DECISION FRAMEWORK FOR SHIPOWNERS TO COMPLY WITH AIR EMISSION REDUCTION MEASURES – A CASE STUDY OF METHANOL AS A FUEL

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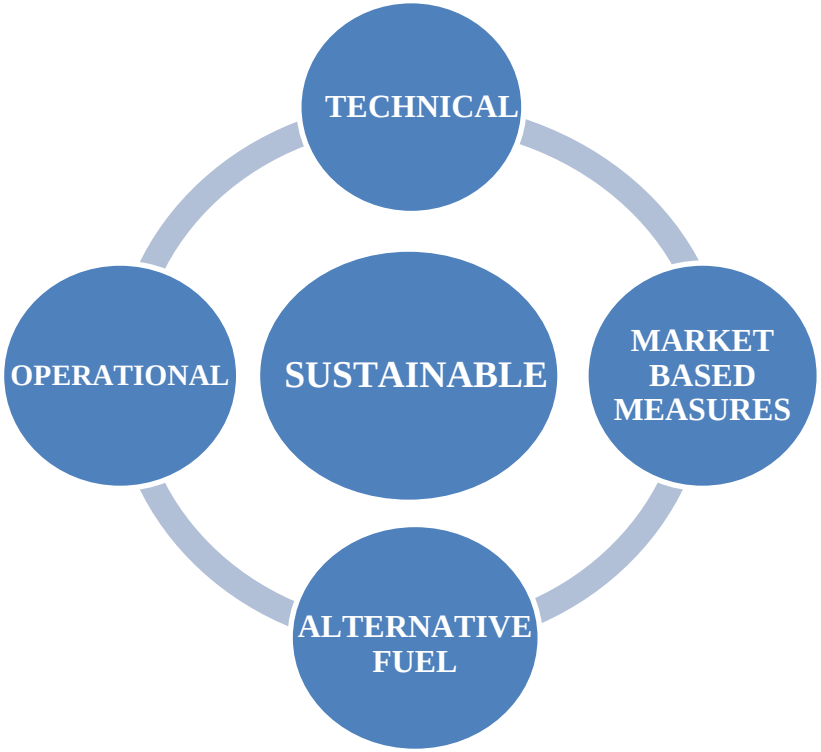
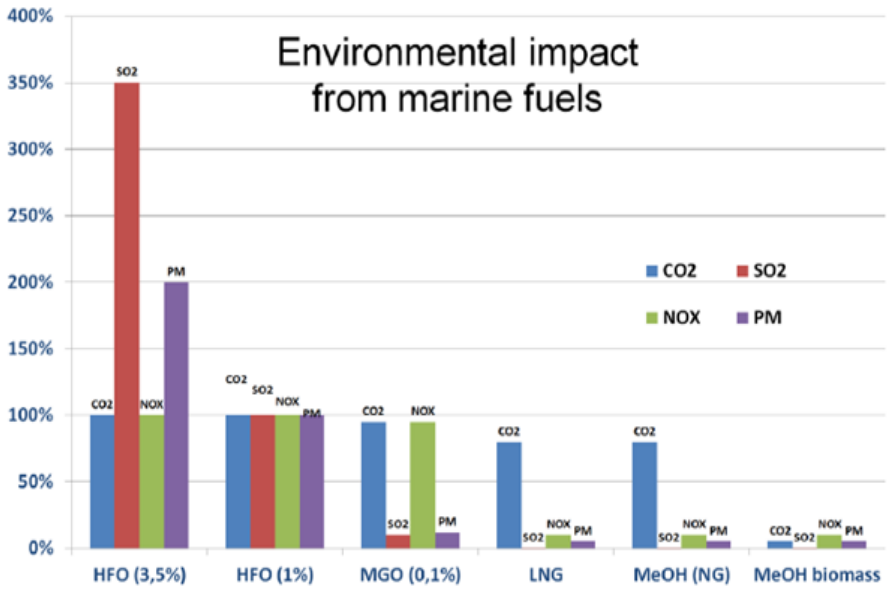
MEASURES AVAILBLE



LIMITED COMPLIANCE OPTIONS

1. HFO with Scrubber.
2. Low Sulphur Marine Gas Oil.
3. Selective Catalytic Reduction.
4. Exhaust Gas Recirculation.
5. Dual fuel engine (Liquefied Natural Gas and Methanol).

