THE CONSERVATION FUND

Atlantic Salmon Federation

Research & Environment Committee Meeting

The Conservation Fund - Freshwater Institute Annual Update

November 13, 2013
University Club
New York, NY

Outline

1. Atlantic Salmon Growout Trials in Freshwater Closed-Containment Systems at the Conservation Fund Freshwater Institute

2. Land Based RAS and Open Pen Salmon Aquaculture: Comparative Economic and Environmental Assessment

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Atlantic Salmon Growout Trials in Freshwater Closed-Containment Systems at The Conservation Fund Freshwater Institute

Steven Summerfelt, Thomas Waldrop, John Davidson, Christopher Good

Acknowledgments

- Support for **TCF/FI**:
  - **U.S. Department of Agriculture - Agricultural Research Service**
    - 1st salmon studies finished in 2011
    - Gaspe and St. John River strain
  - **Atlantic Salmon Federation**
    - 2nd Growout Trial finished April 2012
    - St. John River strain salmon at 40 kg/m^3
  - **Gordon & Betty Moore Foundation**
    - 3rd Growout Trial finished April 2013
    - Cascade strain salmon at 100 kg/m^3
  - **GBMF and ASF**
    - 4th Growout Trial to finish April 2014
    - Cascade strain salmon with two photoperiods and 120 kg/m^3 biomass density

Land-based, closed-containment systems

- Exclude chemicals and obligate pathogens
  - No pesticides, antibiotics or chemotherapeutics in closed-containments systems w/over 10 years of operation at TCF/FI
- Prevent escapees and interaction between wild and farmed fish
- Minimize water use and release of pollution
- Optimize water temperature and photoperiod
- Locate farm in best location and away from sensitive ecosystems

Atlantic Salmon Growout Trial

- Atlantic salmon - Cascade Strain
  - Eggs purchased from American Gold Seafood (WA)
- Jan. 5, 2011 Eyed eggs received
- Jan. 21, 2011 50% hatch (Day 1)
- Feb. 23, 2011 First feeding (Day 34)
- Aug.–Sept. 2011 Photoperiod manipulated to S0 smolt
- March 12, 2012 Moved into growout system (Day 417)




Atlantic Salmon Growout Trial

Growout System

- 145 m^3 Culture Tank Volume
  - 4,900 L/min recirc flow
  - 30 min HRT
- 260 m^3 System Volume
  - 45 L/min mean makeup
  - 8 to 150 L/min makeup
  - 4 day HRT (1.2–23 days)
  - 99.8 to 96.9% flow reuse

High flushing rate to keep water ≤ 17°C in summer

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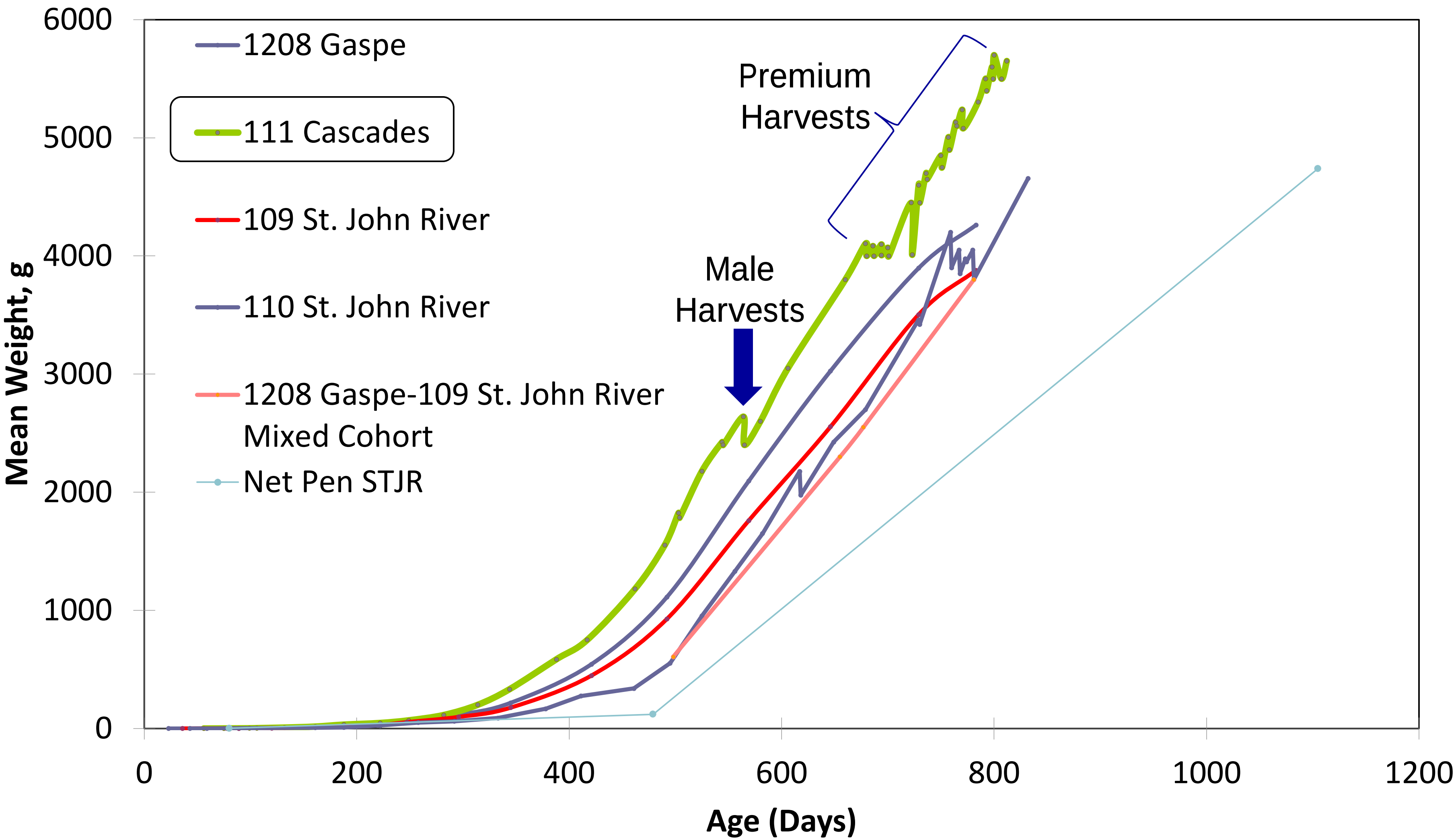
Atlantic Salmon Growout Trial



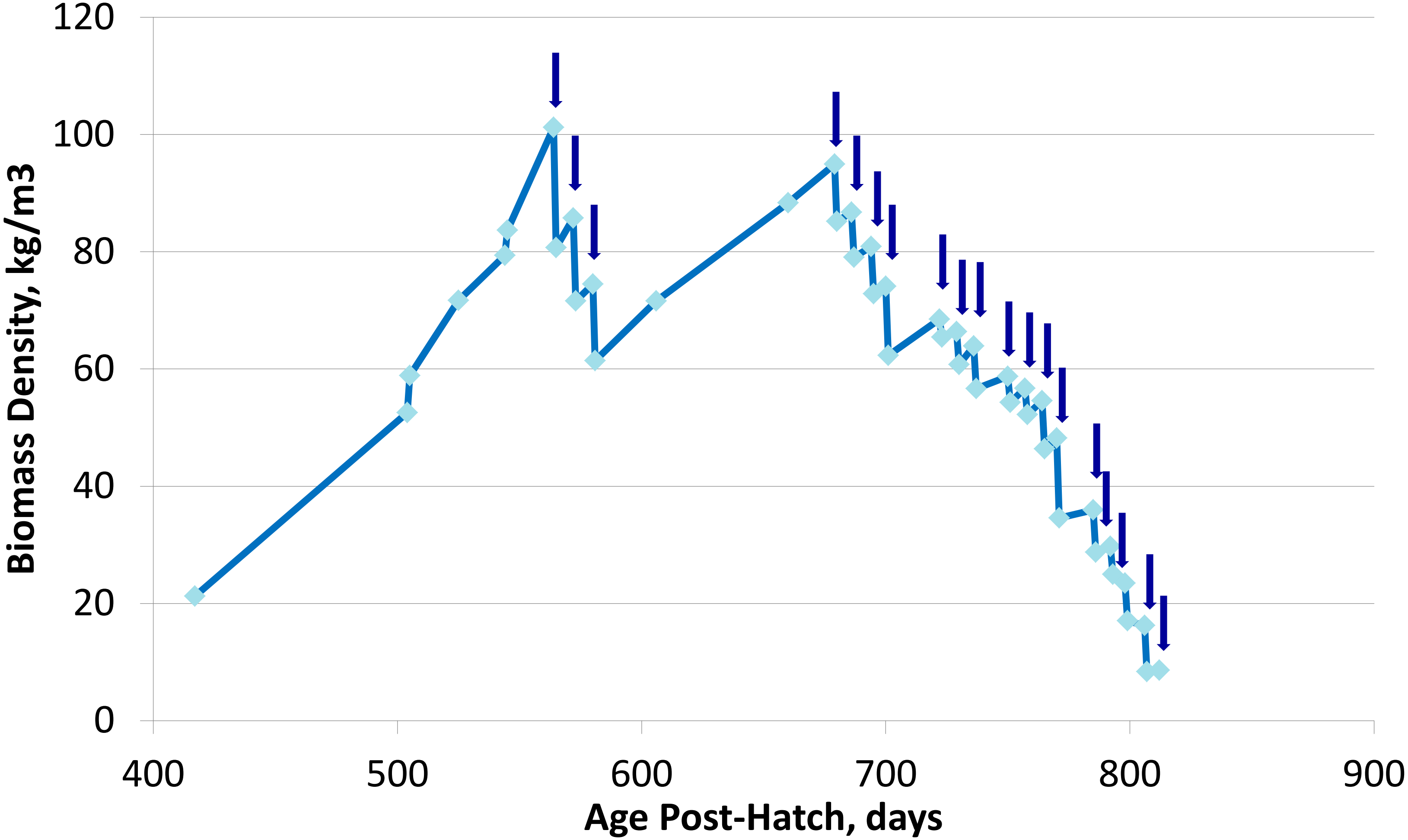
Atlantic Salmon Growout Trial

Milestones

- 430 g Post-smolt at 12 months post-hatch
- Maturing Male Harvests
  - 2.6 kg mean size
  - August 6, 14, 22 (2012)
  - Days 564, 572, 582
- Premium Salmon Harvest
  - 4.2 to 5.6 kg mean size
  - Nov. 29 (2012) to April 11 (2013)
  - Days 679 to 812
  - 16 harvest events (approx. weekly)

