Challenging the status quo
Kaldnes® RAS

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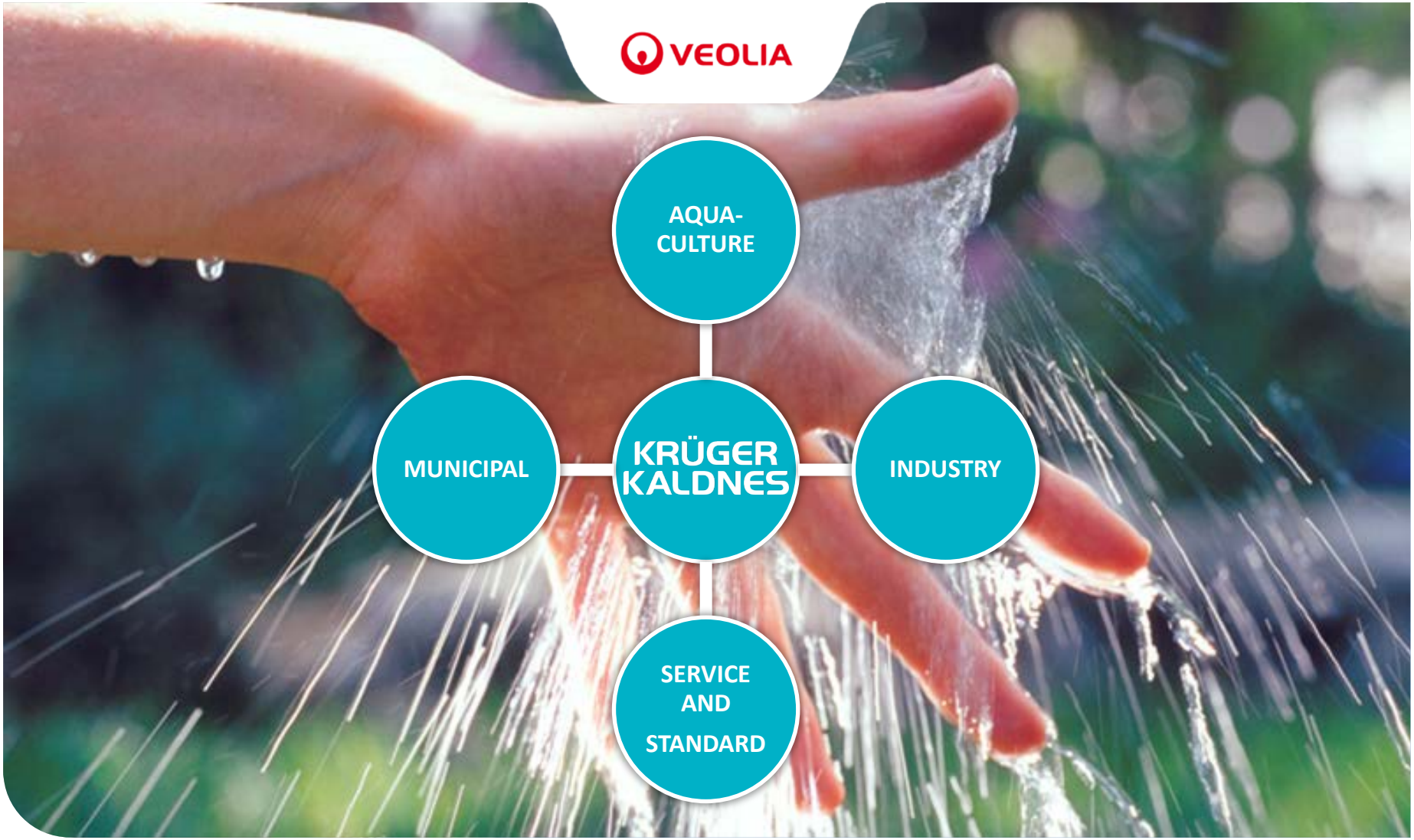
Outline

- Brief intro to Krüger Kaldnes
- Kaldnes® RAS
- Macro trends in Salmon aquaculture
- New production schemes
- High priority R&D
- Concluding remarks

