‘Namgis

simply pure salmon

Strategies for Significant Heat Loss Reduction in RAS Using Modern Energy Recovery Equipment

by

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Background & Motivation

- SOS Marine Conservation Foundation was formed in 2006
  - A solutions focused organization with a mandate to resolve environmental impacts associated with ocean net-pen salmon farms
  - Advocates industrial migration to land-based closed containment

- Mandate to demonstrate technical, biological and economic feasibility of producing market size Atlantic salmon on land
  - ‘Namgis closed containment Atlantic salmon farm
  - First 470MT module of a five module commercial facility
  - Full suite of performance monitoring metrics
    - Economic
    - Fish Health
    - Environmental

The ‘Namgis Farm

- Located 5km south of Port McNeill
- Owned by the ‘Namgis First Nation
- Jointly funded by Tides Canada, ‘Namgis Nation and the Federal Government
- SOS is a project partner with technical oversight
- Construction started in 2012 with commissioning January 2013
- Operating costs are central to profitable operation
  - Feed, Power, Labour
- Minimizing power consumption is integral to competitive performance when compared with ocean net-pen operation

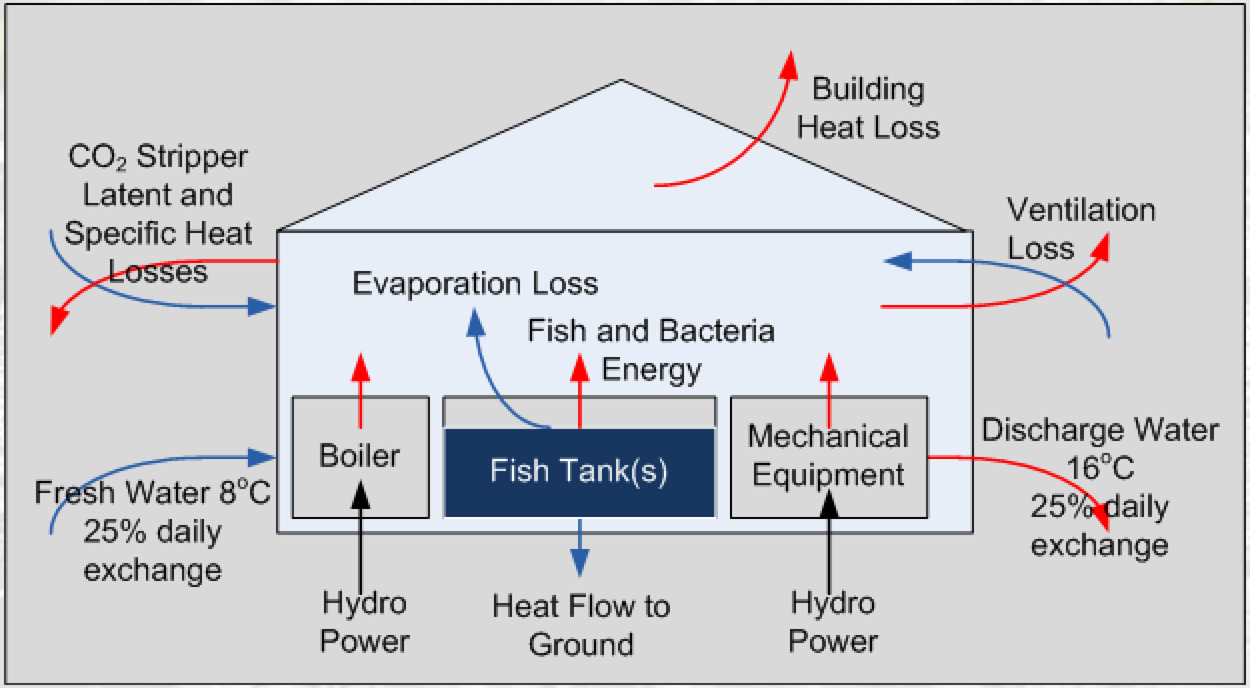
Basic Farm Module Attributes

- Baseline design, provisioned by the system architects
  - 470MT annual production – 3 cohorts per year
  - Sequential harvest over-stock strategy yields 5-6kg market size and 2-3kg table weight fish
  - Bio-plan based on 15-16^{o}C culture temp, TGC 2.5 and a 12-15 month grow out as per Freshwater Institute’s experience with a peak density of 90kg/m^3
  - Module one of a five module 2500MT facility
  - 3000m^3 footprint (35m x82m)
  - 1x 250m^3 quarantine tank 5x500m^3 grow out tanks and 1x250m^3 purge tank
  - Bio-isolated farm, UV, Ozone and brackish well water
  - Allows for chemical therapeutant, pesticide and potentially vaccine free fish to be raised