ENVIRONMENT COMPLIANCE

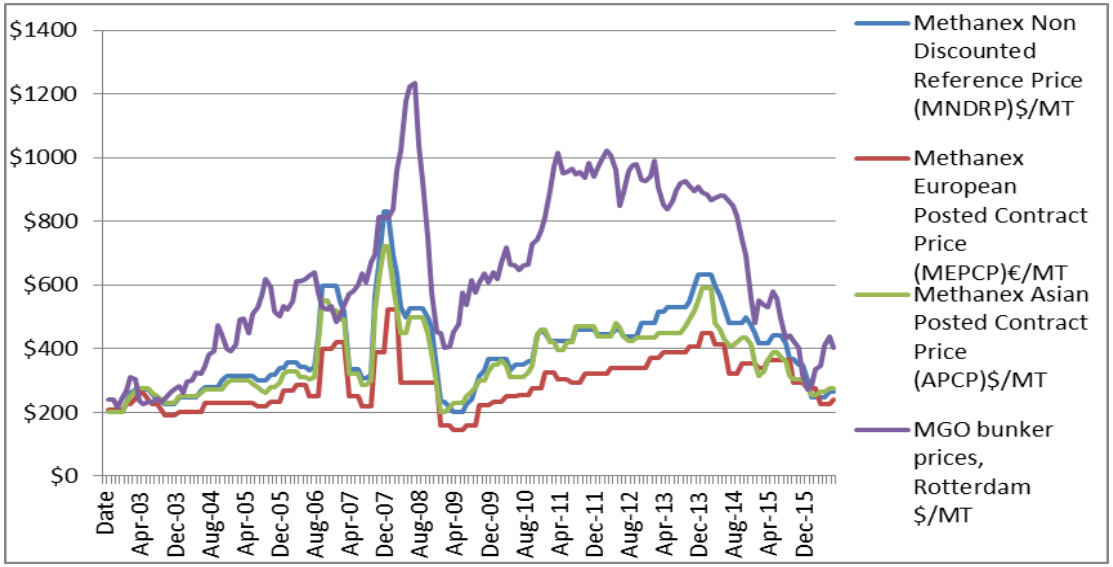


Source: Environmental Assessment of present and future marine fuels (Brynolf, 2014)

1. Globally, 100,000 Vessels consuming 372 Million of fuel (HFO and MGO) leading to emissions.
2. 60,000 deaths per year and $330 bn were spent on health costs around the world.
3. Danish Health Service report $5 bn health cost and 1000 died prematurely.

Source:https://www.theguardian.com/environment/2009/apr/09/shipping-pollution

ALTERNATIVE FUEL- COMPARISON BETWEEN MGO, LNG & MeOH



- **MGO prices are more fluctuating and expensive than Methanol.**
- **Fuel cost per unit energy is less for MeOH**
- **Less emissions in MeOH**

