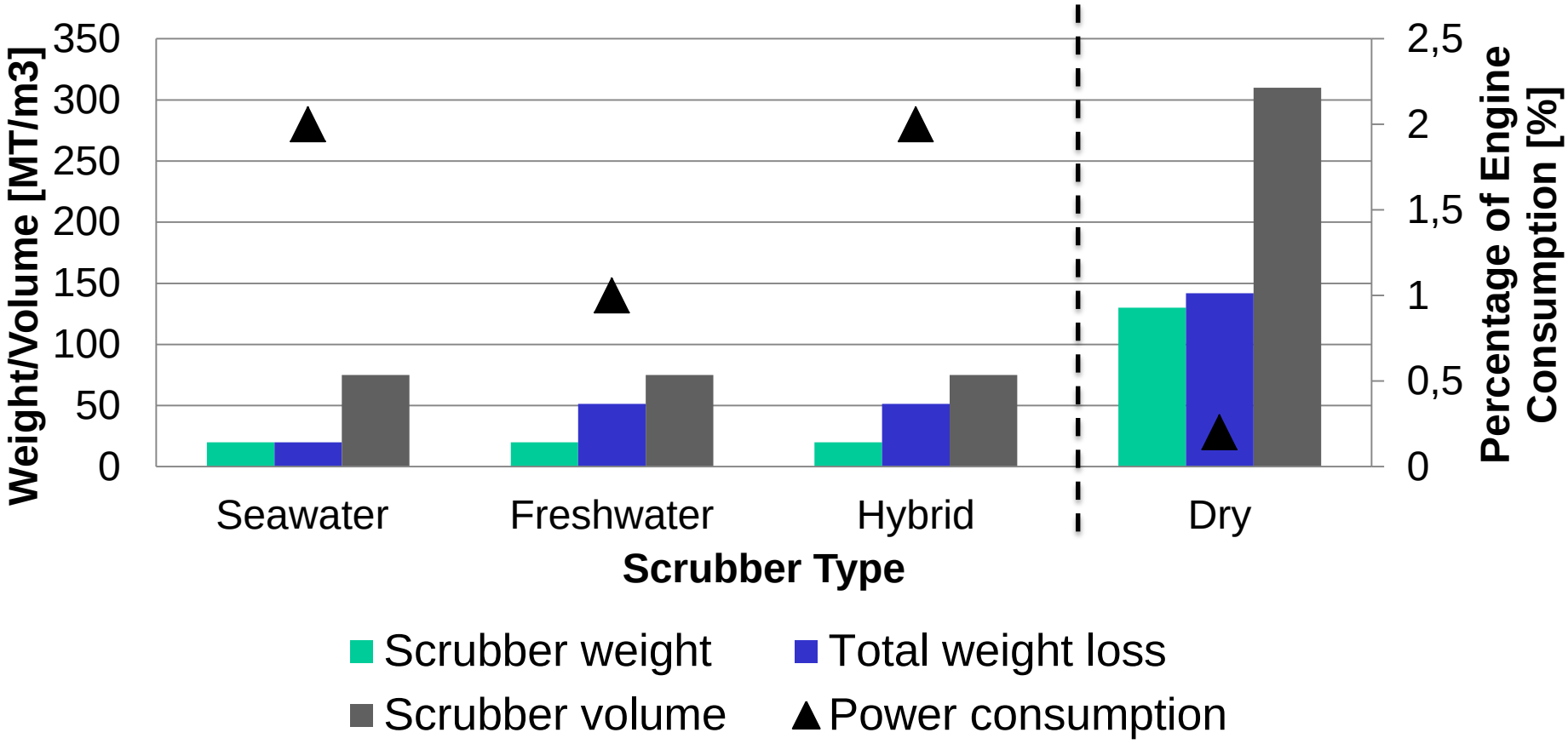


*image courtesy of Couple System

Scrubber Comparison

- Total engine power: 10MW
- Sulphur content: 3.5%
- Continuous operation: 1 day (24hrs)

Total weight loss = Scrubber unit weight + Consumable weight



Scrubber – Installation Impacts

- **Economical**
  - capital investment
  - operational and maintenance
  - end-of-life cost
- **Technical**
  - back pressure
  - extra power consumption
  - space and weight
  - chemical usage
  - …..
- **Environmental**
  - wash water discharge
  - sludge disposal
  - end-of-life hazardous wastes