Krüger Kaldnes AS

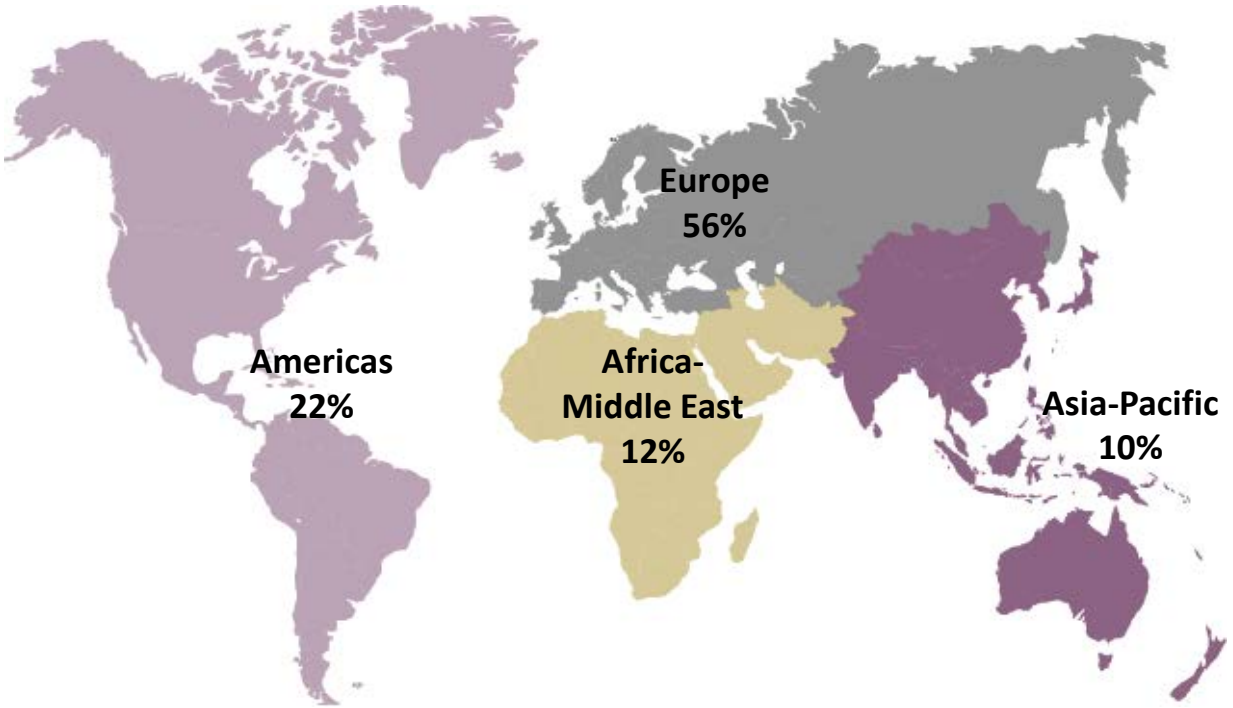
Krüger Kaldnes AS is Norway's leading contractor within the water industry. As a part of Veolia Water, we have access to technologies and expertise that enables us to offer the most in water and wastewater treatment.

Business Areas – Krüger Kaldnes



Veolia Water Technologies

- ~11.000 employees in 57 countries



workforce breakdown by geographical area

Background to Krüger Kaldnes' involvement in RAS

25 YEARS!

Biomedia for aquaculture

2008

MBBR to Nofima - largest R&D RAS facility in Europe.