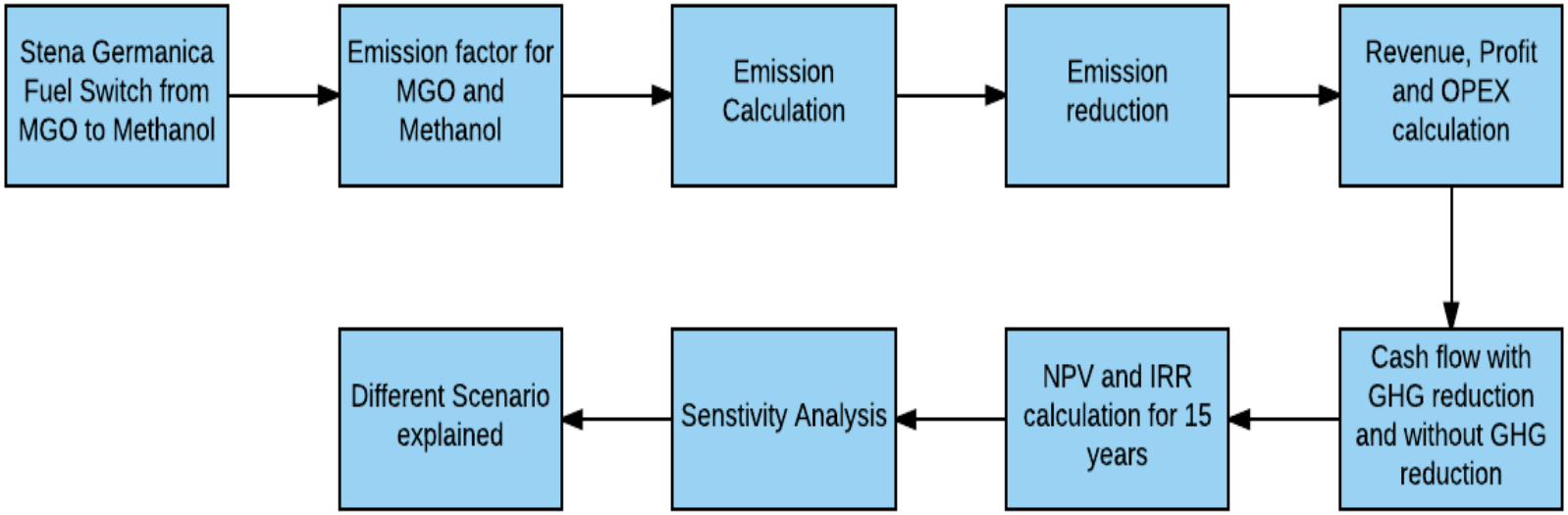
Source: Methanex and Clarkson database

- **At lower loads LNG produces Methane gas which has 25 times more Global warming potential**

	MeOH	LNG
CAPITAL COST	Less	More
MAINTENANCE COST	Less	More
STORAGE COST	400000 euros	50 million euros
RETROFIT COST	250-350 euro/Kw	1000 euro/Kw
BUNKER VESSEL	1.5 million euros	30 million euros

Source: Methanol as a marine fuel report (FCBI Energy, 2015)

