ForesightAqua

J. Bostock & Associates

Aquaculture Knowledge

Sustainability & Certification of RAS

Seafish ACIG Meeting

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(With inputs from John Bostock & Dr. Richard Newton)

Contents

- Investment trends in grow-out RAS & sustainability drivers
- Life cycle assessment (LCA) of environmental impacts of grow-out RAS
- Environmental certification & potential use of LCA in setting metric requirements for grow-out RAS

Investment in RAS for salmon farming

The story of aquaculture RAS is now dominated by salmon with announced projects suggesting investments of between US$ 10-20 billion

EY

Identified planned land-based capacity

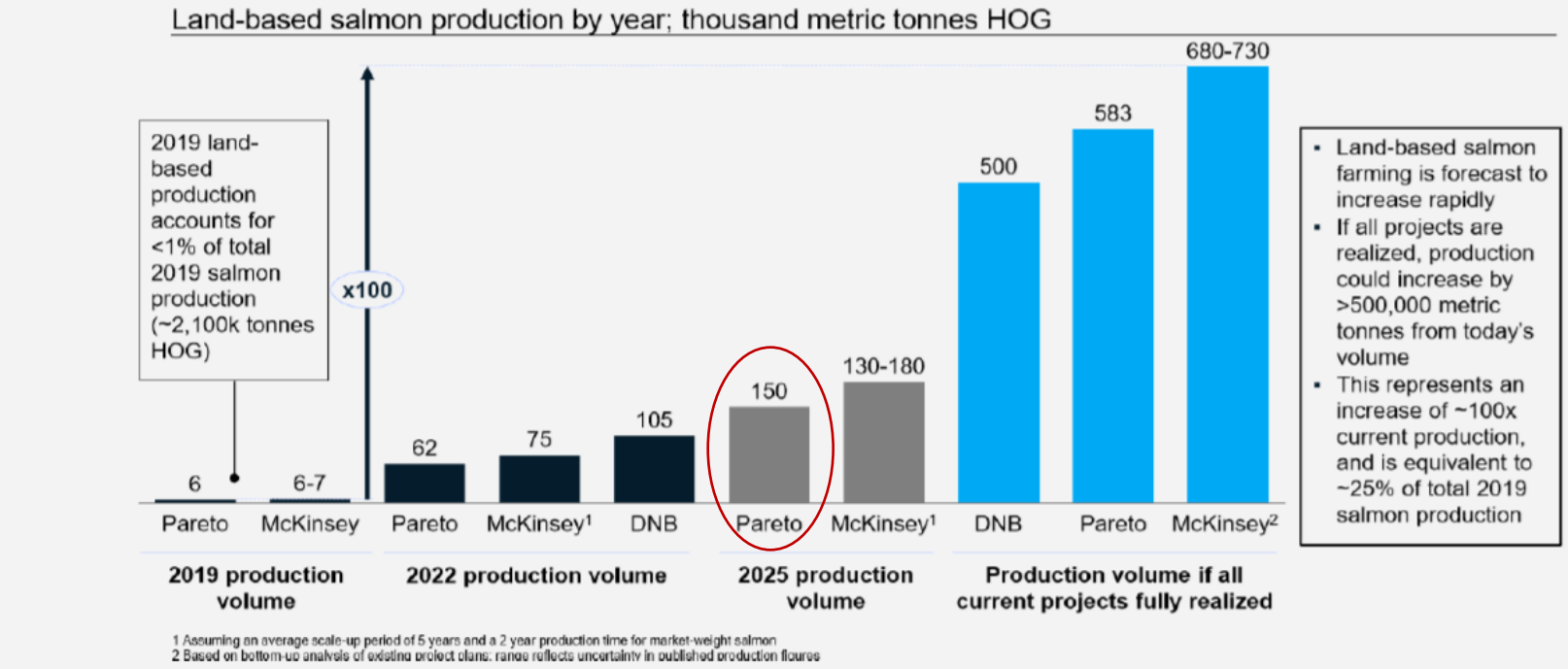
2019 analysis

1.0m tonnes

2020 analysis

2.3m tonnes

Land based salmon farming expected to yield 150k tonnes in 2025…



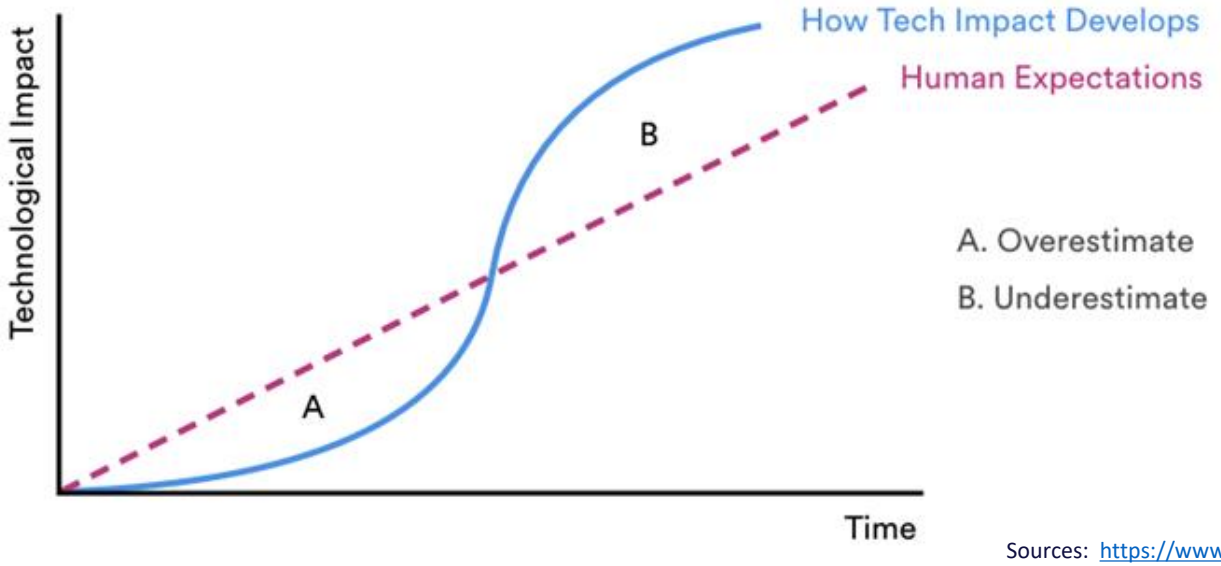
Source: McKinsey analysis

Even if the use of RAS for growout fails, the demand for large smolts is increasing;
AKVA projects 40-50 new or expanded RAS smolt units to be constructed in Norway alone before 2030

Sources: McKinsey Analysis via AKVA + EY

Not just salmon

- Substantial new investments for **shrimp & yellowtail** with research & pilot projects in other species inc. **jade perch, pike-perch & sole**.
- RAS has also become important for the production of **wrasse for salmon lice control**
- However, the use of RAS for **grow-out production** has a long history with many commercial failures. Are we finally on the steep upward section of Amara's law?