Water Quality Parameters

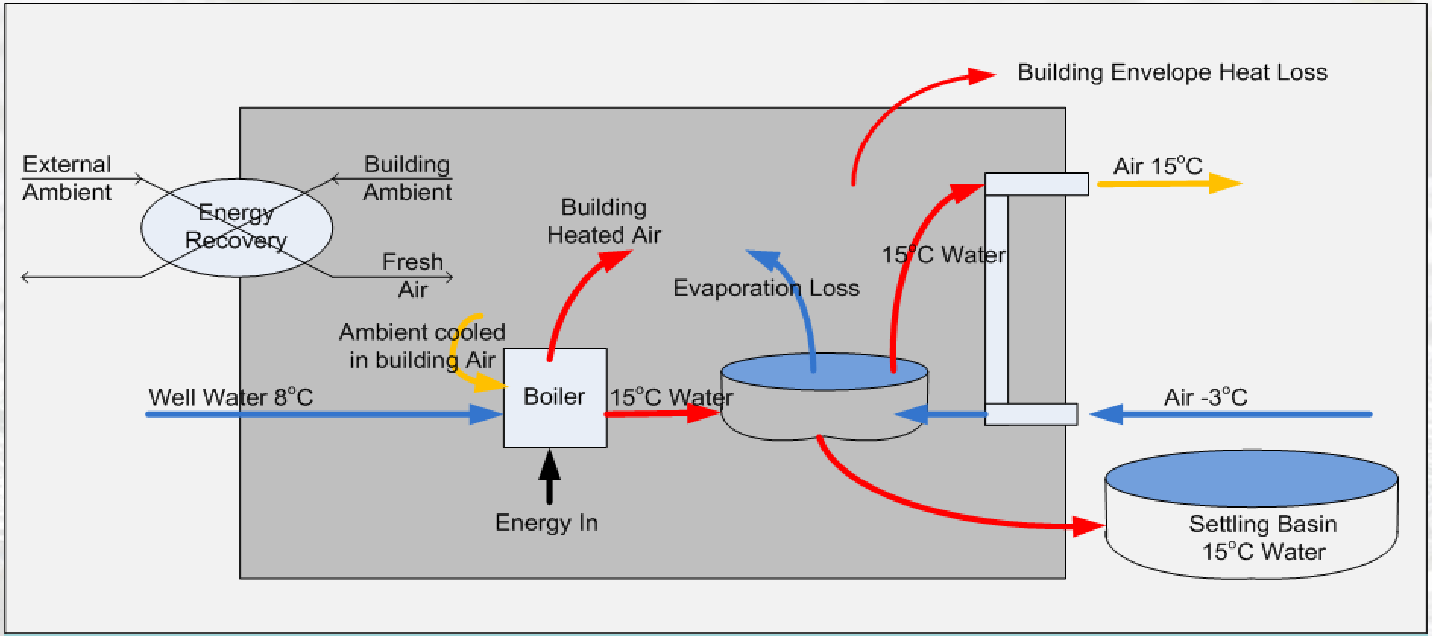
Water Quality Parameters	Level	Units
Max un-ionized Ammonia Max Ammonia Max Nitrate	0.01 2 75	mg/l NH_3 - N mg/l NH_3 - N mg/l NO_3 - N
Range $C0_2$	12 20	mg/l mg/l
TSS	10	mg/l
O_2	100	% saturation
Tank retention time	45	mins

Initial Recommended System Design



- 25% daily discharge of warm culture water
- Stripper draws from and vents to the external environment (10:1 G:L ratio)
- The proposed design was the equivalent of a jet bath tub with the plug out
- The technical review team anticipated the heating bills would be extreme!