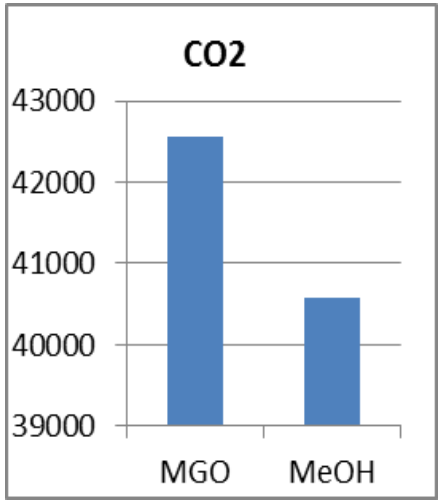
CASE STUDY OF METHANOL- STENA GERMANICA

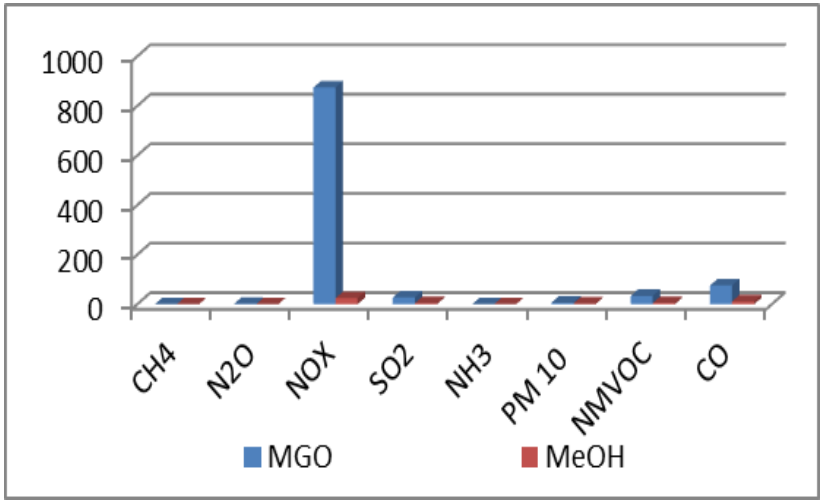


Source: http://ostseefaehren.com/minikreuzfahrt-ostsee/minikreuzfahrt-kiel-goeteborg-stena-line/

ENVIRONMENTAL BENEFIT

Air emissions when using MGO	43576.91 tCO_2e
Air emissions when using MeOH (85%) + MGO(15%)	40623.21 tCO_2e
Total reduction in air emissions in one year	2953.70 tCO_2e
Carbon tax (Sweden)	126.85 € / tCO_2