A FRESHWATER FISH THAT'S PURE TO THE BONE

Bio-engineers from KU Leuven have premiered the most sustainable feeding and farming program for the omega perch ever developed. It's vegetarian, full of healthy fats and environmentally friendly.

Startup looks to develop RAS based shrimp production in Scotland

By Jane Byrne
10-Dec-2021 - Last updated on 10-Dec-2021 at 12:04 GMT

RELATED TAGS: shrimp, RAS, incubator

An aquaculture start-up is working with Farm491, an agritech hub based at the UK's Royal Agricultural University, to create the largest land-based production facility for shrimp in the UK.

Sources: https://www.feednavigator.com/Article/2021/12/10/Startup-looks-to-develop-RAS-based-shrimp-production-in-Scotland , https://www.kuleuven.be/english/research-stories/2020/a-freshwater-fish-thats-pure-to-the-bone & Illustration of Amara's law https://uxdesign.cc/speculative-design-for-the-real-world-551130b22827

New losses for land-based salmon farmer. Danish Salmon has only been in the black once since its inception in 2009

News by **Aslak Berge** - 27 July 2021

Losses continue.

There have been no celebrations for land-based salmon farming in Denmark.

Danish Salmon, which has been competing with Atlantic Sapphire-owned Langsand Laks for a number of years, to be the world's largest land-based salmon farmer posted a new loss from last year.

Pre-tax profit was EUR -0.7 million in 2020. Turnover was EUR 6.1 million.

Atlantic Sapphire knocked off its perch as world's most valuable land-based salmon farmer

SALMON EVOLUTION

After a stunning run on the stock market, this Dongwon and Cargill-backed group is the clear favorite among investors.

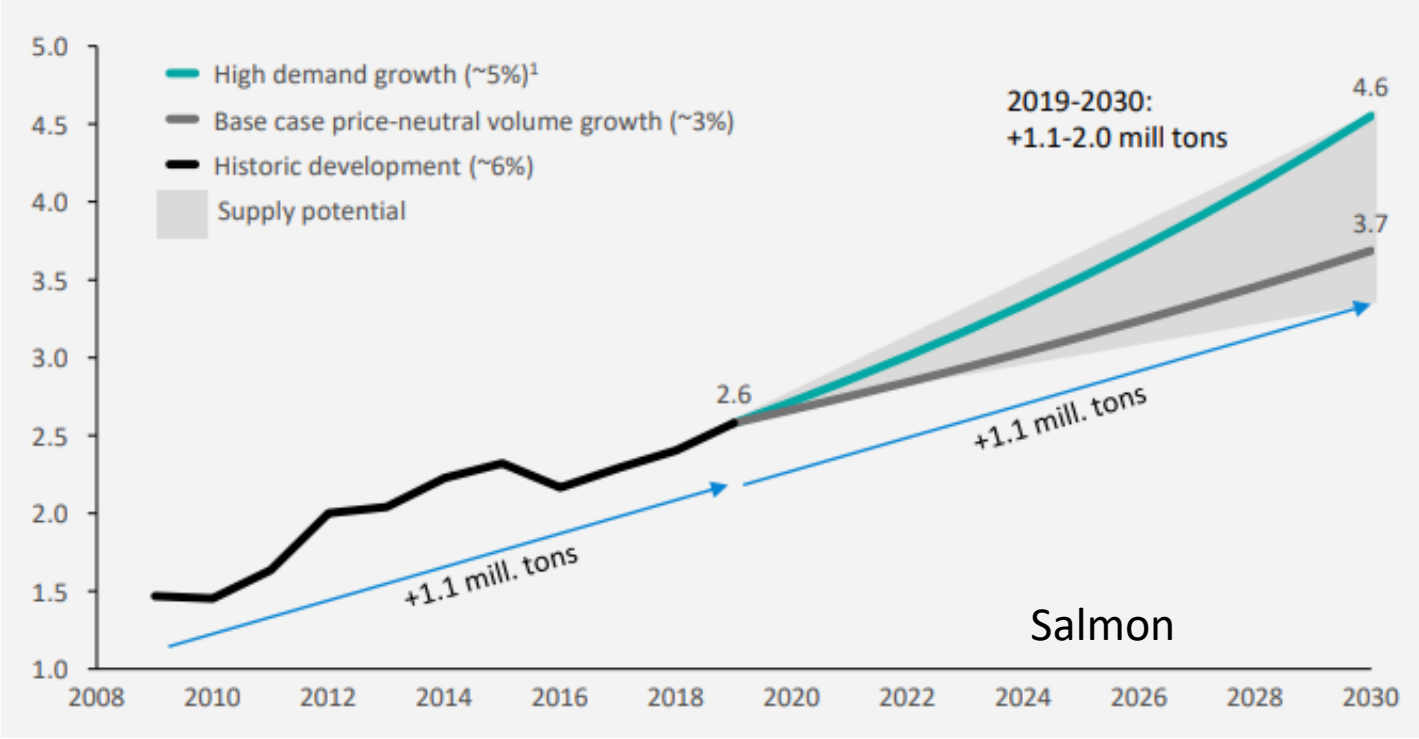
Salmon Evolution constructing a 36,000t land-based salmon farm in Molde, Norway, **with a mix of flow-through & recirculation technology**, is now the world's most valuable producer of salmon grown on land, knocking Atlantic Sapphire off its perch

