BLUE ECONOMY
COOPERATIVE RESEARCH CENTRE

Australian Government
Department of Industry, Science and Resources

AusIndustry
Cooperative Research Centres Program

SHORT SUMMARY

1.21.002 Novel Offshore Fish Pen Design: Phase 1 (Conceptual Development)

KEY POINTS

- Using an innovation method comprising ofoptimizing, transferring and fusing to develop SeaFisher
- SeaFisher's innovative features includemodularity, submersible, HDPE frame structure,single point mooring system
- Hydrostatic and hydroelastic analysis of SeaFisherunder wave and current actions
- Power requirements and demand supply forSeaFisher
- Estimation of CAPEX and OPEX for SeaFisher

THE CHALLENGE

To obtain an offshore fish pen design and mooring system that will meet all functional and operational requirements and yet be very cost effective and storm proof.

THE OPPORTUNITY

Offshore fish pen designs are at their nascent stage. Current offshore pens are huge and very expensive in order to withstand a very energetic environment. There is therefore a golden opportunity to develop a cost-effective fish pen that is storm proof for deployment in offshore sites.

OUR RESEARCH

By using an innovation method comprising of optimizing, transferring and fusing, a conceptual design of a novel offshore fish pen named SeaFisher is developed. The SeaFisher features a modular, semi-rigid fish pen whose frame structure is made from bundles of HDPE pipes. The frame structure and the Kikkonet cage net are stiffened and strengthened by using a GFRP diagrid rods. The SeaFisher is kept in position by using a single point mooring system. Hydrostatic and hydroelastic analyses were performed to check the adequacy of the dimensions of the various components of the SeaFisher.

OUTCOMES

This Phase 1 of the project has delivered a conceptual design of a novel offshore fish pen called the SeaFisher whose modular frame structure is made from bundles of HDPE pipes and reinforced by GFRP diagrid rods. Its estimated cost is approximately A$6 million for the fish pen structure and A$8 million including the mooring system. Additionally, 1 book chapter, 9 journal papers, 5 conference papers, 1 report and 1 patent were published based on the findings of this project.

NEXT STEPS

Phase 2 of this project is to conduct model testing of the SeaFisher in a wave basin to calibrate and validate the digital model which will then be used to optimise the SeaFisher. Also, there is a need to develop the ballasting system, the depth control buoy system to ensure that the SeaFisher is kept at the desired water depth, and the essential functional requirements such as feeding, harvesting, and net cleaning.

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PROJECT PUBLICATION

Book chapter

Wang, C. M., Chu, Y., Baumeister, J., Zhang, H., Jeng, D.S., & Abdussamie, N. (2022). Offshore fish farming: challenges and developments in fish pen designs. In *Global Blue Economy* (pp. 87-128). CRC Press.

Peer-reviewed journal papers

Chu, Y. I., Wang, C. M., Zhang, H., Abdussamie, N., Karampour, H., Jeng, D. S., Baumeister, J., Aland, P. A. (2023). Offshore fish farms: a review of standards and guidelines for design and analysis. *Journal of Marine Science and Engineering*, 11(4), 762.

Wang, C. M., Chu, Y. I., Baumeister, J., Zhang, H., Qiao, Y.P., Karampour, H., Jeng, D. S., Savage, L. (2023). SeaFisher—A submersible high-density polyethylene offshore fish pen. *Journal of Marine Science and Engineering*, 11(9), 1795.

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Ma, M., Zhang, H., Jeng, D. S., Wang, C. M. (2021). A semi-analytical model for studying hydroelastic behaviour of a cylindrical net cage under wave action. *Journal of Marine Science and Engineering*, 9(12),1445.

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Ma, M., Zhang, H., Jeng, D. S., Wang, C. M. (2022). A closed-form solution for interactions between waves and an array of fish net cages. *Coastal Engineering Proceedings,* (37), 33-33.

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Conference papers

Chu, Y.I, Wang, C.M., Zhang, X., Zhang, H. and Savage, L.(2023). "Hydroelastic response of submersible opennet fish pens under wave action," *Proceedings of the ASME 2017 42nd International Conference on Ocean, Offshore and Arctic Engineering,* Melbourne, 11-16June 2023, OMAE2023-101407.

Roberts, S., Howe, D., Nader, J.R. (2023) Performancefeasibility of a multi-source offshore renewable energy platform for aquaculture. In *ASME 2023 42nd International Conference on Ocean, Offshore and Arctic Engineering.* American Society of Mechanical Engineers, OMAE2023-105346

Nguyen, H.P., Wang, C.M., Tullberg, R., von Herzen, B.(2023). "Hydroelastic analysis of floating seaweed platform", Proceedings of the *ASME 2017 42nd International Conference on Ocean, Offshore and Arctic Engineering,* Melbourne, 11-16 June 2023,OMAE2023-100857

Nguyen, H.P., Wang, C.M., Penesis, I. (2023). Review of recent research and developments on wave energy production. *Proceedings of the Third World Conference on Floating Solutions,* WCFS2023, Tokyo, Japan.