Atlantic Salmon Growout Trial

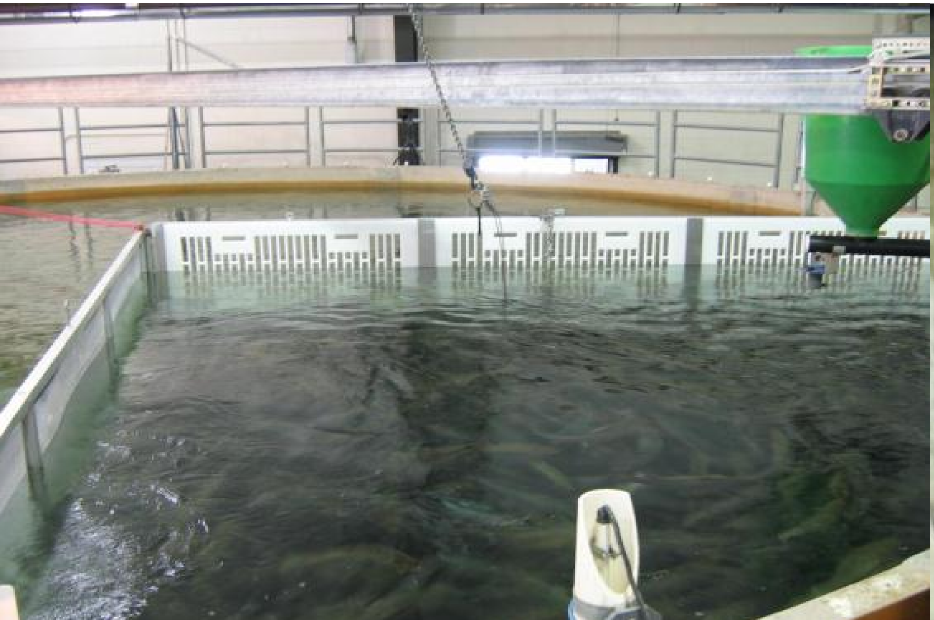
Salmon Biomass Density



Arrows Indicate Harvest Events

Maturing Male Harvest

- 37% of the population harvested August 2012
  - Biomass density of 100 kg/m^3
  - **All maturing males** (slightly larger than females)
  - Mean fish size of 2.64 kg
  - 5.4 metric tonnes (12,000 lbs)
  - Sold to a local processor for hot smoking



Premium Harvest

- Premium salmon:
  - 4.3 kg mean size achieved in early December 2012
    - 22.6 months post-hatch
  - Biomass density reached 94 kg/m^3
    - Good fin condition
  - Produced 17.5 metric tonnes (38,500 lbs)

- Total Harvest (maturing male + premium)
  - 23 metric tonnes (50,600 lbs)

Atlantic Salmon Growout Trial

Loss

Mortality	2.7%
Culls	3.9%
Jumpers	0.4%
Total	7.0%

Feed Conversion Ratio

- FCR of 1.07
- Commercial diet with 40% protein and 30% fat

Atlantic Salmon Growout Trial

Disease Status

- No sea lice
- No obligate pathogens
- No kudoa

Treatments

- No vaccination (saves $$ and fish stress)
- No antibiotics or pesticides used
- No formalin used
- Hydrogen peroxide (H_2O_2) used in the sac fry and early parr stage to treat fungus
- Salt used to treat fungus: 14,400 lbs.

Atlantic Salmon Growout Trial

- No escapees - One parr removed from the effluent exclusion area

Atlantic Salmon Growout Trial

Product Quality

- 56.6 ± 0.6% skin off and trimmed fillet yield
  - after 11-day depuration
- 1.77 ± 0.05 g/mm^3 condition factor
  - net pen industry is approximately 1.3
- 15.2–17.0% lipid content in fillet

Product Quality

- Good fillet color (26-28) & lipid content (15-17%)

Conclusions

- Good growth in freshwater
  - Harvest 9–10 months sooner than net pens
  - Seawater not required!
- Good survival (93%) and feed conversion (1.07)
- Density can reach 100 kg/m^3
- Should use all female eggs to avoid precocious males

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Acknowledgments

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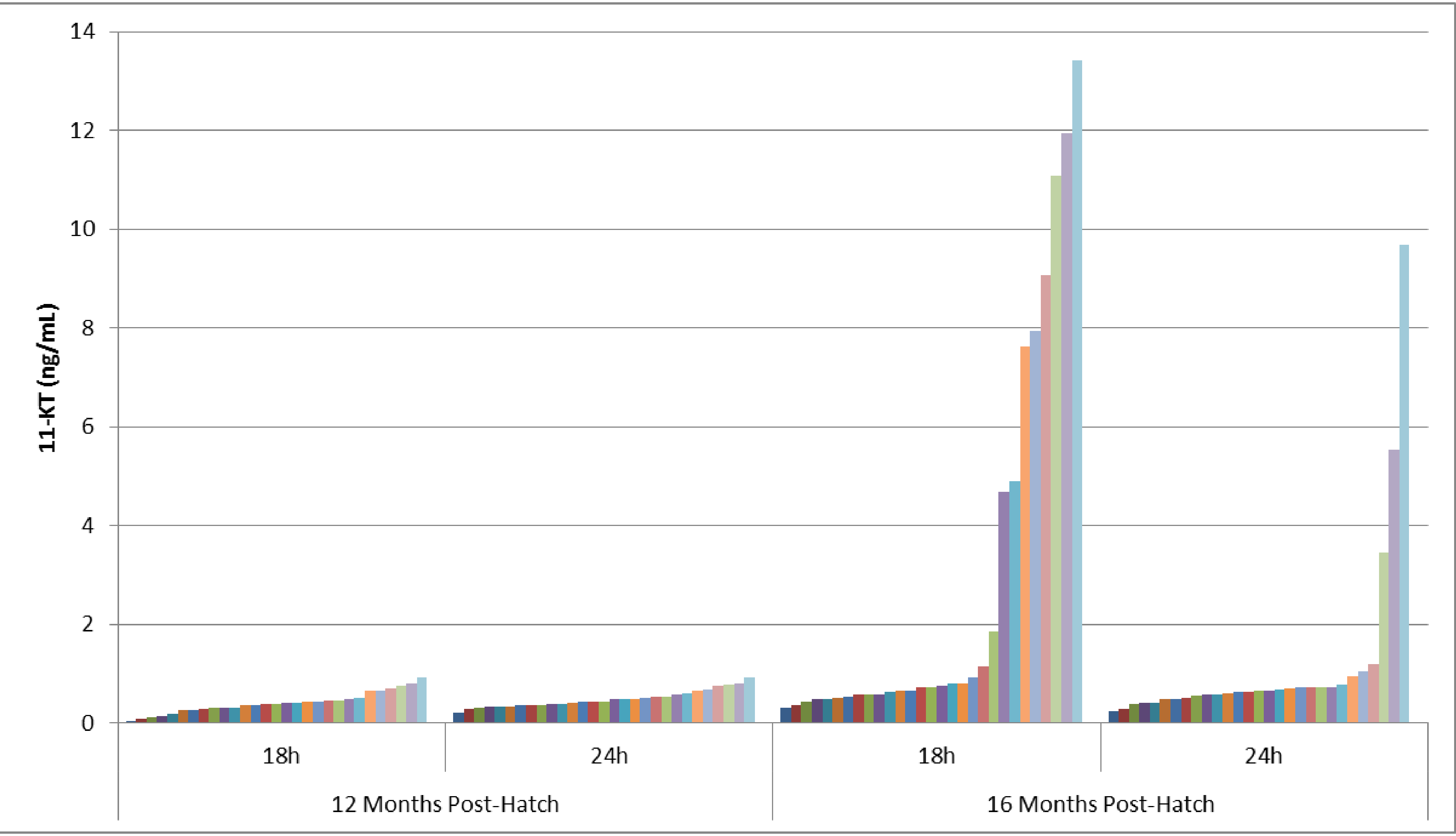
Maturation Assessments

Photoperiod Effect

Two treatment groups:

- 24-hour continuous light
- 18-hour light : 6-hour dark

Maturation Assessments



Maturation Assessments

Photoperiod Effect

- Mature males at 16 months:
  - 18-hr light : 6-hr dark = 23%
  - 24-hr light = 10%

- GSI vs 11-KT:
  - 18h:6h correlation coefficient = 0.1808 (p=0.3538)
  - 24h correlation coefficient = 0.4613 (p=0.0103)

- Additional sampling at 2.5 kg and 5 kg

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Land Based RAS and Open Pen Salmon Aquaculture: Comparative Economic and Environmental Assessment

Trond W. Rosten, Kristian Henriksen, Erik Skontorp Hognes

SINTEF Fisheries and Aquaculture
Norway

Brian Vinci, Steven Summerfelt

The Conservation Fund
Freshwater Institute
USA

Agenda

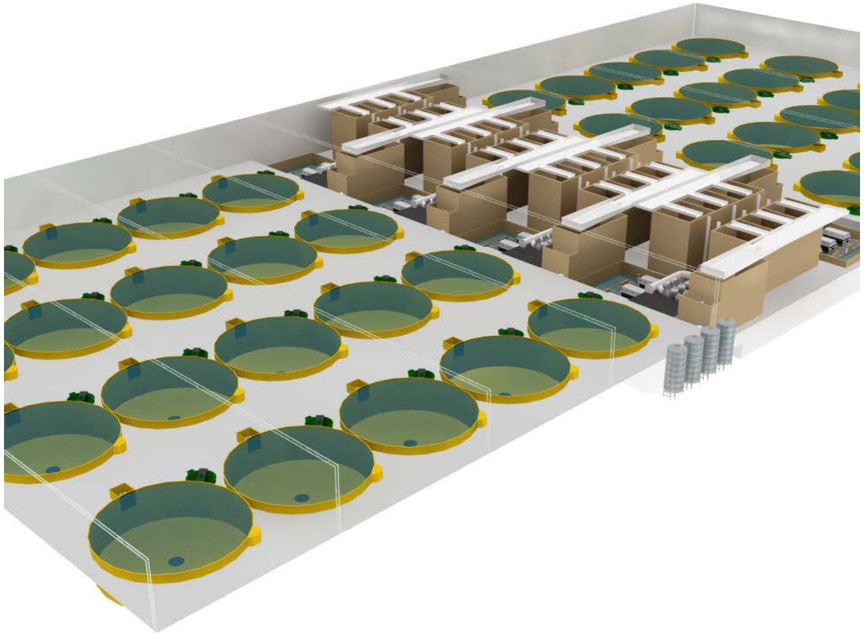
- **Hypothesis**
    - Assumptions
- **Production plan, estimated feed consumption and harvesting plan**
- **Financial comparison**
    - Investments
    - Financial assumptions
    - Production cost, cashflow and net present value
- **LCA Comparison**
    - Assumptions LCA
    - Results comparison LCA
- **Conclusion**