Baseline - Heating Loads at -3ºC 90% Humidity



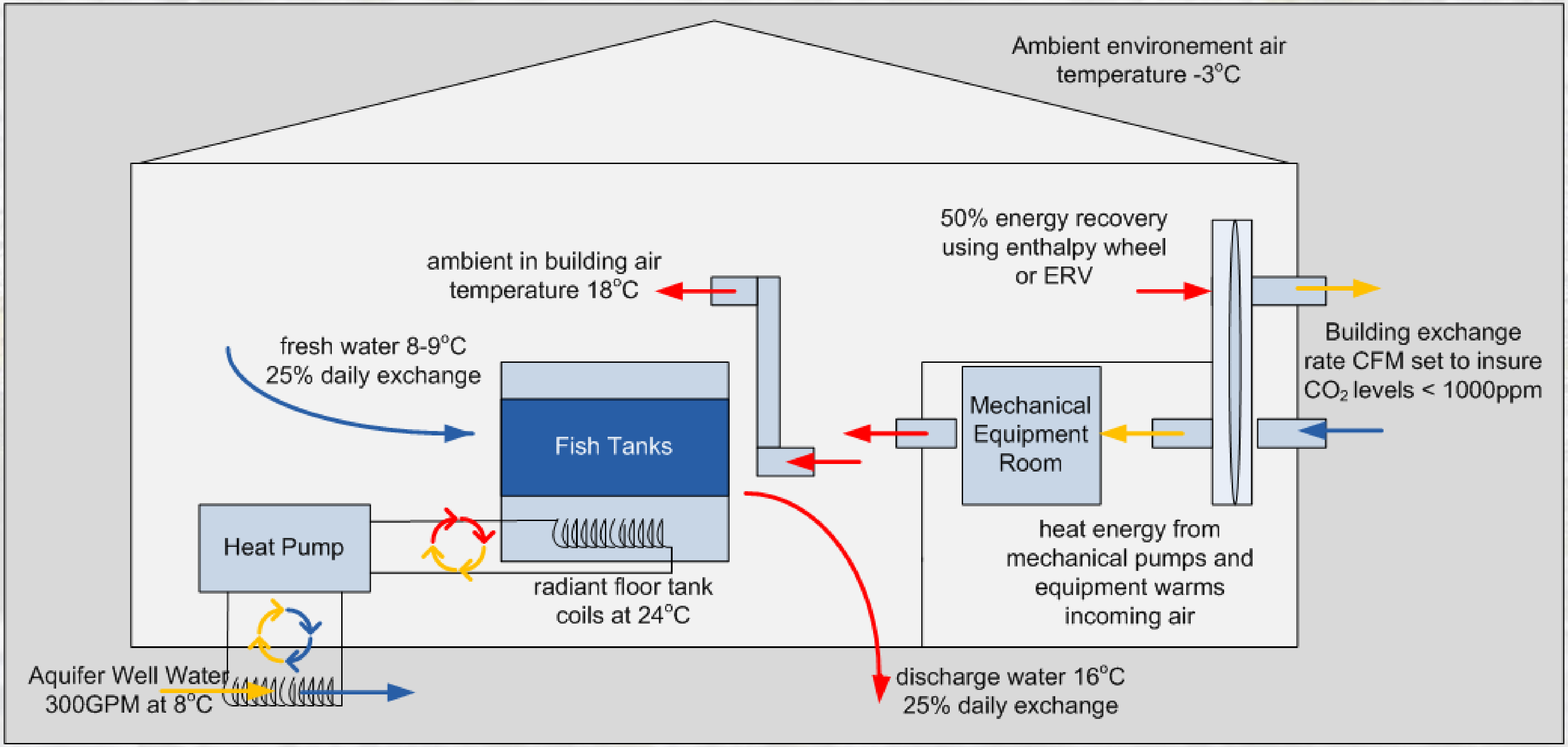
Energy Losses		Yearly Cost To Operate	
Stripper Loss	1.78 e6 btuH	Propane	$540,000.00
Evaporation loss	0.17 e6 btuH	Direct Electric Heat	$380,000.00
Effluent water loss	0.90 e6 btuH	Heat Pump COP 4	$95,000.00
building envelope loss	0.22 e6 btuH	Heat Pump COP 6	$64,000.00
building ventilation loss	0.30 e6 btuH		
		based on Port Hardy weather on an 8 hour min/mean/max	
Fish and biological heat	-0.50 e6 btuH	integration over historical data over a full year	
equipment heat	-0.32 e6 btuH		
Total	2.55 e6 btuH		
Total	750 kw		