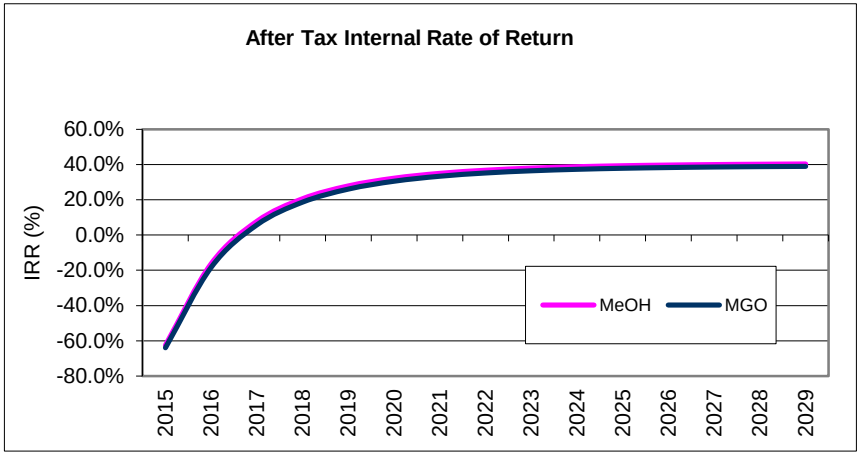




Emission Reduction

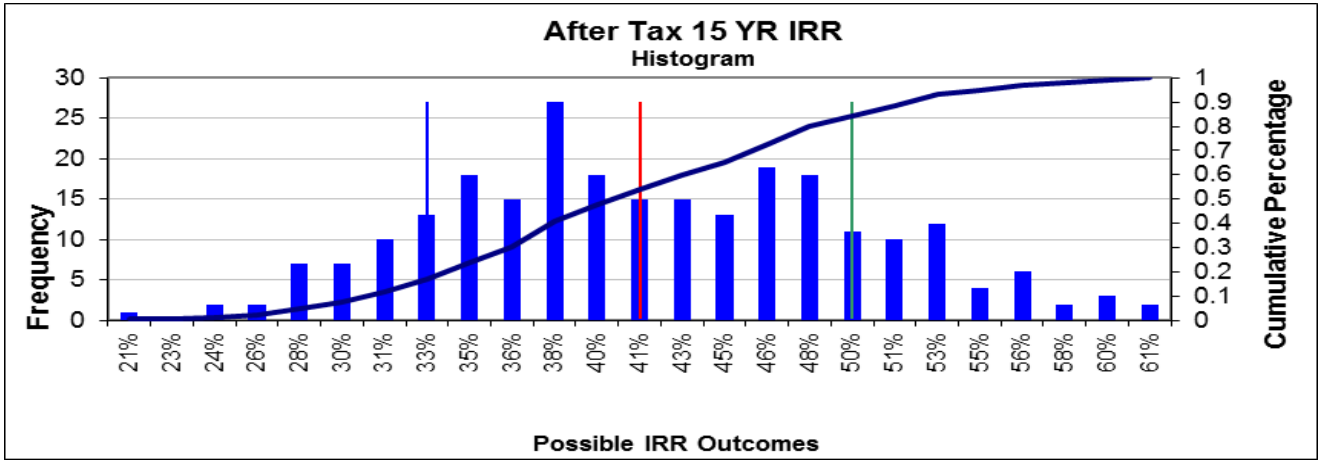
ECONOMIC BENEFIT

STENA GERMANICA	After Tax IRR	NPV (Euros)	Payback (year)
MGO	38.9%	5,01,32,044.5	4
MeOH (85%) + MGO(15%)	40.3%	5,25,21,783.1	4



IRR for Next 15 years for MGO and MeOH for Stena Germanica

SCENARIO AND SENSITIVITY ANALYSIS – MONTE CARLO SIMULATION



Scenario Analysis for price fluctuation of fuel	MGO €/mmbtu	MeOH €/mmbtu	IRR
Scenario 1	5.14	12.75	**51.27%**
Scenario 2	14.89	13.20	**22.57%**
Scenario 3	7.24	8.58	**45.03%**
Scenario 4	10.20	14.10	**36.34%**
Sensitivity Analysis Results			
Confidence Level	0.95	0.9	0.8
Max Expected IRR	**55.18%**	**52.29%**	**48.95%**
Min Expected IRR	**19.20%**	**22.10%**	**25.43%**

DECISION MAKING CRITERIA FOR SHIPOWNERS FOR AIR EMISSION REDUCTION MEASURES

CRITERIA	WEIGHT	RANK
Capex (C1)	0.58	1
Opex (C2)	0.12	3
Payback period (C3)	0.25	2
Carbon tax (C4)	0.05	4

AHP RESULT	VALUE
Consistency Index	0.07
Random Index	0.90
Consistency Ratio	0.07236

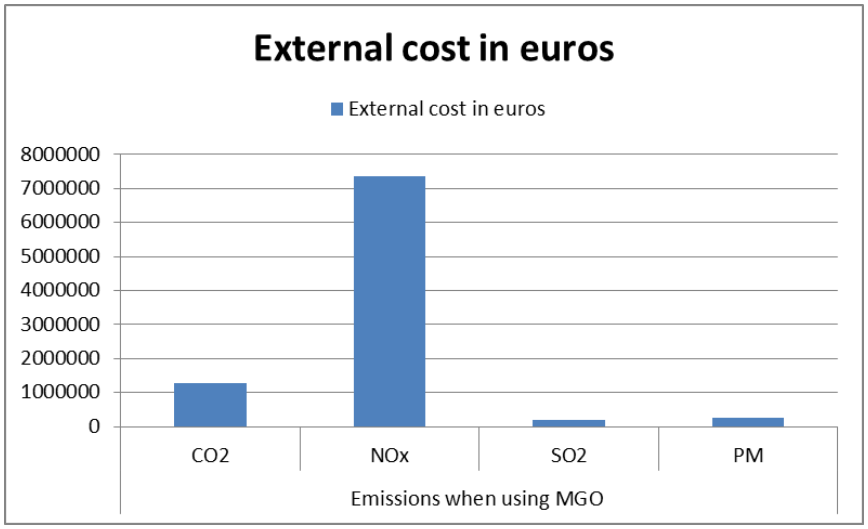
GAPS IN DECISION FRAMEWORK	RECOMMENDED CRITERIA
Future Scenarios	Impact Assessment
Environmental Implications	Health Cost Analysis, Climate Change Cost
Market Based Measures	Carbon Tax
Measurement of Air Emissions	Inventory Techniques