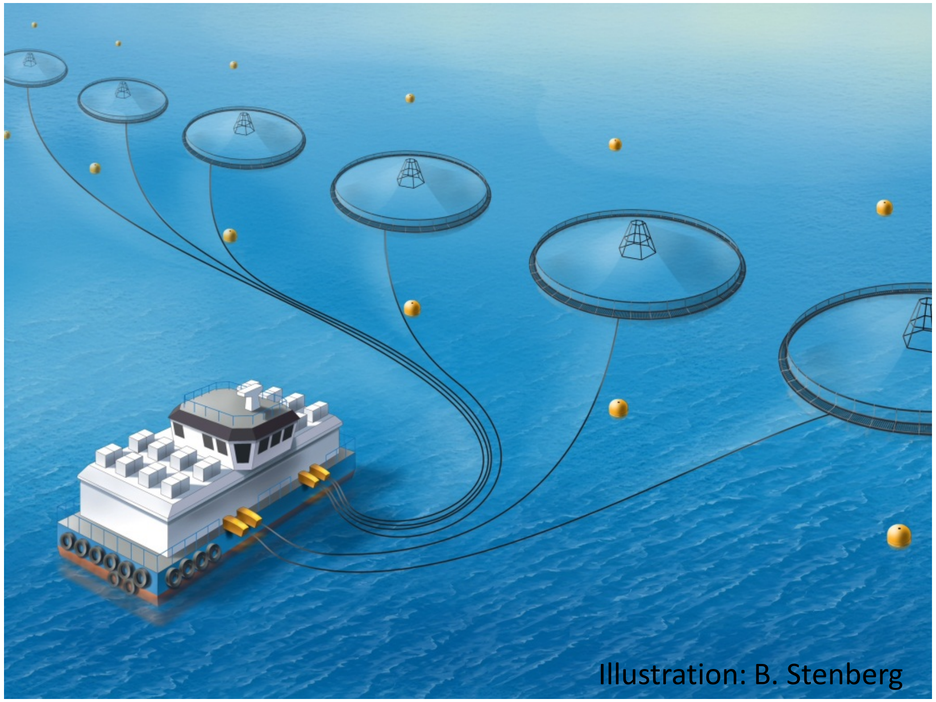
Hypothesis

- **Hypothesis 1:**
  Land-based production of atlantic salmon in Model RAS has a higher CO_2 footprint than production in Model Net Pen

- **Hypothesis 2:**
  Land-based production of atlantic salmon in Model RAS has a higher production cost and lower return on investment than production in Model Net Pen

Models





Land-based RAS fish farm

Producing 3300 M.tons HOG Atlantic Salmon

Model Net Pen farm

Producing 3 300 M.tons HOG Atlantic Salmon

Investments

Model Land-based RAS fish farm (32 million US $)

One production site

Invested equipment:

- 40,000 m^3 of rearing tank volume
- 25,500 m^2 of building area
- 2,500 m^2 processing facility
- 885 m^3/min of pumped RAS flow
    - Pumps and Piping
    - Screen filters
    - Biofilters
    - Gas Conditioning Filters
- 1.08 – 1.26 kg feed per m^3 supply water
- Feeding Systems
- Backup Generators

Investments in total: 32 M US $ - approximately 192 MNOK

Maintenance and reinvestments set equal to the depreciations

Model Net Pen farm (12,3 million US $):

Two production sites, each with six net pen cages.

- ≈587,000 m^3 net-volume
- 120,000 m^2 area footprint visible at sea
    - ≈179,000 m^2 area footprint incl. no thoroughfare zone
    - ≈463,000 m^2 area footprint incl. no fishing zone

Invested equipment:

- 3 licences
- 12 Floating rings (157m Ø)
- 24 nets (25 m deep)
- 2 mooring systems
- 2 boats
- 2 feed barges (150 Mtons)
- 12 camera systems
- 12 feed distributors
- 12 power systems

Investments in total: 72,9 MNOK – approximately 12,3 M US $

Maintenance and reinvestments set equal to the depreciations

Assumptions production

Model Land-based RAS fish farm

- One production site for all life-stages
- Four cohorts per year

- Growth based on thermal growth coefficients from Freshwater Institute growout trials, adjusted down by 10%:
  - 1.1 for Fry
  - 1.25 for Smolt
  - 1.8 for Pre-growout
  - 2.2 for Growout

- Mortality per generation 16%

- Feed conversion ratios:
  - 0.75 for Fry
  - 0.90 for Smolt
  - 1.0 for Pre-Growout
  - 1.1 for Growout
- Overall Feed to Whole Fish Produced (kg/kg): 1.09

Model Net Pen farm:

- 2 production sites & 3 licences of 780 M.tons of maximum total biomass at sea.
- Two transfers of smolts to sea annually, to one site
  - S1 at 1st of April, 100 grams, 520' smolts in three cages
  - S0 1st of August, 75 grams, 520' smolts in three cages

- Growth based on the Skretting table, Specific Growth Rate (SGR), adjusted down by 12 %.

- Mortality per generation approximately 16,1 % (average in Mid-Norway in 2011) (Norwegian Food Safety Authority 2011).

- Economic feed conversion ratio: 1,27 (average in Norway over the last ten years) (Directorate of Fisheries 2013).

Assumptions production

Model Land-based RAS fish farm

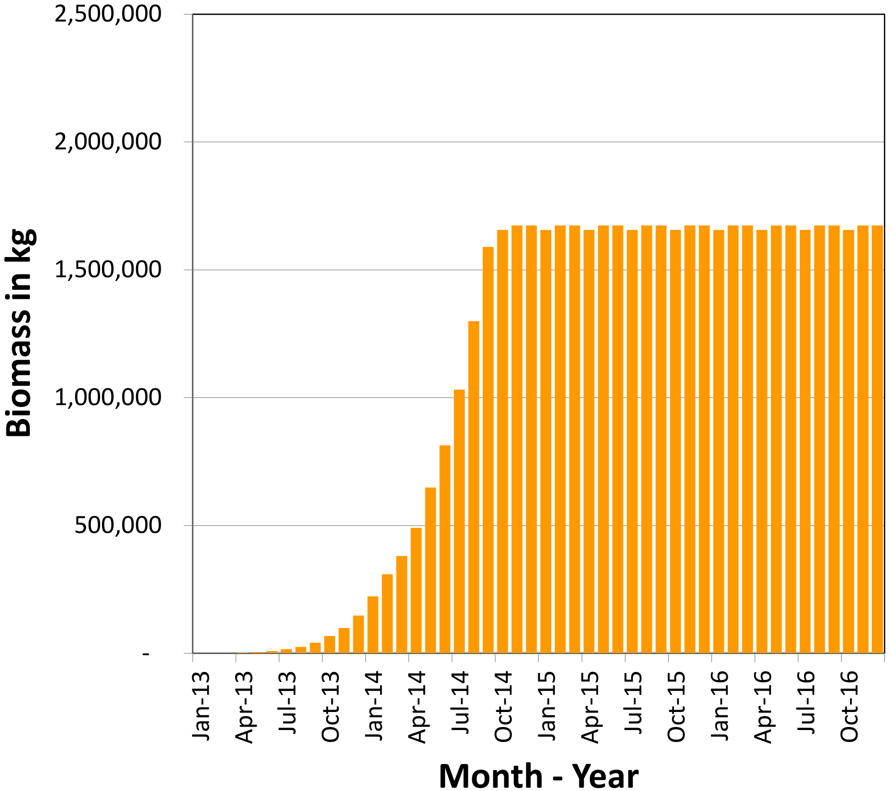
- Rearing Density
  - 80 kg/m^3 maximum
- Harvesting:
  - Time from first feeding to first harvest: 21 months
  - Harvest every week of the year
    - Each cohort harvested over 13 weeks
    - One grisle harvest at ~1.2 kg for 50% of males
  - Harvest in total: 3947 M.tons LWE, 3300 M.tons HOG (5% purge loss / 12% HOG loss)
  - Initial harvest weight (whole fish): 4.5 kg
  - Average harvest weight (whole fish): 5.1 kg
- No downtime in the bioplan

Model Net Pen farm:

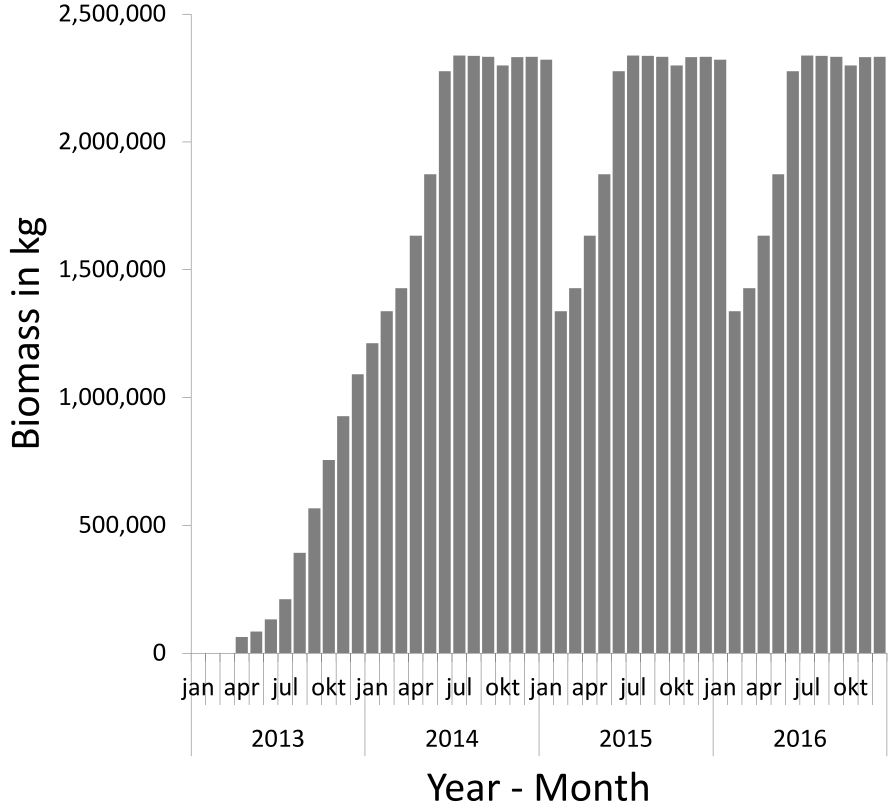
- Rearing Density
  - 25 kg/m^3 maximum
- Harvesting:
  - Time from first feeding to first harvest: 24 - 31 months
  - Time at sea before first harvest: 16 months
  - Harvest 8 months of the year
    - Harvest S1 from July to October
    - Harvest S0 from November to February
  - Harvest in total: 3 975 M.tons LWE, 3 299 M.tons HOG (5 % purge loss /12 % HOG loss)
  - Average harvest weight (whole fish) : 4,5 kg
- Two months of fallowing between production cycles