Ma, M.Y., Zhang, H., Jeng, D.S. and Wang, C.M. (2023). "A comparative study between Morison equation and screen-type method for net cages under waves and currents," *Proceedings of the ASME 2017 42nd International Conference on Ocean, Offshore and Arctic Engineering,* Melbourne, 11-16 June 2023, OMAE2023-104425.

Report

Vickers, T. (2023) Renewable Energy Infrastructure for Offshore Aquaculture: A Probabilistic Decision-Making Approach, Centre for Maritime Engineering & Hydrodynamics, University of Tasmania, Australia.

Patent

Provisional patent application number AU 2023902717 in the name of Blue Energy CRC Co, filed 24 August 2023.

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APPENDIX C - SUPPORTING MATERIALS

Aquapod Fish Pen Details (Christou et al., 2013)

Yield from various-sized Aquapod net pens							
Size of pen m^3	Radius (m)	Diameter (ft)	Approximate cost of aquapod (USD)	Final stocking density (kg/m^3)	Biomass of fish between center of pen and net	Yield per pen (kg)	Yield (kg) per capital cost of containment (kg/$)
7,000	11.87	77.8	$218,000	17	202	119,000	0.55
3,600	9.51	62.4	$140,000	21	200	75,600	0.54
212	4.04	26.7	$20,000	51	189	10,812	0.54

Aquaculture Farming Activities and Intervals (Collings et al., 2019)

Activity	Frequency	Design driving factors
Harvesting	Weekly (Biannual)	250 m^3 refrigerated hold capacity Stun and bleed system Salmon handling system
Consumable supply	Weekly	192 m^3 feed storage silos 36 m^3 diesel tanks Cargo handling system
Mortality removal	Weekly	30 m^3 mortality hold Mortality handling system
Inspection and maintenance	Weekly	Work boat Cranes 120 m^2 working deck
Anchor handling	Weekly to Annually	Anchor handing winch Crane Stern roller
Net handling	Biannually	40 tonne crane capacity 120 m^2 working deck
Net cleaning	Biannually	Net cleaning ROV ROV launch and recovery system
Stocking	Biannually	4800 m^3 tank capacity CO_2 and O_2 control system Salmon handling system
Delousing treatment	Biannually	Specialist delousing system

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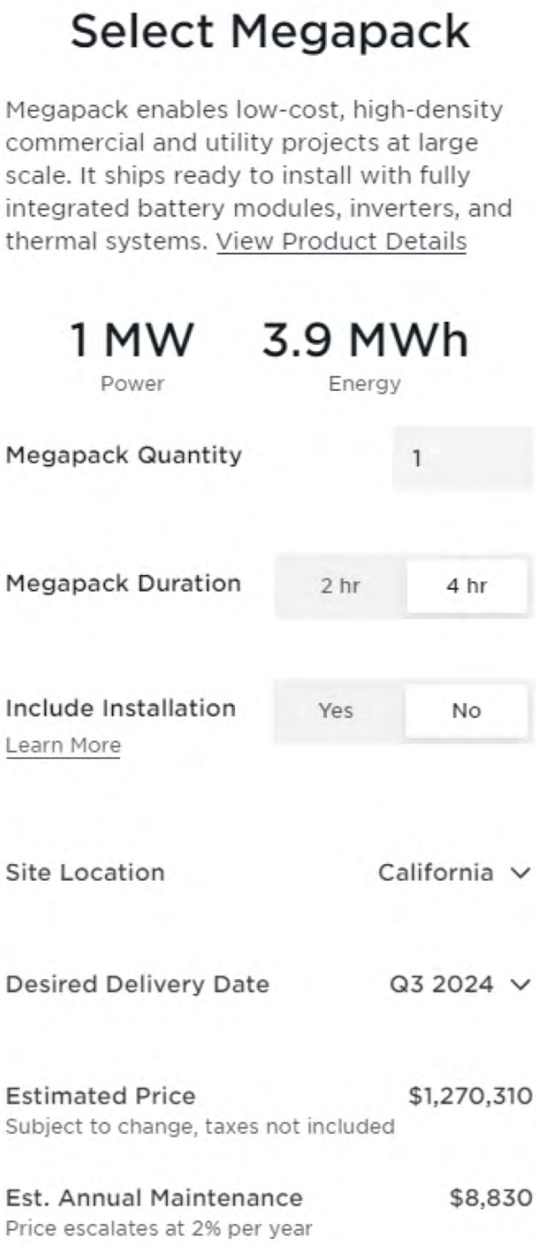
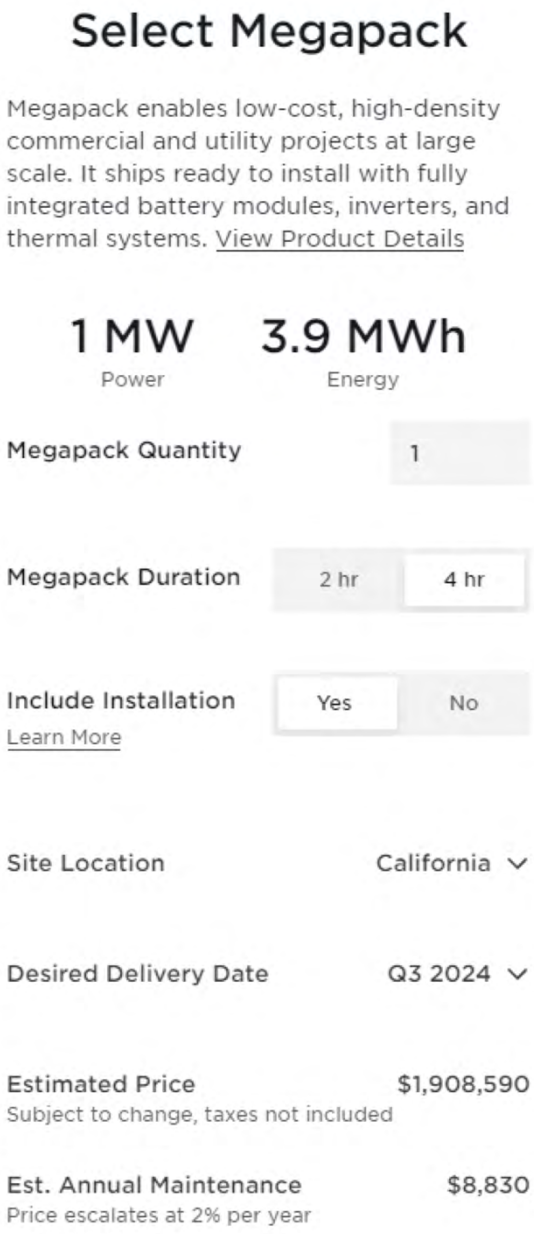
Comparison of Tesla Megapack Battery Storage Solution Cost with or without Installation