Core Loads – Scales of proportion

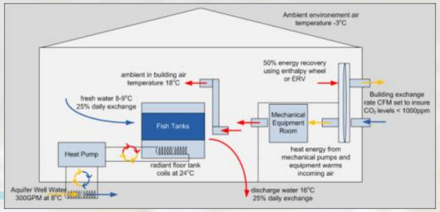
Item	Load btuH	Rounded Load btuH
CO_2 Stripper	1.78e6	**2e6**
Evaporation loss	0.17e6	0.2e6
Effluent water loss	0.9e6	**1e6**
Building envelope Loss	0.22e6	0.2e6
Building ventilation loss	0.3e6	0.3e6
Fish and biological heat production	-0.5e6	-0.5e6
Mechanical heat production	-0.32e6	0.3e6
Total	2.55e6	2.9e6

- Energy losses from CO_2 Stripper and effluent water dwarf all other losses
- Key to reducing energy consumption is to address these losses

Proposed Efficient Design

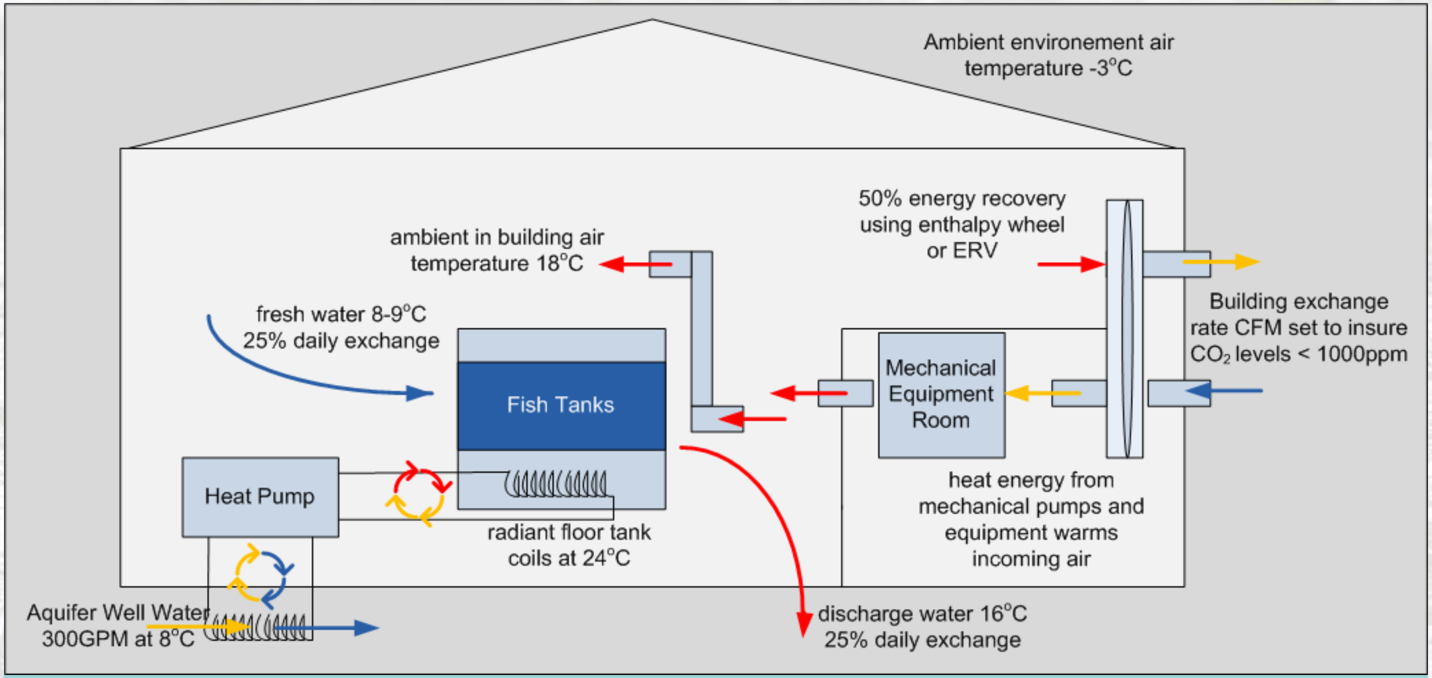


Technical Attributes



- CO_2 stripper draws and vents air within the building
- Ambient 18°C ensures vented 100% saturated 16°C air does not condensate
  - small enthalpy delta ensures non-condensating exhaust
- Mass balance equations define the ERV air exchange rate to be 33% of the stripper's rate
  - maintains moisture at less than 90% relative humidity
  - maintains CO_2 at less than 1ppt within the building
  - ERV efficiencies peak during wide temperature and humidity deltas between exhaust and intake – ideal for -3°C winters
- Eliminates concerns of boiler sizing to address rapid external temperature changes since external fluctuations play a small role
  - Design target of no greater than 1°C per day change in the culture temperature to avoid stressing the fish
- Radiant heat in-floor tank heating of the culture volume allows maximum COP to be attained by the heat pump with a small delta between thermal source and sink

Energy Efficient Design - summary of loads at -3ºC



Energy Losses		
Stripper Loss	0.11	e6 btuH
Evaporation loss	0.13	e6 btuH
Effluent water loss	0.90	e6 btuH