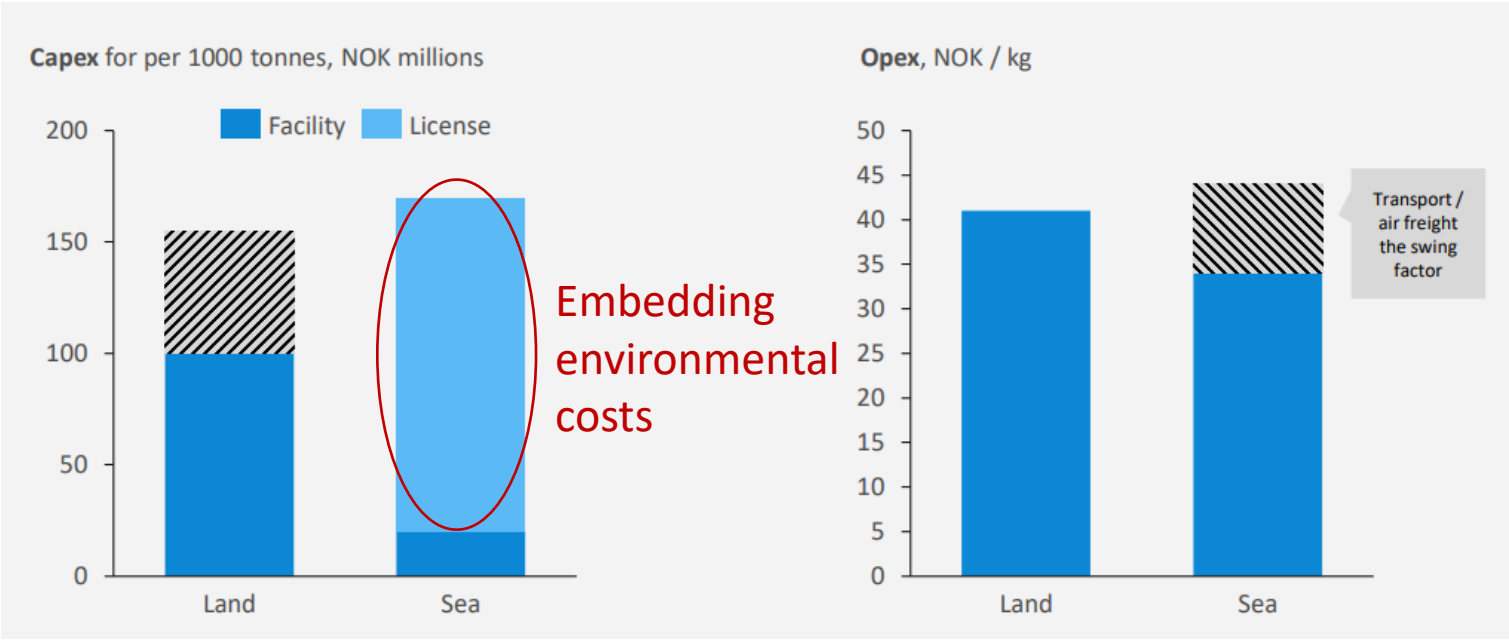
Losing faith in land-based

Atlantic Sapphire made $46.6m operating loss

Drivers for RAS

- Projected growth in global salmon/ seafood demand
- Static or reducing access to suitable sites for conventional 'open' systems (due to environmental-regulation)
- Increasing societal (inc. certification) & regulatory attention to sustainability indicators inc. GHG emissions, nutrient release, acidification etc.
- Changing cost-benefit v conventional production?





Source: AKVA (based on data from Norwegian Directorate of Fisheries, DNB and AKVA analysis)

Sustainability is at the heart of marketing products from RAS

"Sustainability & respect for our fish & the environment are core values. We strongly believe that industry in the 21st century needs to no longer be just about maximum output, our impact & responsible practices are just as important.

We have taken far reaching steps at high cost to operate on 100% renewable energy, use certified organic feed, grow our fish without antibiotics & to set production protocols according to the highest standards of leading certification organizations"

Ohad Maiman, CEO of Kingfish Zeeland

Sustainability attributes of RAS [1]

Salmon	Flow-through (0% re-use)	Re-use (60% re-use)	RAS – standard (96% - 99%) re-use)	RAS – Zero Water Concept (99,9% re-use)
	New water constantly flowing into and through the system, filtering of waste water flowing out (1:1)	*Flow-through with re-use of water including mechanical filtration and CO_2 degassing*	*Full recirculation of water with mechanical filtration, biological filtration and CO_2 degassing*	*RAS technology including removal of dissolved nutrients by phosphor precipitation and de-nitrification*
Water usage, Liters per kg feed per day	*30.000*	*12.000*	*300 – 500*	*30 - 50*
Energy usage, kWh per kg fish produced	Aeration and oxygenation *1 – 2*	Degassing, oxygenation, desalination and intake pumping *4 - 6*	RAS part 3-4 kWh Cooling 1-4 kWh *4 - 8*	RAS/ZWC 3-4 kWh Cooling 1-4 kWh *4 - 8*
Removal of nutrients, % removal	*N: 25% P: 50% SS: 60%*	Nitrogen, Phosphorus and Suspended Solids *N: 25% P: 50% SS: 60%*	*N: 40% P: 90% SS: 95%*	*N: 70% - 90% P: 93% - 98% SS: 99%*

Potential sustainability benefits of RAS include water use, energy use and control over the release of both organic and inorganic wastes. (Souce: AKVA group)

Sustainability attributes of RAS [2]

- Waste nutrient re-use?: through ability to concentrate solid wastes
- Enhanced biosecurity: limiting pathogen transmission v open systems
- Feed efficiency: selective-breeding gains assoc. with reduced GxE interaction
- Animal welfare: environmental control & optimal conditions for fish culture
- Food safety: ‘chemical & antibiotic free’
- **GHG emissions?:** market co-location - critical re. carbon neutrality targets

Quantification of RAS environmental impacts/ benefits through LCA?

LCA as metric requirement for environmental certification?