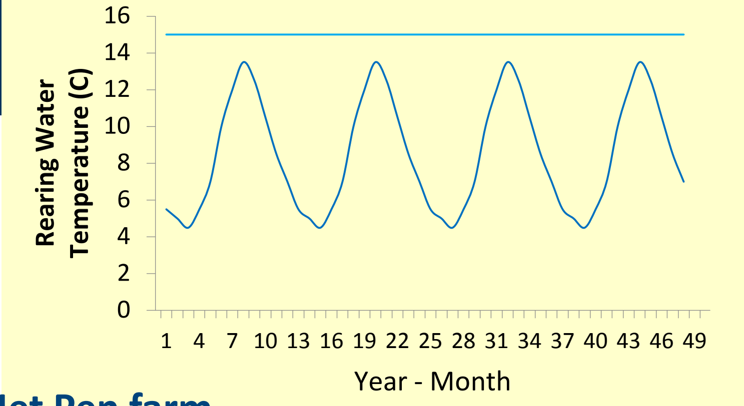
Biomass

Model Land-based RAS fish farm



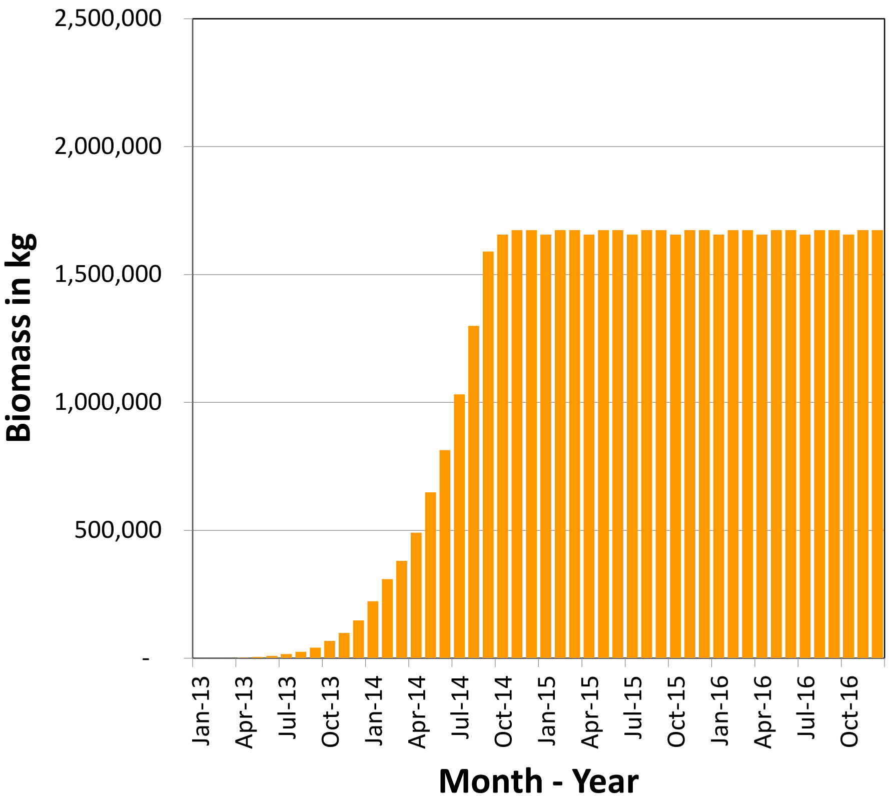
Model Net Pen farm



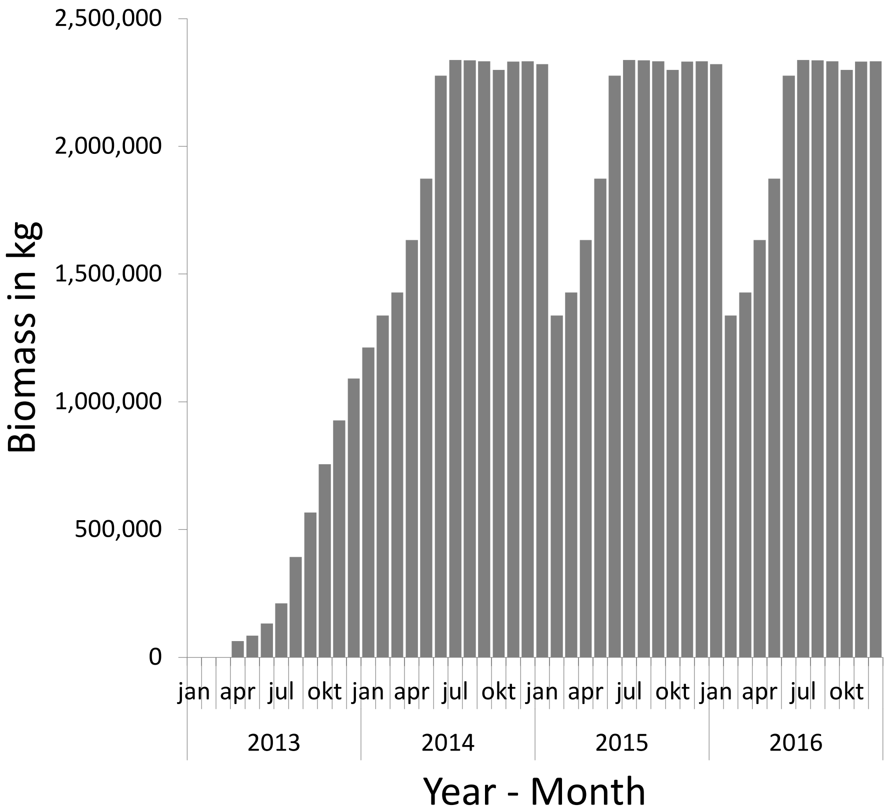


Biomass

Model Land-based RAS fish farm

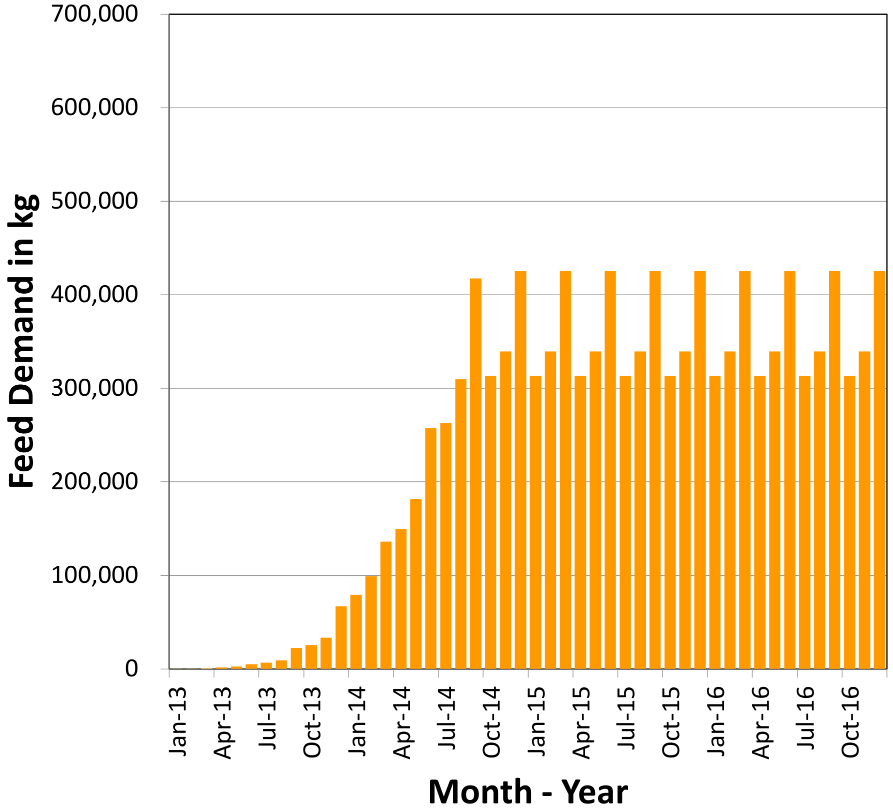


Model Net Pen farm

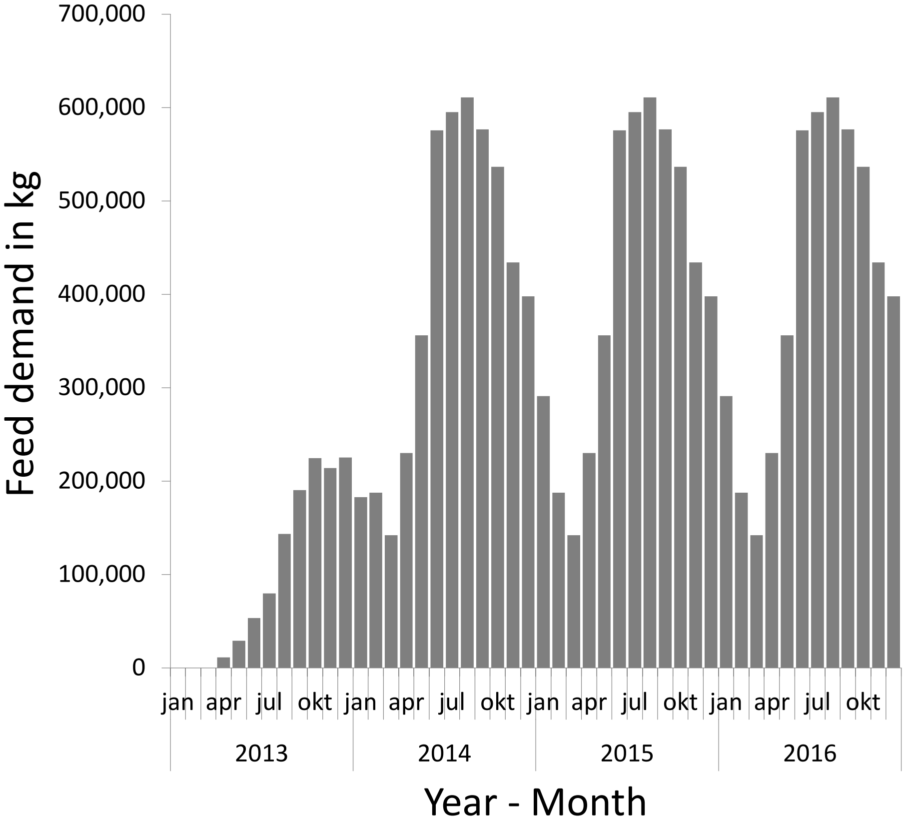


Estimated feed consumption

Model Land-based RAS fish farm

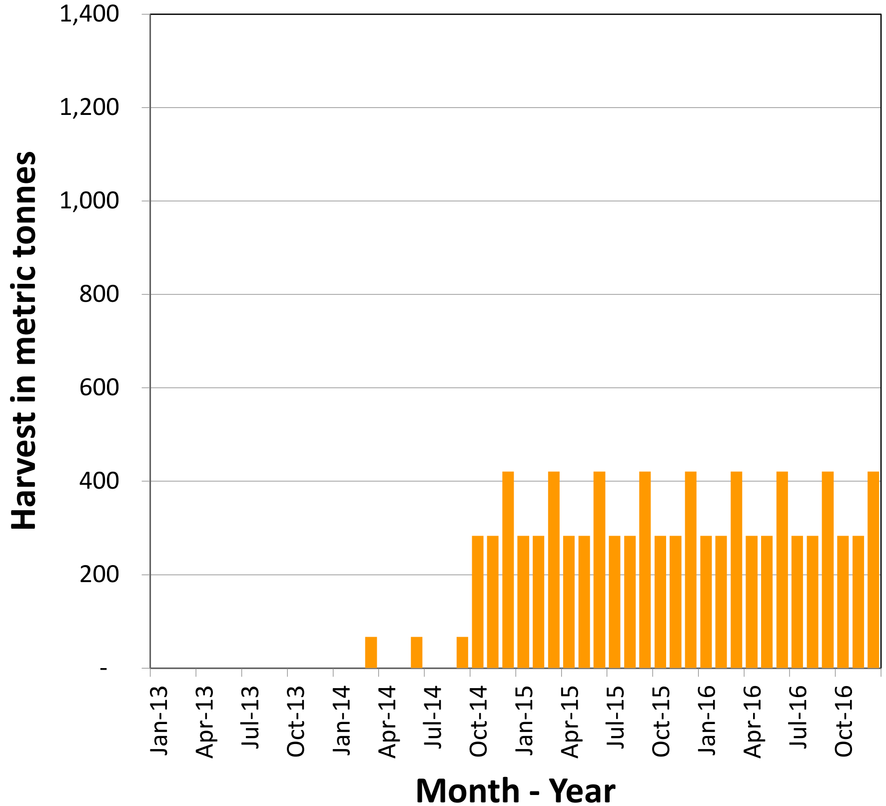


Model Net Pen farm

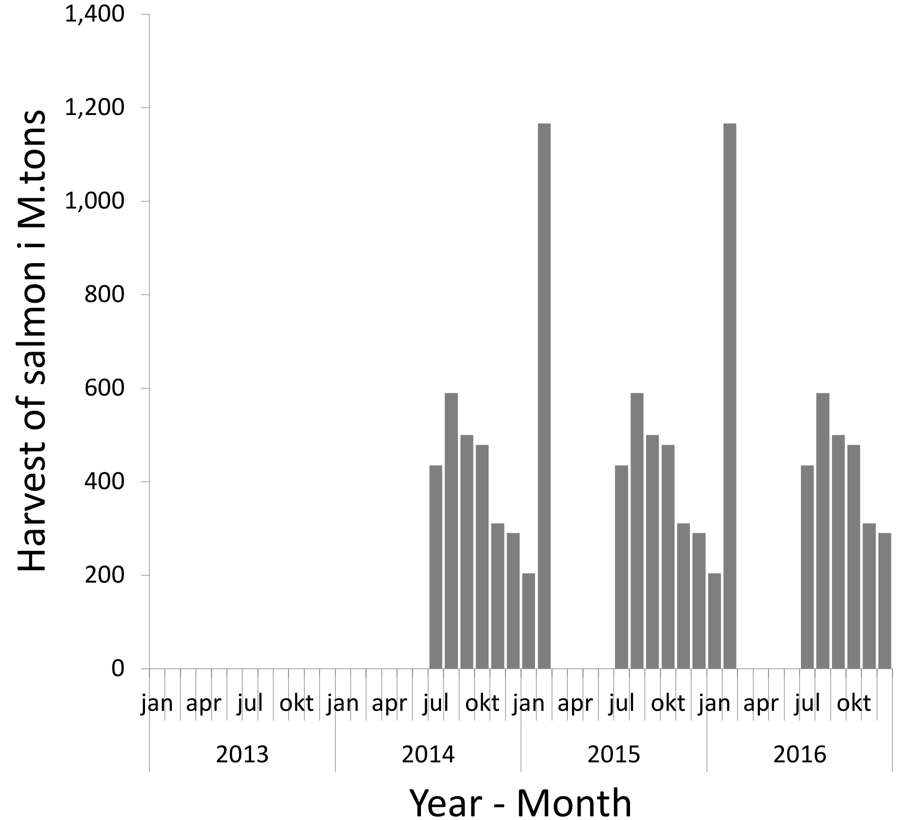


Harvest

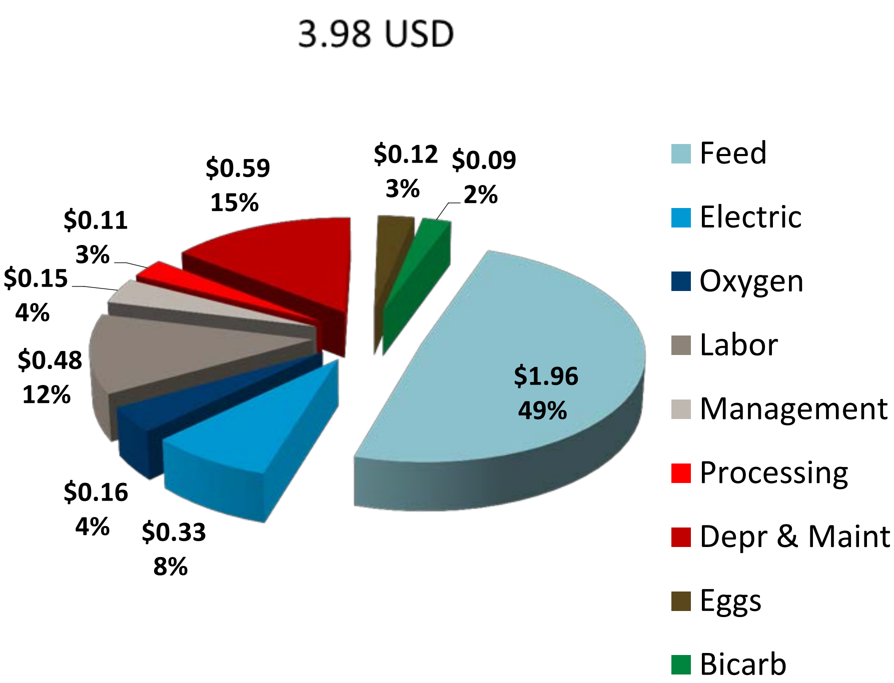
Model Land-based RAS fish farm

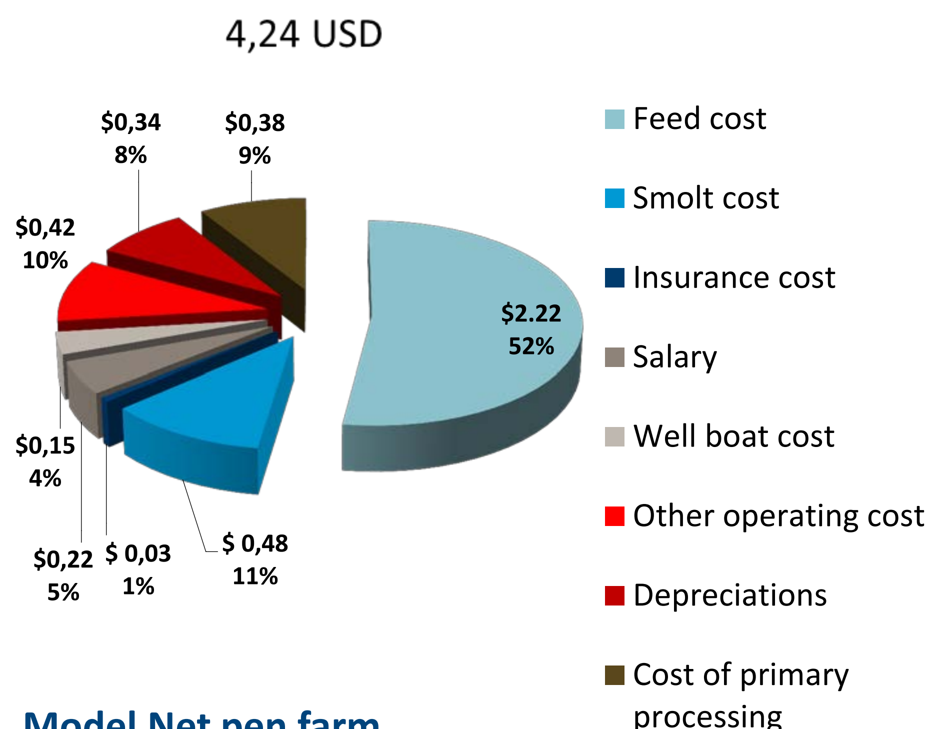


Model Net Pen farm



Production cost at steady state, USD/HOG





Model Land-based RAS fish farm

Total estimated production cost per kilo HOG: 3.98 USD

- Uses $0.05 / kWh (US);
  Comparative Norway is $0.17 / kWh

Model Net pen farm

Total estimated production cost per kilo HOG: 4,24 USD

Comments: EFCR, mortality & utilization: Model Net Pen Farm

- Not a optimal utilization of three licences!
  - It's possible to harvest as much as 1 600-1 700 M.tons pr licence (~2 x Model)
    - Requires a more large-scale operation

- Average EFCR used in the calculation is high: 1,27
  - It's possible to achieve an EFCR more closely to 1.
    - Top 25% EFCR in Norway over the last ten years is 1,14
    - Top 10% EFCR in Norway over the last ten years is 1:04.