building envelope loss	0.22	e6 btuH
building ventilation loss	0.30	e6 btuH
tank floor loss	0.03	e6 btuH
Fish and biological heat	-0.50	e6 btuH
equipment heat	-0.32	e6 btuH
Total	0.87	e6 btuH
Total	250.00	kw

Yearly Cost To Operate	
Propane	$180,000.00
Direct Electric Heat	$128,000.00
Heat Pump COP 4	$32,000.00
Heat Pump COP 6	$22,000.00

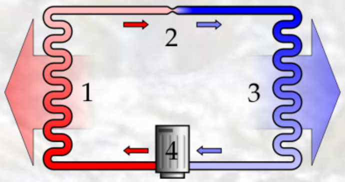
based on Port Hardy weather on an 8 hour min/mean/max

integration over historical data over a full year

Specific Innovations

- In-floor radiant heat
- Heat pumps
- Enthalpy wheel
- System design approach
- Next steps

Innovations - Heat pumps and radiant in-tank heating coils

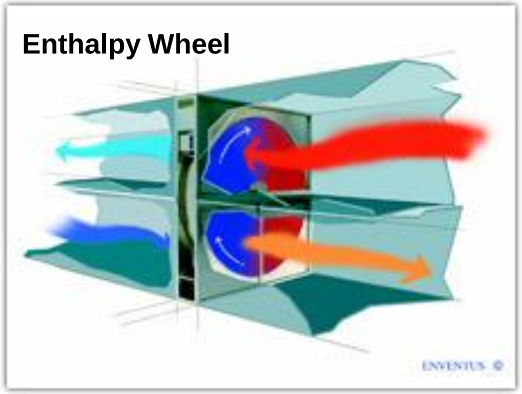


- Heat pumps exploit the Carnot cycle, moving thermal energy from a heat source to a heat sink
- The Coefficient of Performance (COP) is defined by
  - $COP \leq T_{hot}/(T_{hot}-T_{cold})$
  - for each unit of energy expended by the compressor, COP units of energy are transferred into the heat sink
- Particularly efficient in low temperature differential applications
  - The energy source T_{cold}, is 8^{o}C well water
  - Energy sink is the culture volume at 16^{o}C
  - In RAS the energy condenser is the heat exchanger injecting thermal energy into culture water with a T_{hot} of 30^{o}C
- Theoretical COP = 12, practical compressors limit COP to 4.5 ~ 7
- Low temperature delta requires a huge surface area heat exchanger
  - Structural tank floor concrete has a thermal conductivity of 1.63 W/mK (3x higher than standard residential light flooring concrete) and allows 5/8inch pex radiant heating pipes at 8 inch spacing to be utilized, 3 spirals zones per tank.