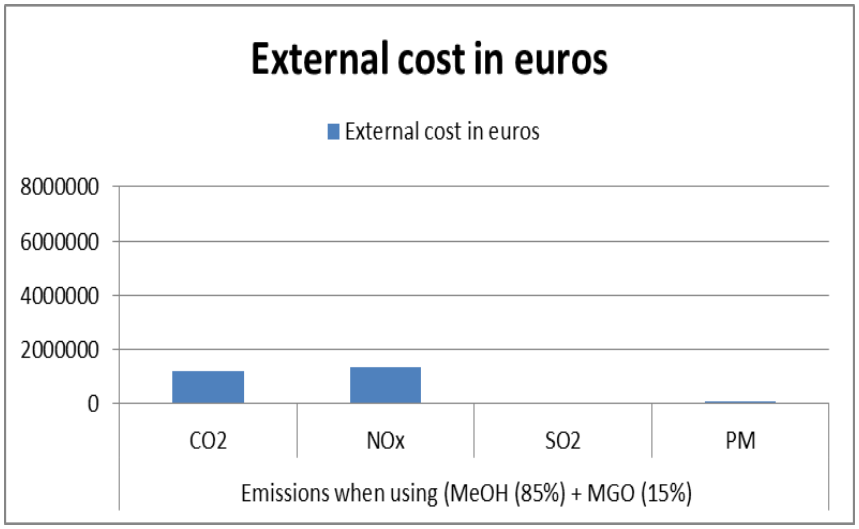
RANKING OF MEASURES AVAILABLE TO SHIPOWNERS THROUGH TECHNIQUE FOR ORDER PREFERENCE USING SIMILARITY TO IDEAL SOLUTION (TOPSIS)

MEASURES	CRITERIA				REFERENCE
ALTERNATIVES	C1 (Euros)	C2 (Euros)	C3(Year)	C4(euros)	
	0.58	**0.12**	**0.25**	**0.05**	Weighting through ahp
A1	22,000,000	25,000	4	374,656	Case study
A2	5,554,839	20,000	10	210,000	IMO EEDI appraisal tool
A3	5,483,870	182,500	3	60,000	IMO study

	MEASURES	CLOSENESS INDEX	RANKING
A1	Alternative Fuel (Methanol)	**0.36**	**3**
A2	Technical (Waste Heat Recovery)	**0.88**	**1**
A3	Operational (Scrubber)	**0.64**	**2**