*image courtesy of Alfa Laval

Life Cycle Costing of Scrubber

- Economical

-1. Capital investment

- acquisition
- installation
- engineering design
- …

-2. Operational and maintenance

- extra fuel and power
- chemical consumables
- sludge disposal
- cargo loss
- …

-3. End-of-life cost

- inventory of hazardous material
- hazardous wastes removal

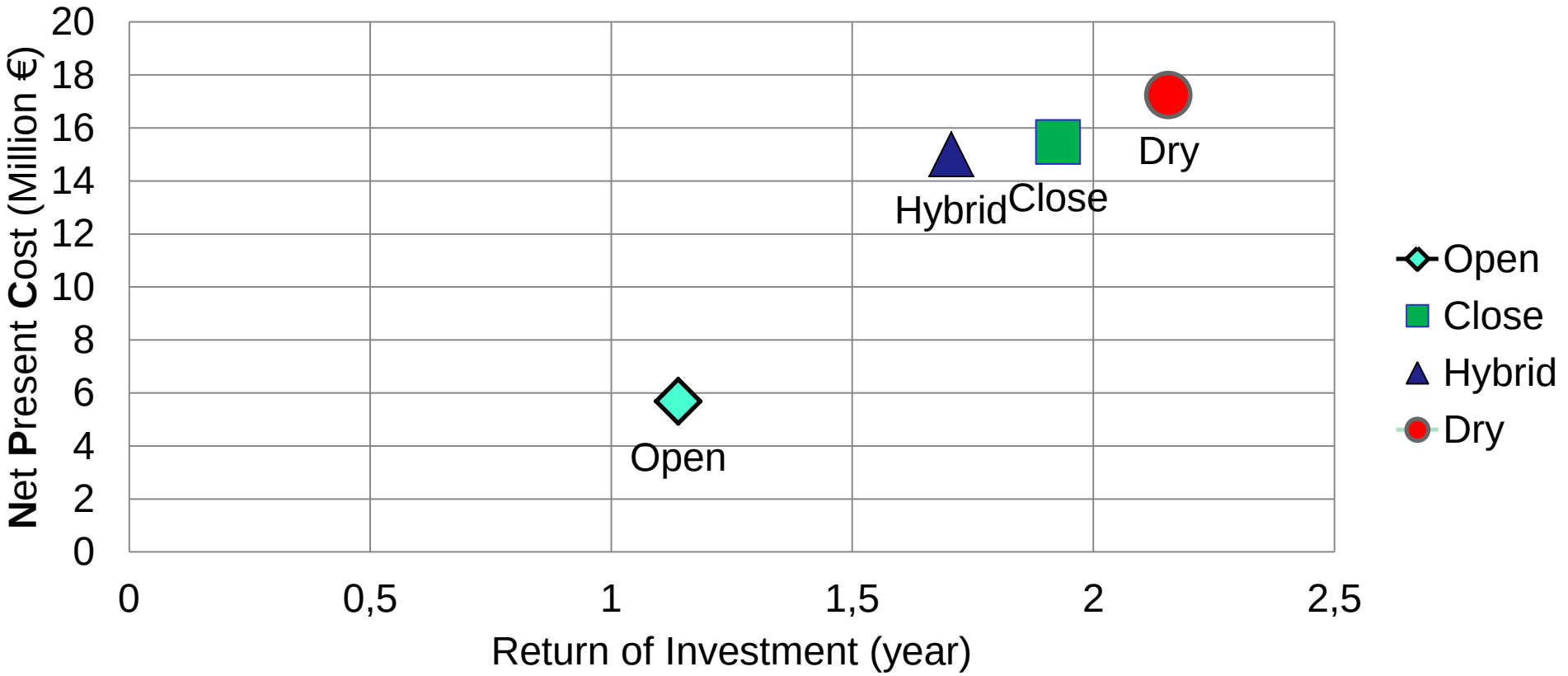
Scrubber – Life Cycle Cost Analysis (1/2)

► Ro-Pax (12MW)

Total fuel consumption: **12,107** tons/year

ECA profile

Sailing in ECA:	**100**%	Life cycle:	15 years
Days of operation:	**270** days/year	Discount rate:	10%
Continuous operation:	**1** day	HFO/MGO price spread:	257 €/ton



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Scrubber – Life Cycle Cost Analysis (2/2)