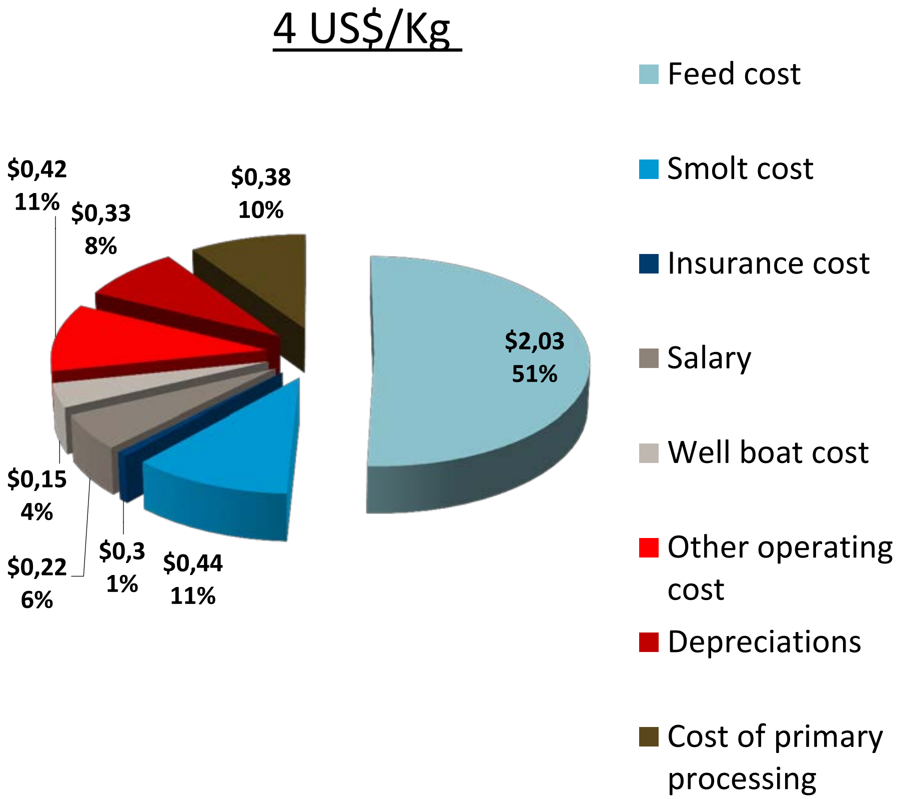
- Average mortality at 16,1 % is high
  - Some sites in Norway are now achieving only 2-4 % mortality
  - Then on the other side, some sites have mortality at over 30 % - mostly due to disease.

Use of "best-practice" inputs

- EFCR: 1.14
- Mortality: 8% pr generation

- Gives a production cost of 4 US$/Kg HOG (Compared to 4,24)
  - Reduction in feed cost
  - Reduction in smolt cost

- Model Net Pen Yield per smolt: 3,44 kg
- (Model Net Pen Base Case: 3,17 kg)
- Model RAS Yield Per Smolt: 3.97 kg HOG



Quick estimation of profitability at Steady State – Base Case

Model Land-based RAS fish farm – No Price Premium:

Investments:

- Investments in total: 32 M US $

Income:

- Price per kilo 34 NOK or 5,66 US $
- Total estimated income: **18.68 M US $**

Costs:

- Production cost excluding financial cost: $3,98
- Total production costs (ex. finance): ≈ **13.13 M US $**

Earnings before Interest and Taxes (EBIT): 5.55 M US $

Model Net Pen farm – Conservative Performance:

Investments:

- Investments in total: 12,3 M US $

Income:

- Fish Pool forward prices
  - 2014: 35,85 NOK/Kilo
  - 2015: 33,88 NOK/Kilo (jan-aug)
- Estimated price pr kilo: 34 NOK ≈ 5,66 US $
- Total estimated income: **18.67 M US $**

Costs:

- Production cost excluding financial cost: $4,24
- Total production costs (ex. finance): ≈**13.99 M US $**

Earnings before Interest and Taxes (EBIT): 4.68 M US $

Quick estimation of Profitability at Steady State – Best Case

Model Land-based RAS fish farm – Premium Price:

Investments:

- Investments in total: 32 M US $

Income:

- Possibility for a 30% price premium
  - Price per kilo (5,66*1,3) ≈ 7,36
- Total estimated income: **24.29 M US $**

Costs:

- Production cost excluding financial cost: $3,98
- Total production costs (ex. finance): ≈ **13.13 M US $**

Earnings before Interest and Taxes (EBIT): 11.16 M US $

Model Net Pen farm – High Performance:

Investments:

- Investments in total: 12,3 M US $

Income:

- Fish Pool forward prices
  - 2014: 35,85 NOK/Kilo
  - 2015: 33,88 NOK/Kilo (jan-aug)
- Estimated price pr kilo: 34 NOK ≈ 5,66 US $
- Total estimated income: **18.67 M US $**

Costs:

- Production cost excluding financial cost: $4,00
- Total production costs (ex. finance): ≈**13.20 M US $**

Earnings before Interest and Taxes (EBIT): 5.47 M US $

Cash Flow Assumptions

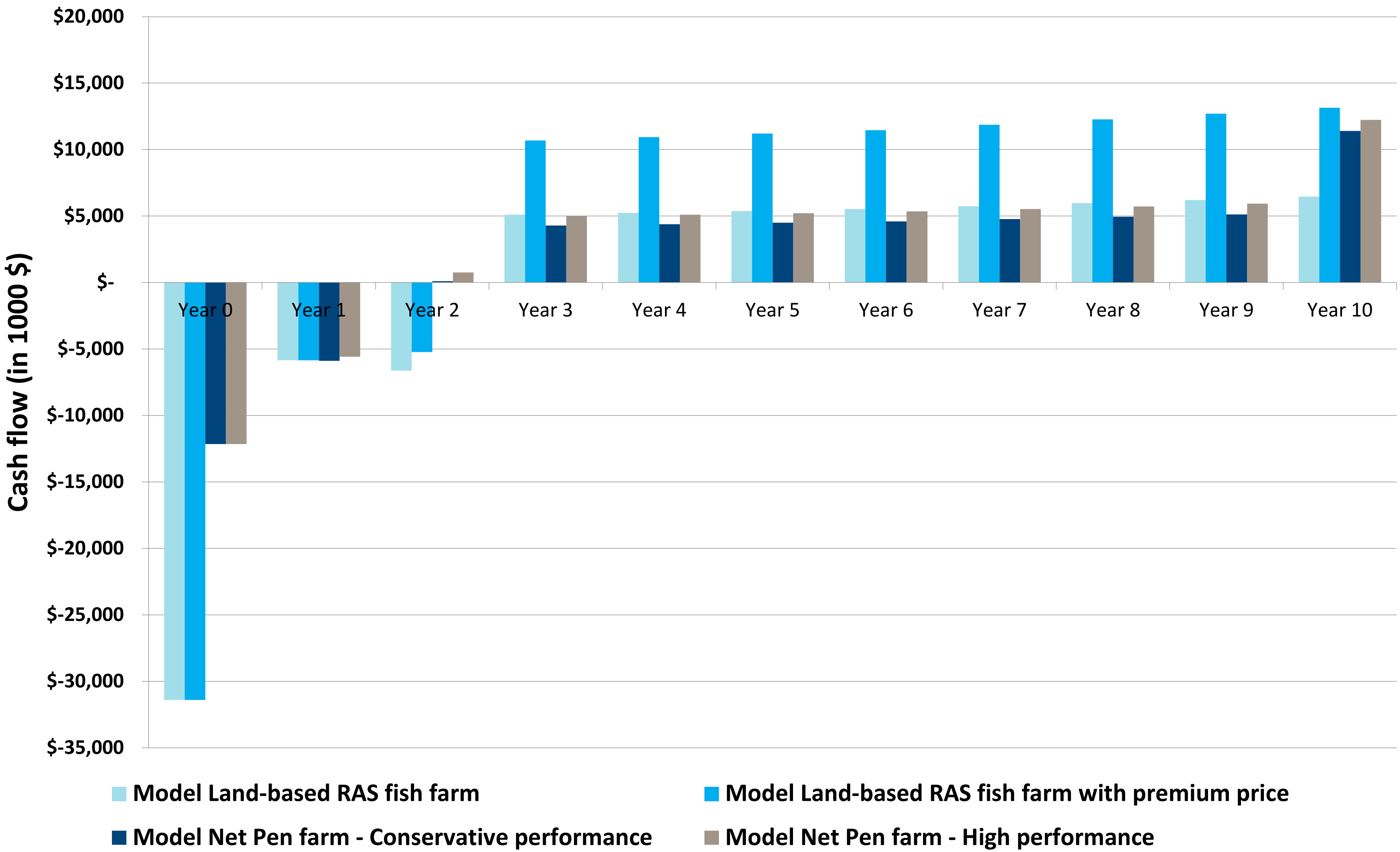
Both:
2% inflation first 6 years
3% inflation four last years
Value of equipment/buildings etc set to 0 after ten years