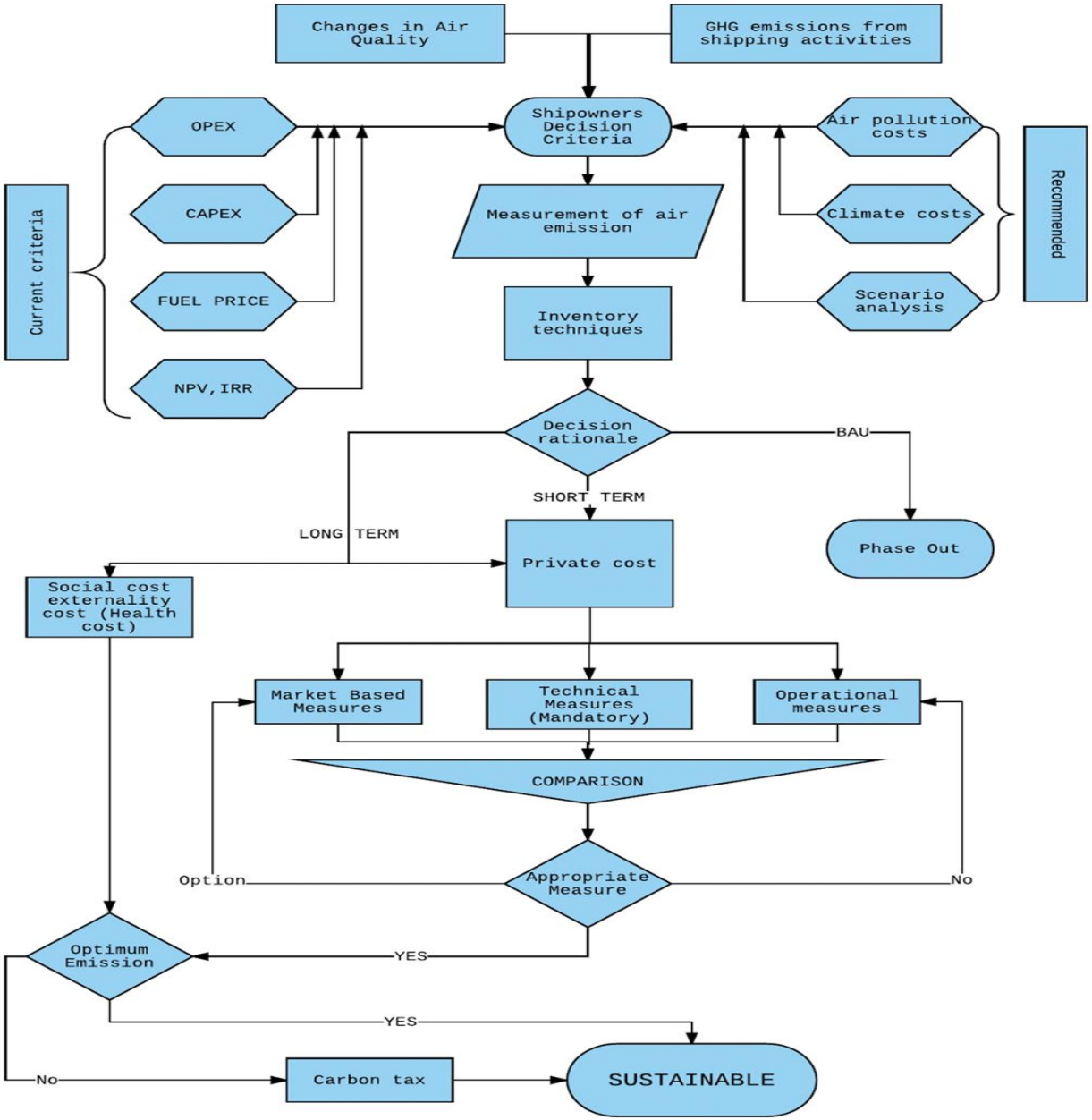
EXTERNALITY COSTS





Reduction in Climate change cost in euros	CO_2	69956
Reduction in Health cost in euros	NO_X, SO_2, PM_{10}	6346376

PROPOSED DECISION FRAMEWORK



FINDING AND CONCLUSION

1. Environment benefit: CO_2,CH_4, N_20, NO_X, SO_2, PM_{10} emissions reduced by 5%, 85%, 85%,99%,85% and 52%, respectively.

2. Economic benefit: Reduced OPEX .NPV, IRR evaluated positive and payback period is 4 years.Carbon tax avoided 374676.84 euros.

3. Scenario Analysis : IRR lies between 22.57% to 51.27% (Monte Carlo Simulation).
4. Sensitivity Analysis : At 95 to 80% confidence level Min IRR = 19.20% and Max IRR = 55.18%.
5. Externality costs : Reduction in Climate change cost: 69956 euros.
   Reduction in Health cost: 6346376 euros.
6. Ranking for Measures available to Shipowners (TOPSIS):
   1. Technical.
   2. Operational.
   3. Alternative fuel.
7. Proposed Criteria for Shipowners to include in decision framework towards SUSTAINIBILITY and profitability.
   a) Health cost.
   b) Climate change cost.
   c) Future Scenarios.

METHANOL A STEP TOWARDS THE ZERO EMISSION VISION

THANK YOU