2009

Marine Harvest Dalsfjord

2016 →

Leading RAS supplier for large facilities

Kaldnes® RAS

Compact and efficient

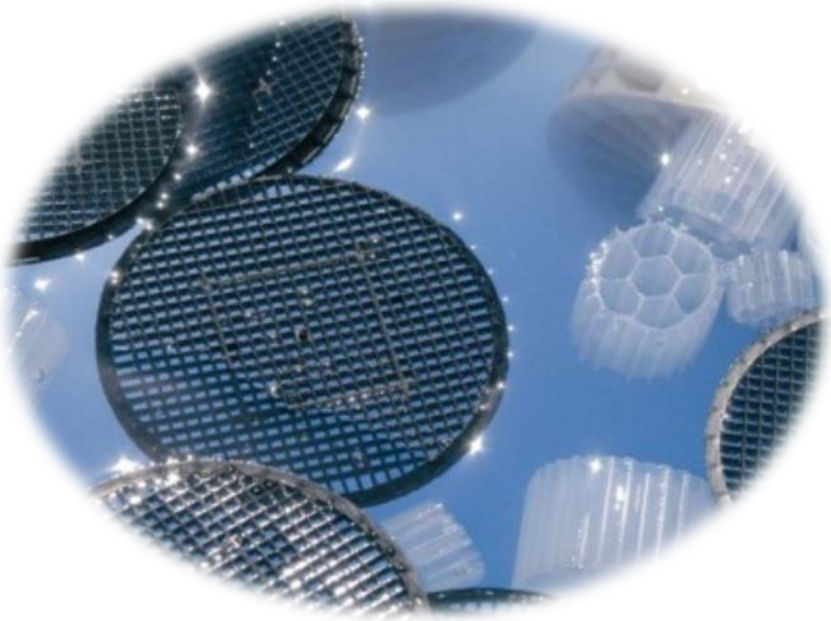
The ultimate combination

HYDROTECH Micro screens

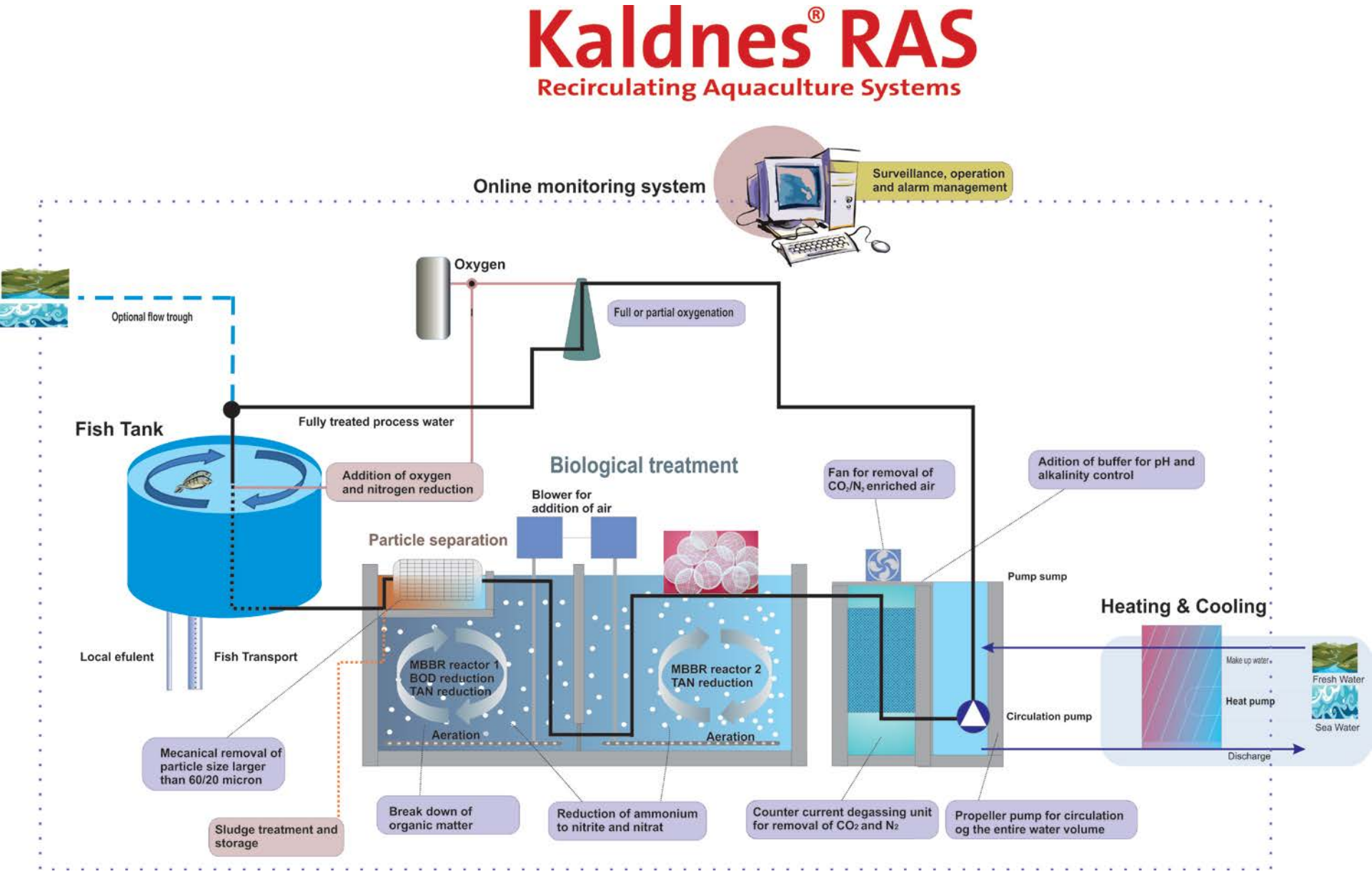
- Market leading
- Designed for aquaculture
- High hydraulic capacity
- Easy to operate