Model Land-based RAS fish farm

- Salary: 1 575 000$/year
  - 35 persons
- Electricity: ≈ 21.5 mWh
  - Cost pr kWh: $0.05
- Oxygen: ≈3000 M.tons
  - Cost pr kilo: $0.2
- Bicarb: ≈862 M.tons.
  - Cost pr kilo: $0.35
- Feed: $1.50 pr kilo
- Eggs: ≈1,2 million
  - Cost: $0.30 each
- Management: 500 000 $/year
- Primary processing:
  - Salary: 375 000 $/year
    - 10 persons
    - Other cost included in the total calculation
- Price per kilo HOG: $5.45 – $8.77

Model Net Pen farm

- Salary: ≈750 000$/year
  - 6 persons
- Primary processing ≈0,38$/kilo HOG
- Well boat 0,92$/kilo HOG (includes smolt and slaughter transport)
- Insurance premium ≈0,8% of the value of the biomass
- Feed: $1.48 pr kilo
- Smolts: Conservative performance 1030'/year
  High performance: 960'/year
  Cost: ≈$1.53 each
- Other production cost (Ex. Electricity, de-liceing etc.) ≈ 0,43$/kilo HOG
- Price per kilo HOG: $5,45-$6.75
- Licences not depreciated and is sold after 10 years


$20,000
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$-35,000
Cash flow (in 1000 $)
Year 0
Year 1
Year 2
Year 3
Year 4
Year 5
Year 6
Year 7
Year 8
Year 9
Year 10
Model Land-based RAS fish farm
Model Land-based RAS fish farm with premium price
Model Net Pen farm - Conservative performance
Model Net Pen farm - High performance

Net present value

- Rate of return calculated to 8,91 %. (6% loan interest, 28 %tax, 27,23% required return on equity before tax, 30/70 private equity/loan)

Risk free return	3,23 %
Commercial risk	10 %
Financial risk	10 %
Liquidity premium	4 %
Required rate of return before tax	27,23 %
Tax (28%)	7,63 %
Estimated required rate of return on equity	19,61 %
Estimated required rate of return on total capital	8,91 %

Net present value at 8,91% required rate of return

NPV is for 10 years

Model Land-based RAS fish farm:

- NPV: -16 M US $
- NPV & NO Required Rate of Return: $1,810,000

Model Land-based RAS fish farm with premium price

- NPV: 13.33 M US $
- NPV at 0, at a required rate of return of: **≈14,35 %**

Model Net Pen farm - Conservative performance

- NPV: 7 M US $
- NPV at 0, at a required rate of return of:**≈15,07 %**

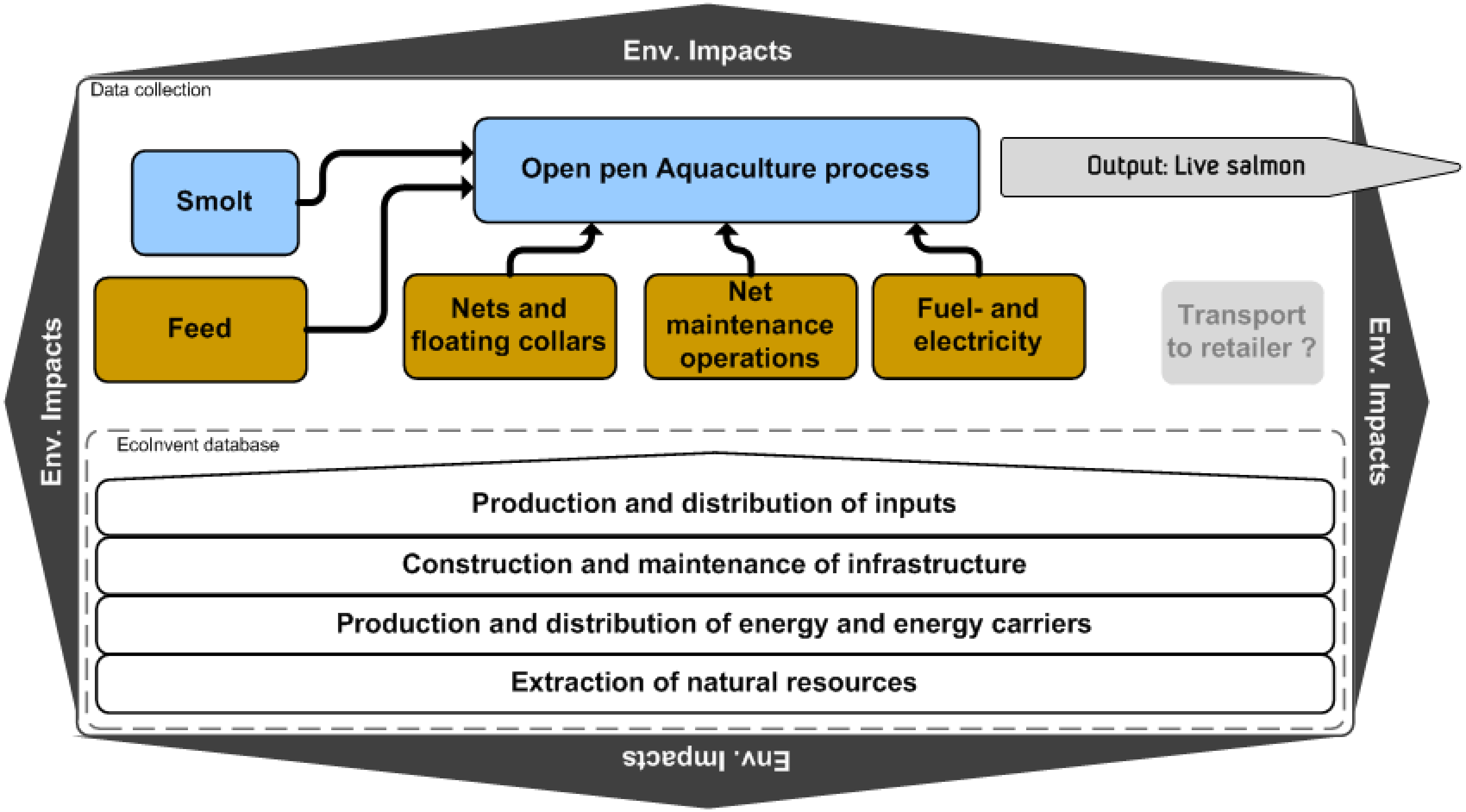
Model Net Pen farm - High performance

- NPV: 11,39 M US $
- NPV at 0, at a required rate of return of: ≈18,67 %

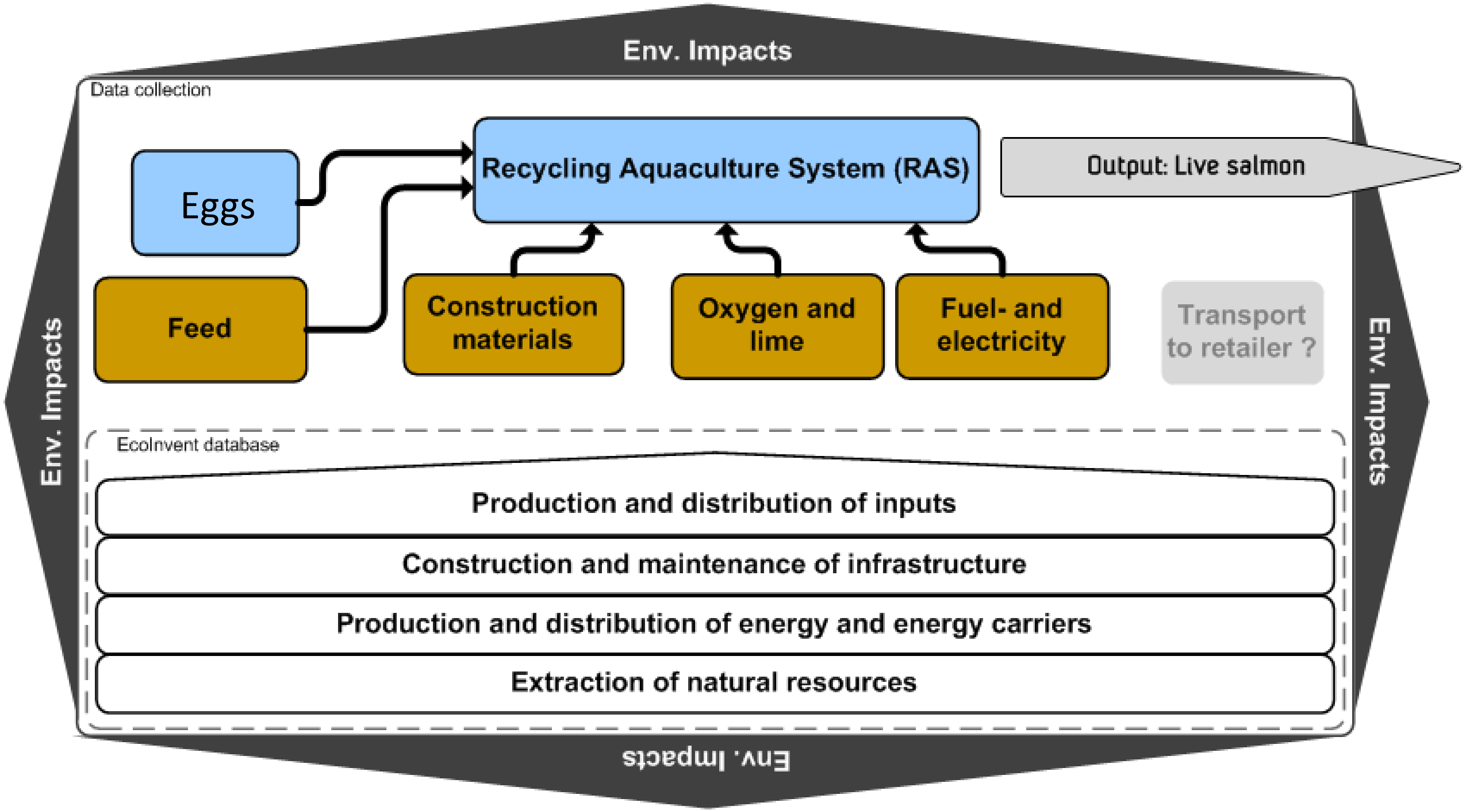
Comparative GHG assessment of Model PEN and RAS salmon production: Goal and scope

- Goal: To study the potential climate impact from the production of 1 kg of salmon in live weight
- Method: GHG assessment performed with the Life Cycle Assessment (LCA) method. Impact assessment calculate the potential climate impact in CO2 equivalents (CO2e) according to IPPC guidelines
- System boundaries: The assessment includes resources use production of feed ingredient and till the salmon is ready for slaughter at the production site. Construction of production equipment and production facilities are included.