Life Cycle Assessment (LCA)

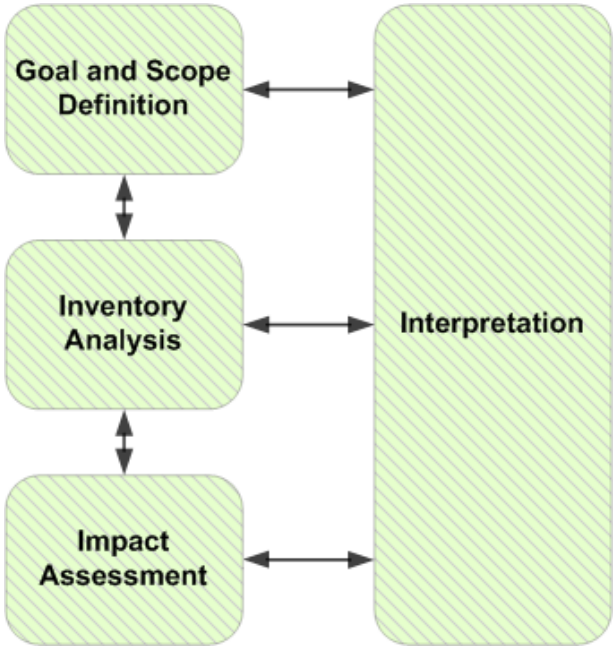
- Mass-balance modelling for comparing environmental impacts of products over their entire life cycle
- Comprehensive coverage: raw materials, processing, manufacture…. distribution, consumption, disposal/ recycling
- ‘Functional units’ as input/output reference (e.g. per t or £ LWE, HoG, fillets)
- Four stages:

  (1) goal & scope definition,

  (2) life cycle inventory analysis (LCI),

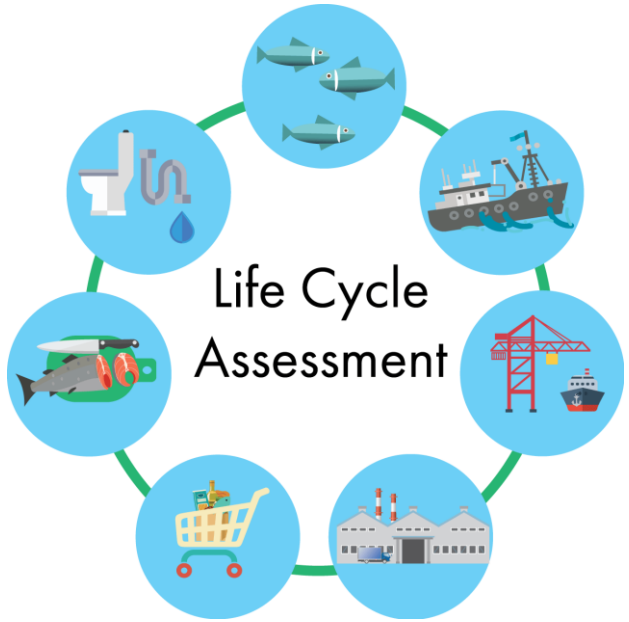
  (3) life cycle impact assessment (LCIA),

  (4) interpretation of the results.



LCA benefits

- Systematic method based on internationally accepted standards
  - Consistency, reliability, independence from commercial pressure
- Holistic (cradle-grave) approach avoids burden shifting
  - Inc. allocation to co-products & recycling for resources & releases
- Potential to incorporate sustainability concerns in decision-making
  - Input quality & provenance (seed, feed, energy)
  - RAS location, design & operation
  - Waste re-use/ value-added
  - Processing, marketing strategy…..



LCA impact categories – seafood application

Impact Area	Impact Category
Ecological health	Global warming (GHGs: Kg CO_2 equivalent)
	Eutrophication (N & P: Kg PO_4 equivalent)
	Acidification (g SO_2 equivalent)
	Aquatic (marine & FW) / terrestrial ecotoxicity
	Ozone depletion
	Photochemical oxidant formation
Resource depletion	Energy use (non-renewable Mj)
	Abiotic resource use (inc. Land & Water use)
	Biotic (renewable) resource use (marine ingredients?)
Human health	Human toxicity

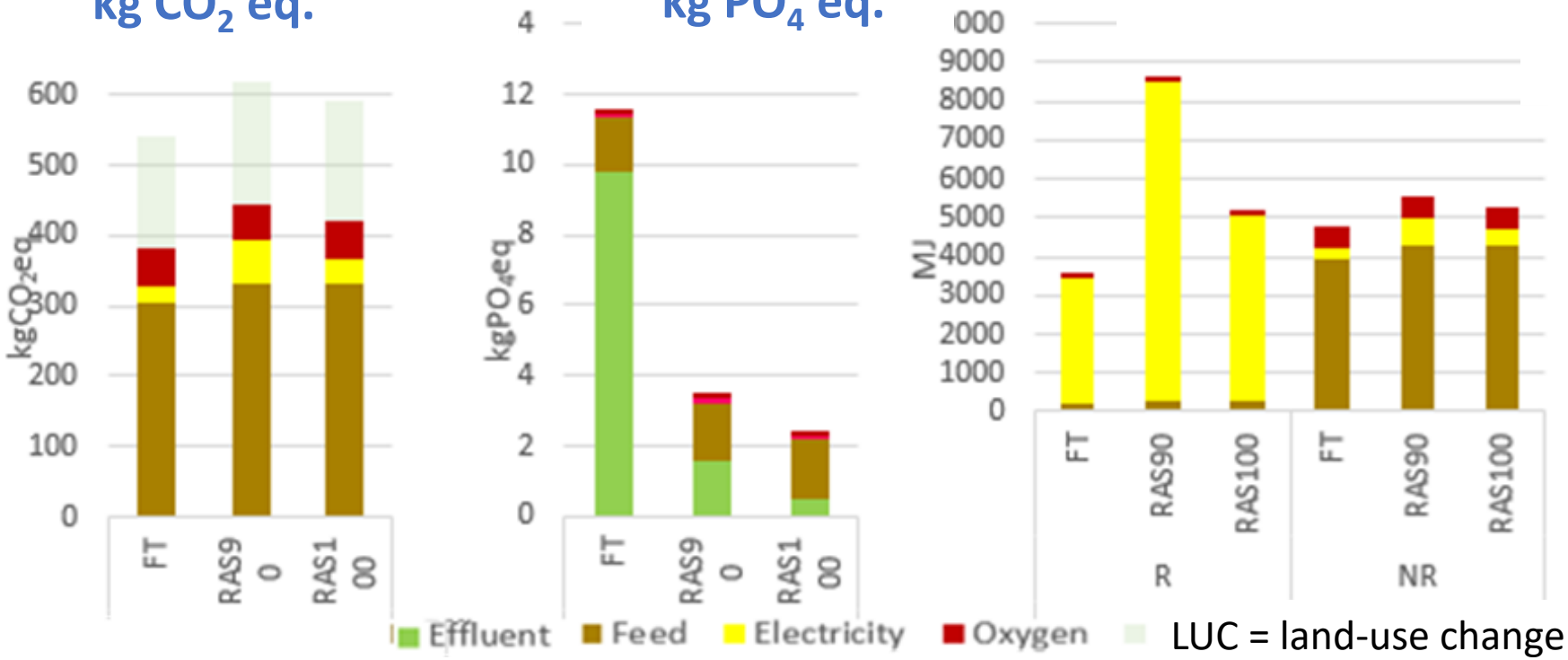
LCA comparison of Norwegian Flow-Through(FT), 90%RAS & 100%RAS **smolt units**

Global Warming Potential
kg CO_2 eq.