ANOXKALDNES™ MBBR

- “The biological engine” of Kaldnes® RAS
- Sheltered biofilm
- No clogging
- No back flushing



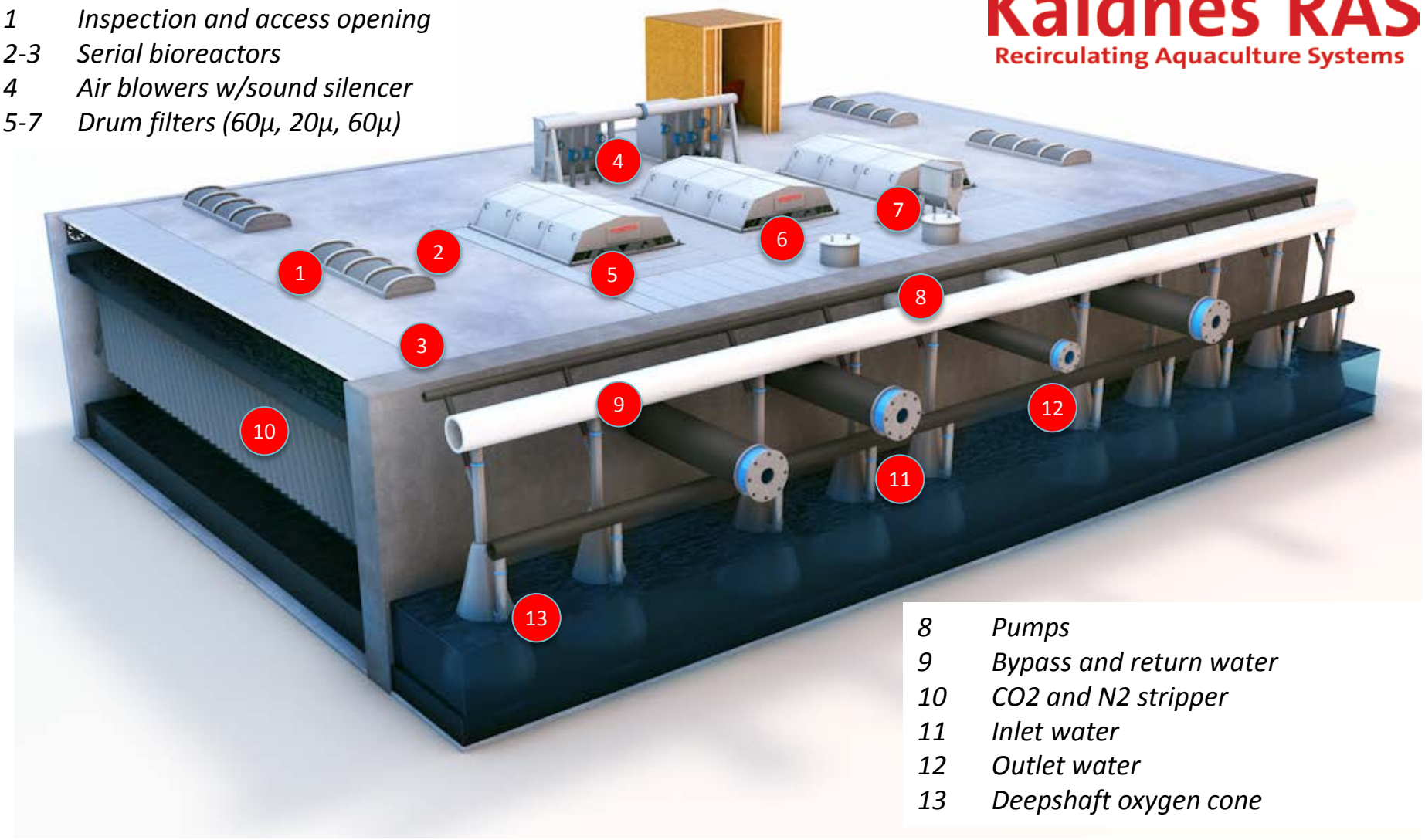
Schematic view of concept



The core technology!