Source: www.tesla.com/megapack/design

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Cost parameters for Turkish Salmon Production Farm in 2023 (Yigit et al., 2023)

Cage type	Production and operational cost ($ US)	
	Surface cage	**Submerged cage**
Cage volume (m^3 $cage^{-1}$)	7000	7000
Variable cost		
Fish cost		
Biomass (kg/m^3)	15	15
Initial weight (kg $fish^{-1}$)	0.4	0.4
Harvest weight (kg $fish^{-1}$)[a]	3.5	5.7
Absolute growth rate (AGR, g $month^{-1}$)[b]	443.0	443.0
Initial fish per cage (# $cage^{-1}$)	30,000	30,000
Initial fish per cage (kg $cage^{-1}$)	12,000	12,000
Initial fish cost ($ kg^{-1})	4.5	4.5
Initial fish cost per cage ($ $cage^{-1}$)	54,000.0	54,000.0
Feed cost[c]		
Investment per unit production ($ ton^{-1})	1095.7	784.0
Investment per unit production ($ kg^{-1})	1.10	0.78
Feed cost ($ ton $fish^{-1}$)	2175	2175
Feed cost ($ kg^{-1} fish)	2.18	2.18
Feed cost per cage ($ $cage^{-1}$)	205,537.5	334,732.5
Total variable cost	**259,537.5**	**388,732.5**
Fixed cost		
Production period (PP, months)	7	12
No. of employees per cage	2	2
Salary per employee per month ($)	1100	1100
Salary per employee per production period ($)	15,400	26,500
Fuel cost per production period ($)	21,000	36,000
Health maintenance per production period ($)	400	400
Other operating costs per production period ($)	5000	5000
Annual depreciation rate (%)	10	10
Annual depreciation cost per farm ($)	10,354.0	12,065.0
Total fixed cost	**52,154.0**	**79,865.0**
Total cost (variables and fixed cost)	**311,691.5**	**468,597.5**

Values in bold indicate variable costs, fixed costs and the sum of total variable -and fixed costs for surface and submerged cages

[a]Harvest weight: a fish grow-out from an initial weight of 400 g to a harvest weight of 3000 g in a 7-month period is a predominant farming practice for Turkish salmon in the Black Sea

[b]The harvest weight of fish in submerged cage was estimated using absolute growth rate (AGR) obtained from actual AGR of Turkish salmon in surface cage over the 7-month grow-out period and applied for the fish in submersible cage for 12-month grow-out period that resulted in 5700 kg

[c]Feed cost calculated according to 1.65 $ kg^{-1} feed price and FCR value of 1.5

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