Eutrophication
kg PO_4 eq.

Energy-use - Mj

Per 200kg (of 200g) smolts

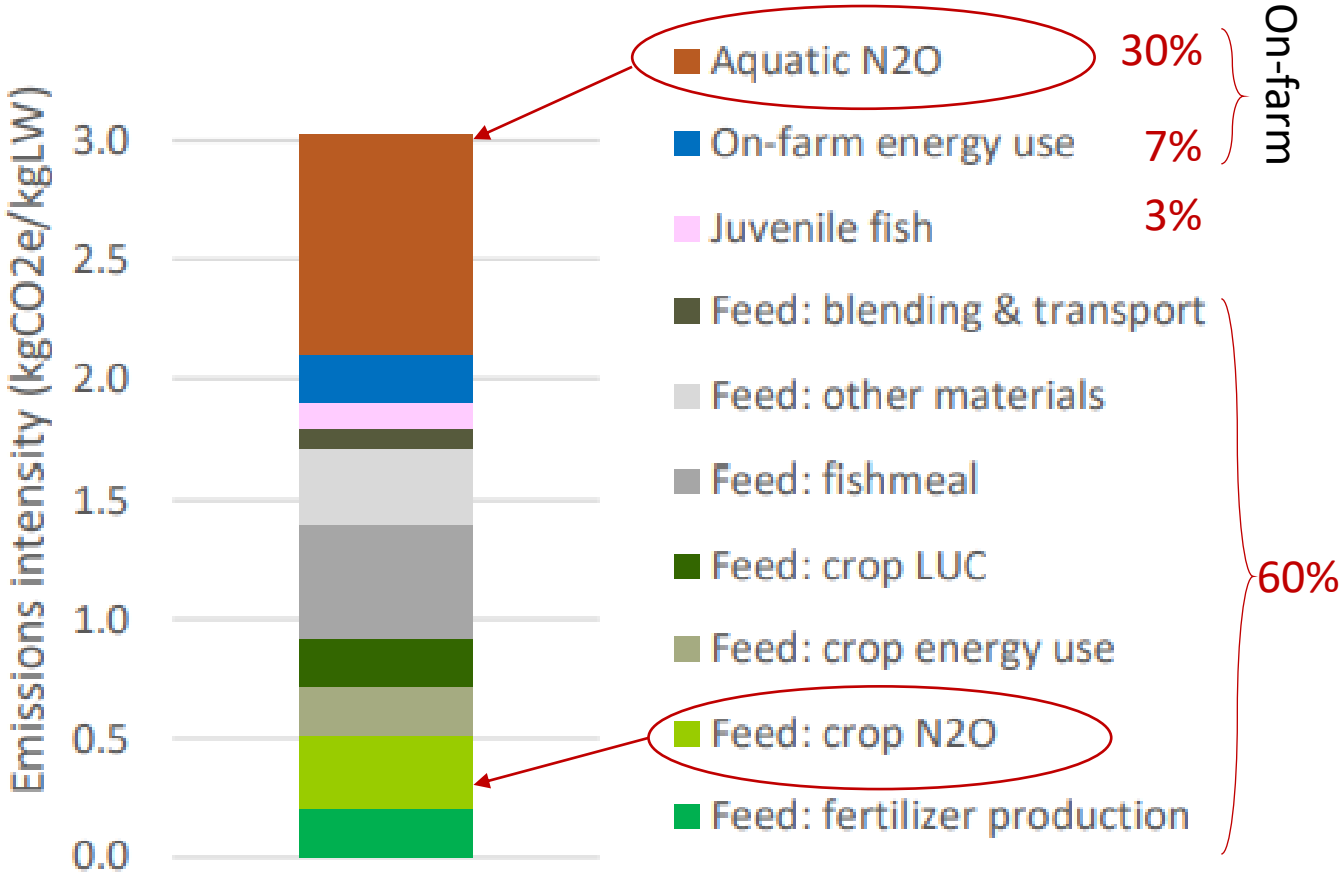


R = Renewable hydro
NR = Non-renewable

Figure 8.3 Global Warming Potential, Eutrophication Potential and Cumulative Energy Use (R = renewable, NR = non-renewable) from three Norwegian smolt units, adjusted for smolt size **per 1000 smolts (200g)** at **Flow Through (FT),** 1333 smolts (150g) at **RAS90** and 500 smolts (400g) at **RAS100**.

Total GHG emissions (kgCO2 eq.) per Kg LWE Scottish cage salmon – to farm gate 2019