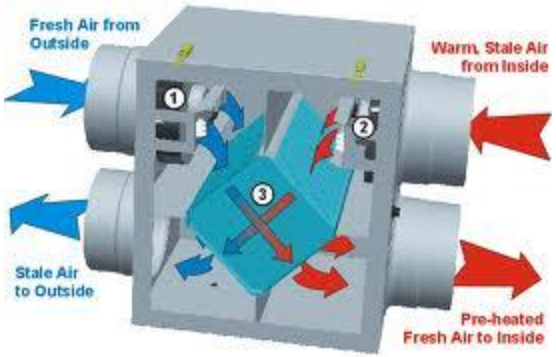
Enthalpy Wheel / Energy Recovery Ventilators

- Transfers both latent and specific heat from exhaust air to incoming air
- Composite aluminum and desiccant wheel that revolves between the exhaust and intake airstreams
- Aluminum transfers specific/sensible heat
- Desiccant and/or porous material transfers latent heat
- Available in a non-moving part configuration as an energy recovery ventilator
- Achieves a range of energy transfer performances from 50% to 90% depending upon moisture and temperature differentials between the air flows

Enthalpy Wheel



Energy Recovery Ventilator



Commercial Technology Offerings and Economics

- Utilizing two industrial/commercial heat pumps specified to produce 35 ton heat each at a COP > 5 for a 8^{o}C source 30^{o}C (22^{o}C delta)
- Energy recovery wheel capable of 10000 CFM
- Capital and installation cost is currently estimated to be $\leq$\$900k
- Simple pay back
  - Propane baseline opex = \$500k - simple pay back <2 years
  - Resistive electrical heating opex = \$400k - simple pay back <3 years
- Capital costs are at the cusp between industrial and commercial level equipment, further energy saving strategies will reduce capital costs since lower cost commercial grade equipment can be utilized rather than industrial class

Future Innovations – Waste water heat recovery

Energy Losses			
Stripper Loss	0.11	e6 btuH	
Evaporation loss	0.13	e6 btuH	
Effluent water loss	0.45	e6 btuH	<- 0.9
building envelope loss	0.22	e6 btuH	
building ventilation loss	0.30	e6 btuH	
tank floor loss	0.03	e6 btuH	
Fish and biological heat	-0.50	e6 btuH	
equipment heat	-0.32	e6 btuH	
Total	0.42	e6 btuH	
Total	124	kw	

Yearly Cost To Operate	
Propane	$90,000.00
Direct Electric Heat	$64,000.00
Heat Pump COP 4	$16,000.00
Heat Pump COP 6	$11,000.00

based on Port Hardy weather on an 8 hour min/mean/max

integration over historical data over a full year

- Current design does not reclaim heat from 16ºC effluent water
- If just 50% of this could be recovered further significant savings in both operating and capital costs could be made
- Water quality has high suspended solids (fish poop); means plate and tube heat exchangers foul and can not be used.
- De-nitrification – simply cut the discharge rate

Considerations for Mass Balance Design Stage Interaction

- Single loop RAS designs are defined by mass balance for each process
  - hydraulic retention time & equipment sizing set by the fastest rate
  - results in higher power consumption
  - excess capital cost to accommodate process rates that are non optimal
- Inclusion of supplementary side loops for specific processes has allowed optimized power consumption and capital equipment sizing.
- But heating (cooling) has been considered independently.
- However, RAS designs for salmon require:
  - very high water quality targets
  - lower husbandry densities
- Heating (& cooling) is inextricably linked to the basic processes
  - heating capital costs are directly coupled to nitrate levels, CO_2 levels and TSS
- Thus, a design paradigm that acknowledges these interactions is required to ensure optimal designs for salmon RAS farming.

Recommendations

- Integrated design flow
  - Acknowledge that heat, pumping regime, water quality are all interconnected
- Flexible air venting strategy to permit active “free” cooling
- Flexible effluent control to allow “free” cooling
- Tight systems allow net zero heat energy consumption regimes to be approached

Conclusions

- British Columbia offers significant first mover advantages for a wide scale land-based closed containment salmon farm industry
  - Access to source water
  - Smolt availability (Coho & Atlantic)
  - Localized feed production industry
  - Trained employee and skill set base (Gov. & Industry)
  - Access to low lease Crown land & First Nation Land
  - Lowest continental power costs
  - Low – near zero GHG power
  - Nascent equipment industry (Pr Aqua - Point 4 etc)
  - Investor tax credits
  - AIMAP – DFO funding programs

Come to BC, invest, profit and help protect wild eco-systems

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