System boundaries for the PEN system



System boundaries for the RAS system

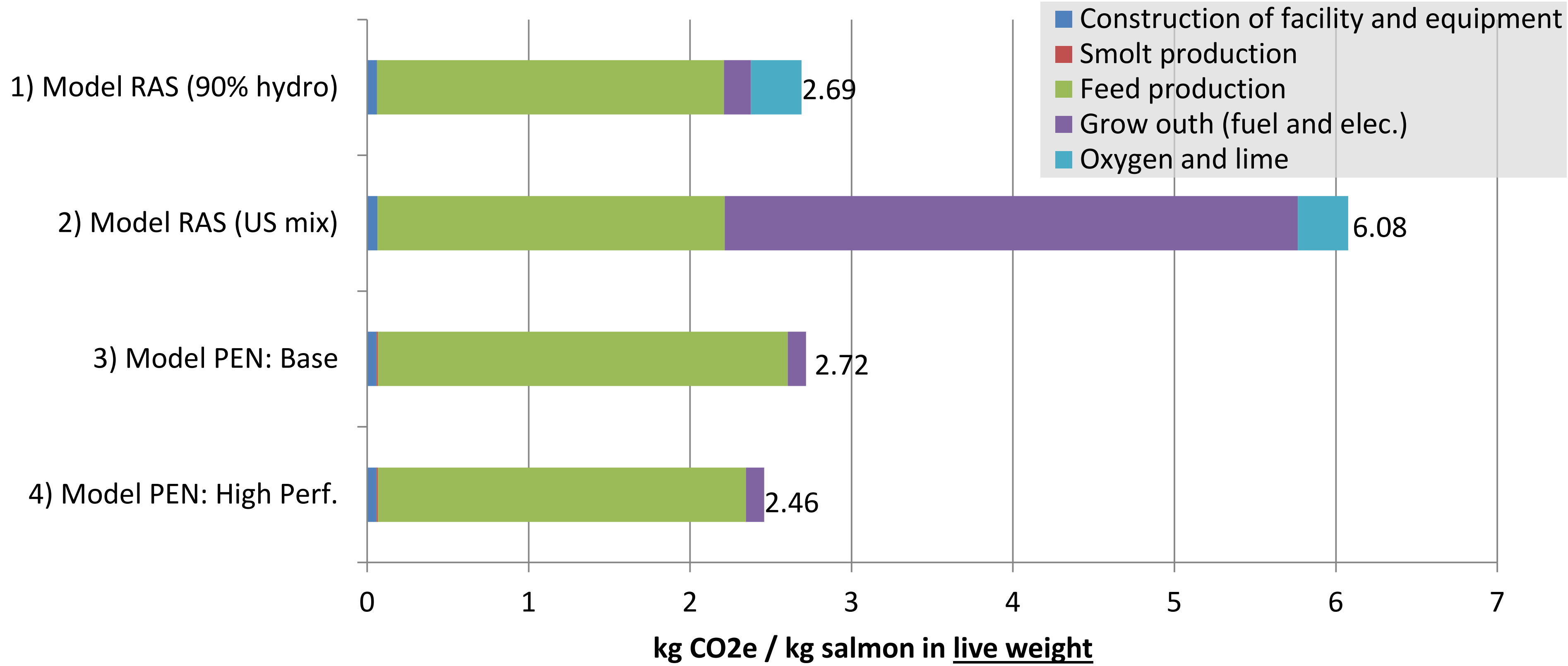


Data

- Important data:
  - Model RAS: 1,09 kg feed/kg salmon in live weight. Electricity input: 4,6 kWh/ kg salmon in live weight
  - Model PEN 1,27 kg feed/kg salmon in live weight

- Feed production is modelled with data from the project "Climate impact and area use of Norwegian salmon production" (Hognes, 2011) and "Carbon footprint and energy use of Norwegian seafood products" (Winther et al., 2009)

- Other inputs to the system e.g. electricity, oxygen, construction materials, fuel etc. is modelled with data from the life cycle assessment database EcoInvent v2.2.



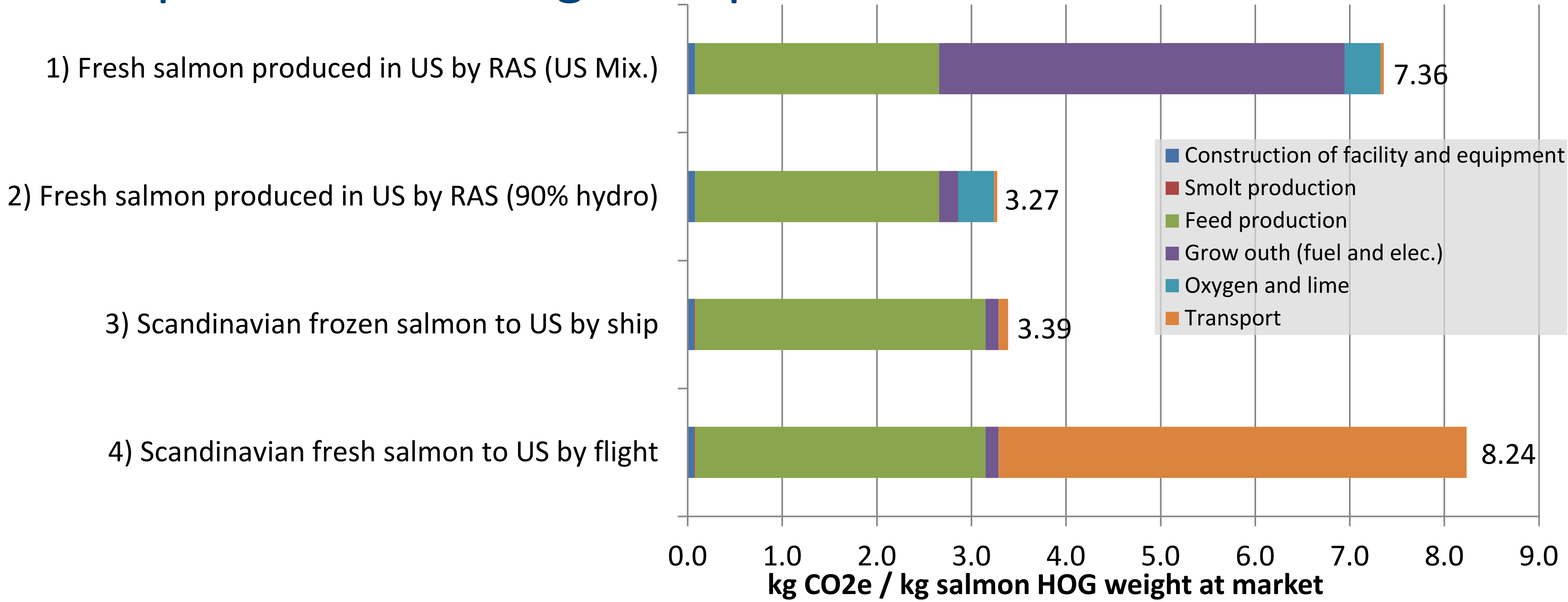
Sum of GHG emissions caused by the production of one kilo of salmon in live weight from production of feed ingredients and up to salmon is ready for slaughter.

Cases:

1. Model RAS system using a 90% hydropower / 10% fossil fuel electric mix with a GWP of: 0,04 kg CO2e/kWh*
2. Model RAS system using an average electric mix for the US with a GWP of 0,77 kg CO2e/kWh*
3. Model Net pen system. Average FCR: 1,27
4. Model Net pen system with best practice, FCR: 1,14

*: Modelled with data from the EcoInvent v2.2 database

Comparison including transports to retailer in the US



Sum of GHG emissions caused by the production and transport of one kilo of salmon in head on and gutted (HOG) weight (from production of feed ingredients and up to delivery at retailer gate)

Cases:

1. **Fresh** salmon from RAS system using an average US electricity mix and transported 500 km to retailer with **efficient truck**
2. **Fresh** salmon from RAS system using 90 % hydro power electricity mix and transported 500 km to retailer with **efficient truck**
3. **Frozen** salmon from PEN system in Norway transported 5 600 km to the west coast of the US by **large container ship**
4. **Fresh** salmon from PEN system in Norway transported 5 600 km to the west coast of the US by **airfreight**

Important remarks to the GHG assessment

- A GHG assessment **only assess the potential climate impact and not the wide range of environmental impacts that food production cause** and its over all environmental sustainability. A GHG assessment is not a complete indicator of the environmental sustainability .
- Several potentially important climate aspects of food production and consumption is not included, e.g.: Waste (how much of the salmon is actually eaten); processing; packaging; transport efficiency; by product utilization and nutrient recovery (e.g. phosphorus).
- The results presented here can not be compared to LCA results from other sources unless it can be proven that identical data and methodical choices is used. According to the relevant ISO standards for LCA these results can not be used to make commercial claims.

Conclusions from the GHG assessment

- Feed efficiency is the dominating parameters of the carbon footprint of the salmon production

- The most straight forward and clear assumption is to use the electricity mix in the power market in which the production occur.
  - In a market where electric power is a commodity in short supply, and where power markets are connected through economy and/or the grid, it is challenging to argue that power is supplied from one specific source. As a minimum there must be a consistency between the price paid for the power and the data used in the GHG assessment.

- Construction of production facility and equipment is not an important contributor to the total carbon footprint of the salmon, but the ability to produce closer, or choose transport to the market is potentially important.

Wrapping up - conclusions

- **Hypothesis 1:**
  The land-based production of atlantic salmon in this Model RAS system has a higher CO_2 footprint than production in a Model Net Pen farming system.
  - FALSE – with clean energy source
  - TRUE – with typical US/EU mix based on fossil fuels

- **Hypothesis 2:**
  Land-based production of atlantic salmon in this model RAS system has a higher production cost and lower return on investment than production in a Model Net Pen farming system.
  - Prod.cost FALSE – given the assumptions in this presentation
  - ROR TRUE – if it is not a premium price

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