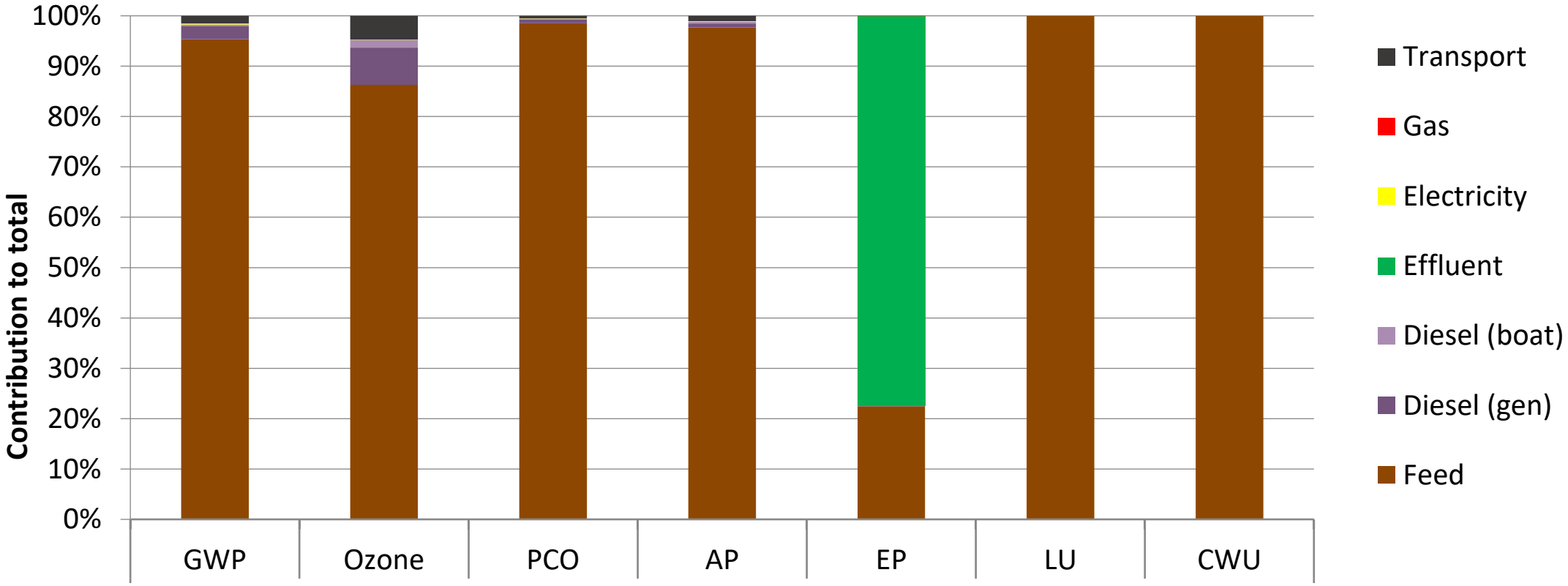
- Total - cradle to farm-gate 616k t CO2e in 2019
- 3kg CO2e/kg liveweight
- Global fish farming 263m t in 2017 (0.5% of anthropogenic emissions)
- Nitrous oxide (N_2O) from microbial denitrification; 300x CO_2 GHG potency, 114yrs in atmosphere
- Adapted FISH-e (FAO aquaculture GHG tool)



SRUC 2021: https://www.sruc.ac.uk/media/anhhptmv/rpc-research-briefing-quantifying-aquaculture-greenhouse-gas-emissions.pdf

% contribution across multiple impact categories per tonne LWE

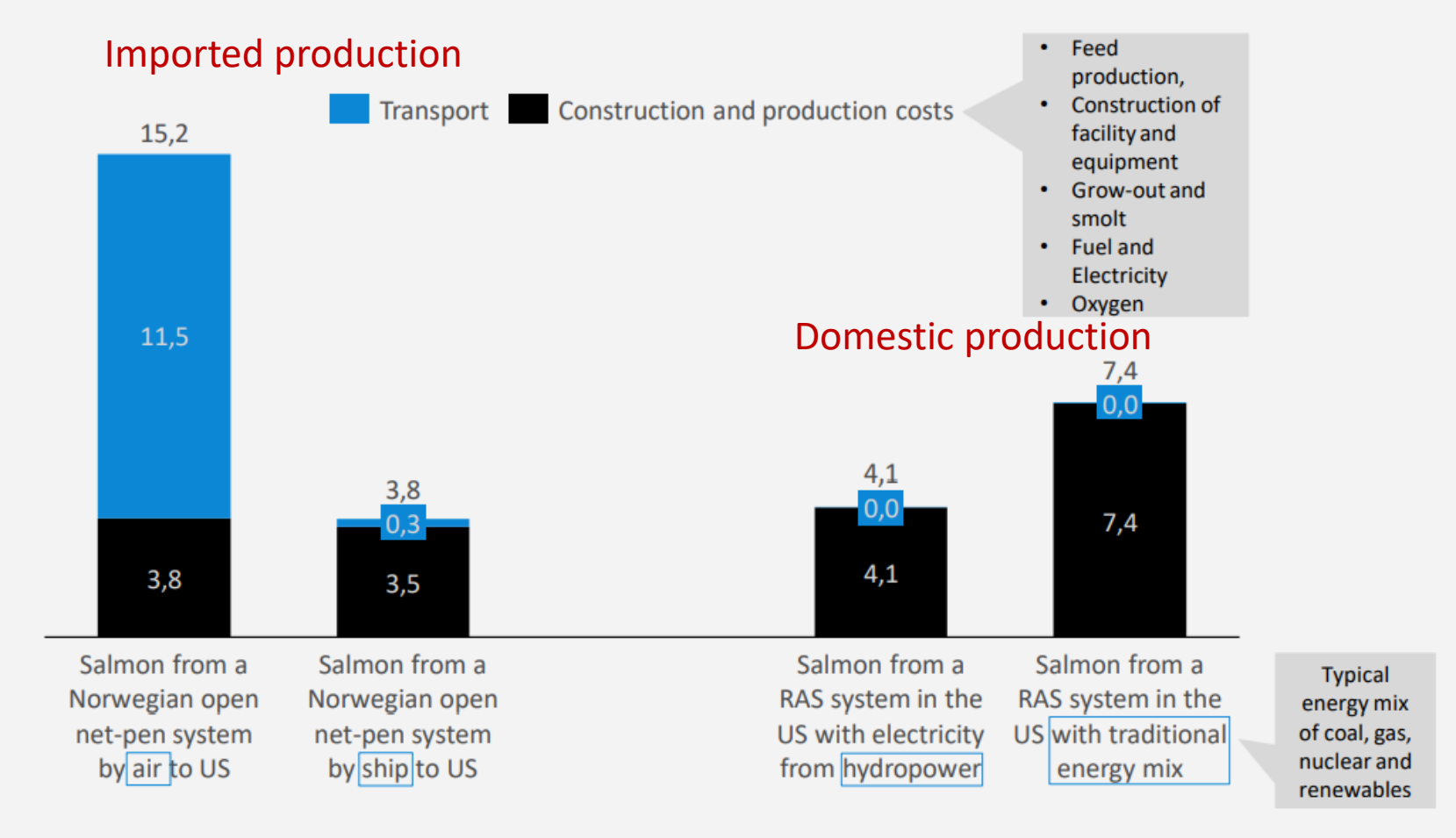
Scottish cage salmon – to farm gate 2017



GWP – Global Warming Potential, AP- Acidification Potential, EP – Eutrophication Potential, CWU – Cumulative Water Use (Green and Blue), LU – Land Use, PCO – Photochemical Oxidation Potential

Newton and Little 2018, Mapping the impacts of farmed Scottish salmon from a life cycle perspective

The advantage of "local" – GHG emissions Norwegian salmon net-pens & US RAS



Demand for fresh salmon in markets inc. USA & China is being met through the air freight with a high carbon footprint.