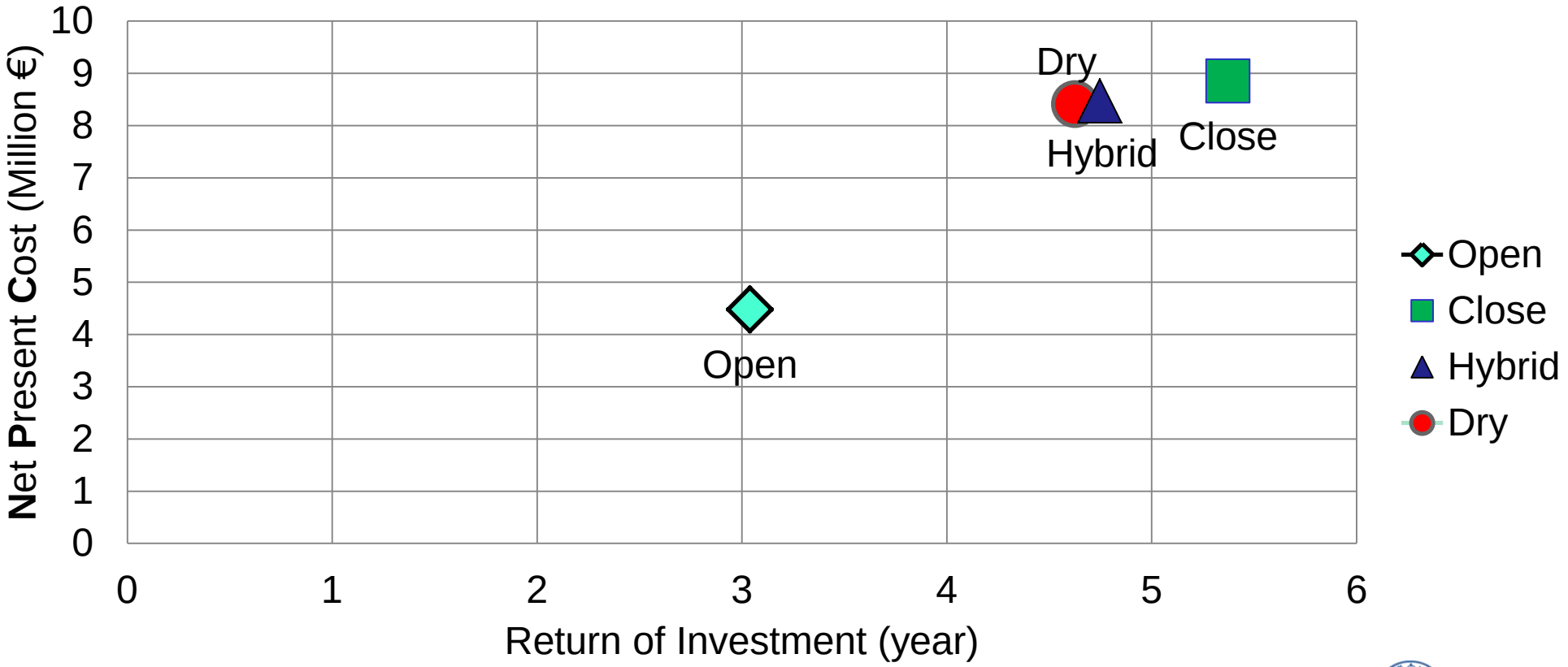
▶ Tanker (10MW)

Total fuel consumption: **4,484** tons/year

ECA profile

Sailing in ECA:	**50**%
Days of operation:	**270** days/year
Continuous operation:	**5** day

Life cycle:	15 years
Discount rate:	10%
HFO/MGO price spread:	257 €/ton



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Scrubber – Sensitive Analysis

► Fuel price sensitivity

Seawater open-loop scrubber (**16**MW)
Total fuel consumption: **11,300** tons/year

Time in ECAs (%)	100 USD	200 USD	300 USD	400 USD	500 USD	600 USD
100 %	4yrs4ms	2yrs0ms	1yrs4ms	12ms	9ms	8ms
90 %	4yrs11ms	2yrs3ms	1yrs6ms	1yr1ms	10ms	9ms
80 %	5yrs7ms	2yrs7ms	1yrs8ms	1yr3ms	12ms	10ms
70 %	6yrs6ms	2yrs11ms	1yr11ms	1yr5ms	1yr1ms	11ms
60 %	7yrs8ms	3yrs5ms	2yrs3ms	1yr8ms	1yr4ms	1yr1m
50 %	9yrs6ms	4yrs2ms	2yrs8ms	1yr12ms	1yr7ms	1yr4ms
40 %	12yrs5ms	5yrs4ms	3yrs5ms	2yrs6ms	1yr12ms	1yr8ms
30 %	never	7yrs5ms	4yrs8ms	3yrs5ms	2yrs8ms	2yrs2ms
20 %	never	11yrs11ms	7yrs4ms	5yrs3ms	4yrs1ms	3yrs5ms
10 %	never	never	never	11yrs8ms	8yrs11ms	7yrs3ms

Price spread between HFO/MGO

Discussions and Conclusions

- Discussions:
  - 1.Seawater open-loop: lowest Net Present Cost
  - 2.ECA operation profile
    - days of operation
    - time in ECA
    - continuous operation days
  - 3.Return of investment in 3 years
    - minimum 40% of ECA-SOx time
    - over 5000 tons of fuel used

- Conclusions:
  - 1.MARPOL Annex VI, 2015: 0.1%S in ECA-SOx
  - 2.Understanding of Scrubber Technology
  - 3.From cradle to grave: Life-cycle costing