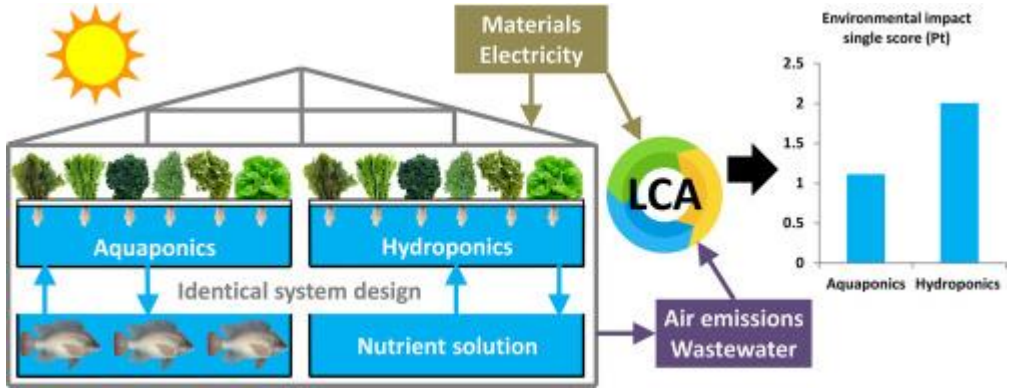
Localised production in RAS solves this problem & favours national food security & economic development

Kg CO_2 eq. per kg HoG salmon. Source: The Norwegian Aquaculture Analysis 2019, EY. Via AKVA.

LCA limitations

- LCA is expensive, complex and difficult to communicate
- LCA is not absolute….
  - Optional (non-standardised) elements under ISO standards (14040 & 14044):
    - Data collection methods
    - Normalisation of results relative to reference information
    - Grouping, weighting & quality analysis Choice of LCA tool? e.g. SimaPro, GaBi - & input inventories
  - Subjectivity of judgements re: impact categories, system boundaries, time horizon, geographical areas… potentially even functional units?
  - LCA cannot by itself determine cost-effectiveness or practicality
- Global v local scale of some impact categories e.g. is water locally limiting

Strategic applications?



- ‘Hotspot analysis’: for more general reference or comparison & thinking!
- Attributional LCA: life-cycle flows & impact allocation to co-products
- Consequential LCA: how flows & impacts affected by change in demand for the functional unit. Involves ‘system expansion’ to consider *avoided production of alternatives* e.g. waste nutrients as fertiliser…

Potential for LCA inclusion in aquaculture environmental certification schemes?

Certification of grow-out RAS

Scheme	RAS Company	Atlantic salmon	Denmark	First Cert	Cert Output	Notes
ASC	GlobalFish	Atlantic salmon	Poland	2015	450t	Converted Sp.*
ASC	Jurassic Salmon	Atlantic salmon	Poland	2016	1,000t (est. capacity)	World 1st for Sp.
ASC	Swiss Alpine Fish AG	Atlantic salmon	Switz.	2016	600t (est. capacity)	Withdrawn
ASC	Danish Salmon AS	Atlantic salmon	Denmark	2017	825t (2017)	
ASC	Pure Salmon (formally GlobalFish*)	Nile tilapia	Poland	2019	1,000t (est. capacity)	World 1st for Sp.
ASC	DanishRAS Farming A/S	Rainbow trout	Denmark	Announced	No data	
ASC	Noray Seafood	Whiteleg shrimp	Spain	2021	70t (2021)	
ASC	Seafarm	Turbot	Holland	2022	No data	World 1st for Sp.
ASC/BAP	Kingfish Zeeland	Yellowtail kingfish	Denmark	2018	600t (2018)	World 1st for Sp.
BAP	Finger lakes Fish - Local coho	Coho salmon	NY USA	2019	400t (2019)	World 1st for Sp.
BAP	Superior Fresh - RAS & Aquaponics	Atlantic Salmon, steelhead trout	USA	2018	72t (2018)	
ASC?	Atlantic Sapphire	Atlantic salmon	Denmark	Announced	2,400t (est. capacity)	Delayed by fire
Monterey Bay			USA	Green listed	2,350t (2021)	Wholefoods cert.

ASC salmon standard grow-out RAS audits

- Many environmental indicators designated N/A for closed RAS:
  - Benthic impacts
  - N&P eutrophication for sites with marine discharge (subject to VR)
  - Sea-lice management requirements inc. ABM membership
- Compliance with other indicators facilitated by RAS attributes:
  - Escape management
  - Use of therapeutants & vaccines (only anaesthetics recorded)
- Some cage-focussed requirements created initial compliance challenges
  - Frequency of visits by qualified health professionals
  - Management/ record keeping of some WQ & chemical-use parameters

RAS specific requirements

- **BAP** finfish & crustacean v3: Specific environmental requirements for reservoir/lake-based cage farms, **RAS & coastal flow-through farms**
- **ASC:** RAS add-on module additional indicators:
  - Water resource use
  - Water discharge
  - Waste disposal
  - Energy use
  - Welfare (proposed)

System	Water exchange/ kg feed
Flow-through	>50 m^3
Re-use	1-50 m^3
Conventional RAS	0.1-1 m^3
'Next generation RAS'	<0.1 m^3

ASC Salmon Standard v1.3 – Energy use & GHGs

- **4.6.1** Energy use assessment of **farm energy consumption** over the whole life cycle at sea; as kJ/mt fish.
- **4.6.2** Records of **GHG emissions on farm** and evidence of an annual assessment (GHG Protocol Corporate Standard or ISO 14064-1).
- **4.6.3** Documentation of **GHG emissions of feed used** during previous production cycle (GHG Product Standard cradle-gate assessment or ISO 14040 & 14044 LCA – provided by feed manufacturers).

No energy GHG emission limits required as yet;

Growers to demonstrate 'means to improve feed efficiency & reduce energy consumption on-farm'

But… requirements re feed GHG performance?

Potential for system-specific limits using LCA inc. RAS?

Comparative literature – salmonid systems farm gate

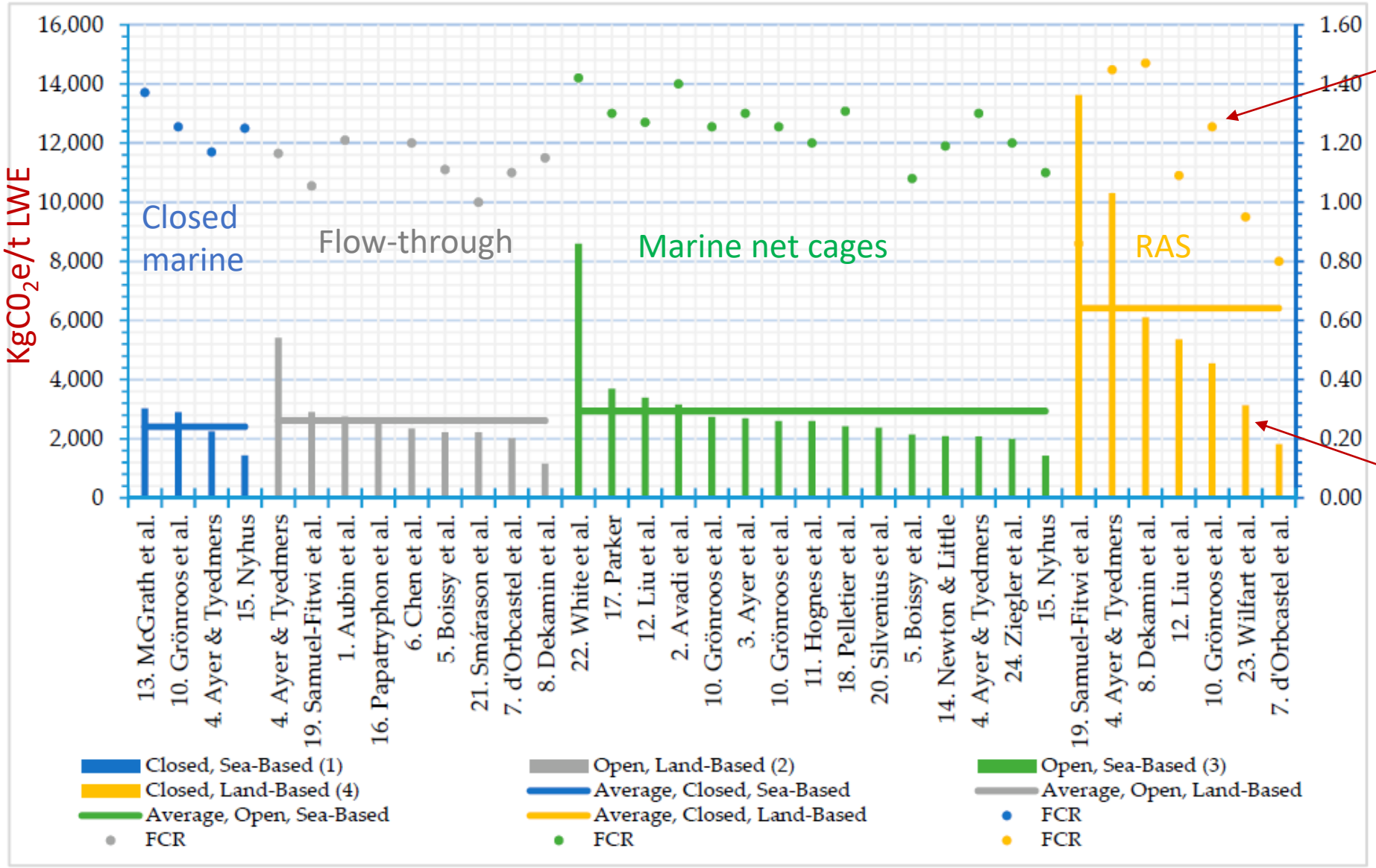
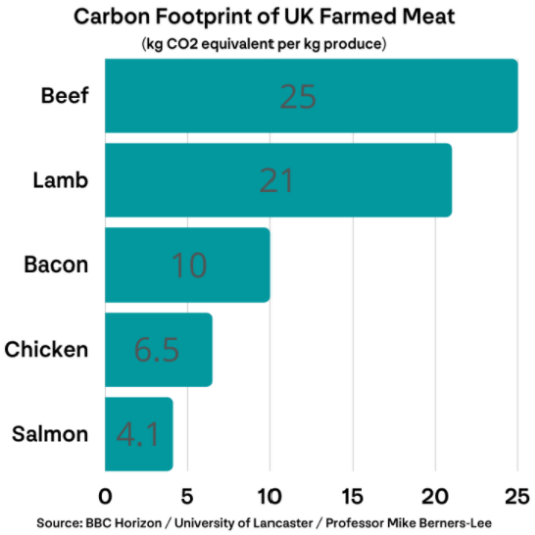


Figure 4. Salmonids global warming potential (GWP) impacts (kg CO2-e) and FCR based on production technology clusters.

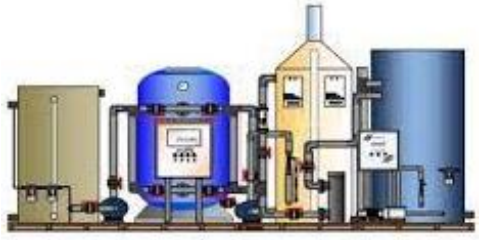
FCR

Gaspard et al 2019 **Comparing Life Cycle Assessment (LCA) of Salmonid Aquaculture Production Systems: Status and Perspectives**

Kg CO2-e/ mt LWE



Conclusions



- Salmon leading investments in grow-out RAS adoption
- Differentiation on sustainability attributes essential re. competitiveness with conventional open net-cage systems
- A key attribute is potential for co-location with markets (subject to energy & feed sourcing constraints)
- RAS attributes facilitate compliance with many existing requirements for environmental certification – RAS specific requirements being added
- Challenges remain for use of LCA for setting metric requirements
- Feed dominant contributor across most LCA impact categories – all systems
- Energy intensity is a primary farm-level sustainability constraint for RAS
- Development of a ‘post-organic’ standard reflecting RAS attributes….?