Kaldnes® RAS
Recirculating Aquaculture Systems

1 *Inspection and access opening*
2-3 *Serial bioreactors*
4 *Air blowers w/sound silencer*
5-7 *Drum filters (60µ, 20µ, 60µ)*



8 *Pumps*
9 *Bypass and return water*
10 *CO2 and N2 stripper*
11 *Inlet water*
12 *Outlet water*
13 *Deepshaft oxygen cone*

Kaldnes® RAS in practice

Recent references for smolt/postsmolt in Norway

Name	Max feeding(kg/d)	Rearing volume (m^3)
Marine Harvest Steinsvik	8.900	10.900
Sundsfjord smolt	3.200	3.000
Helgeland smolt	20.400	21.700
Osland settefisk	1.556	1.611
Sævareid Fiskeanlegg	9.000	7.200
Salangfisk	7.390	9.955
Astafjord smolt	2.700	3.400
Salmar Follafoss	8.000	11.740

Marine Harvest - Steinsvik

- 5,3 million 250g smolt/yr
- 10.900 m^3 rearing volume
- 8,9 MT feed/d

marineharvest
excellence in seafood

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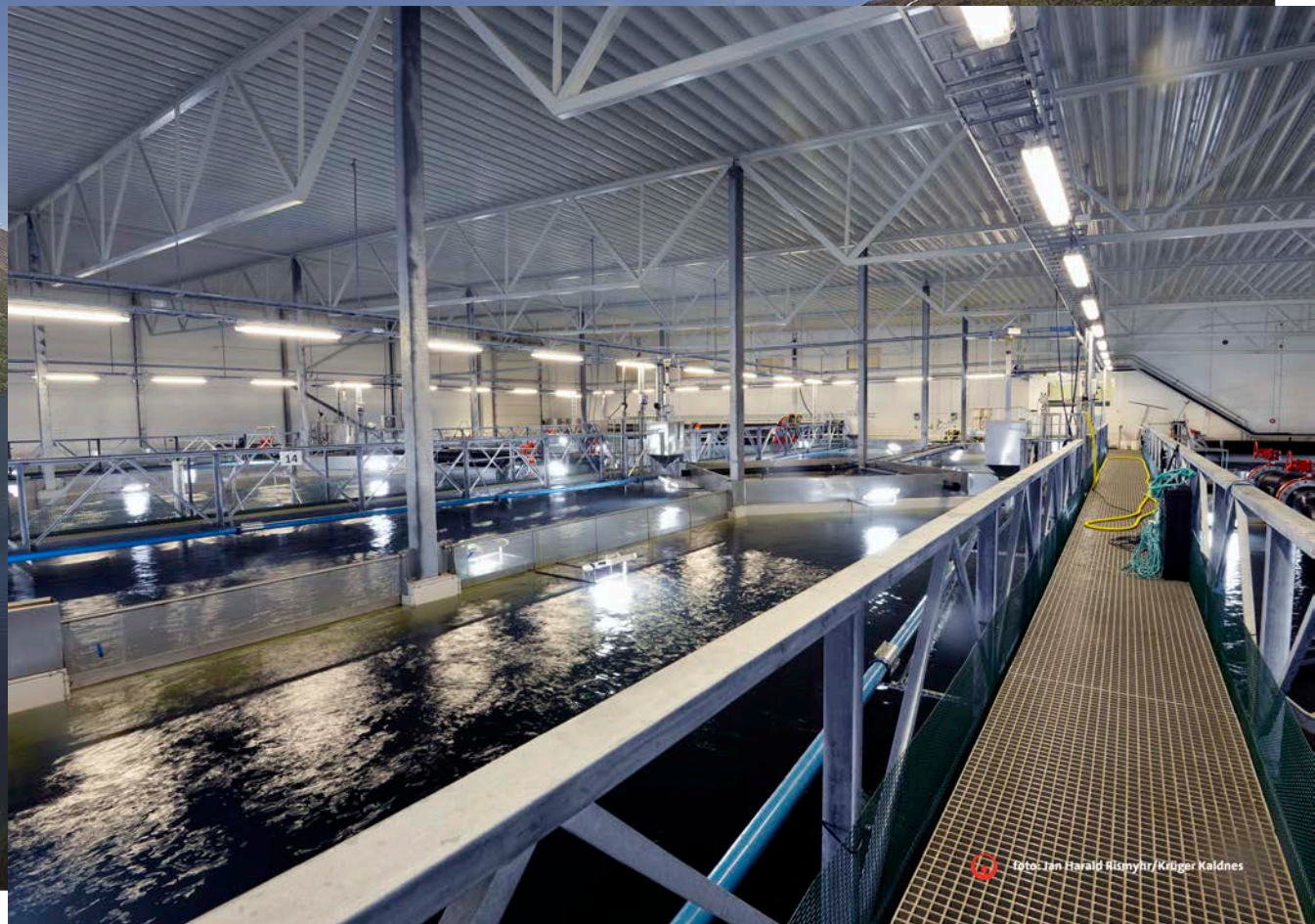

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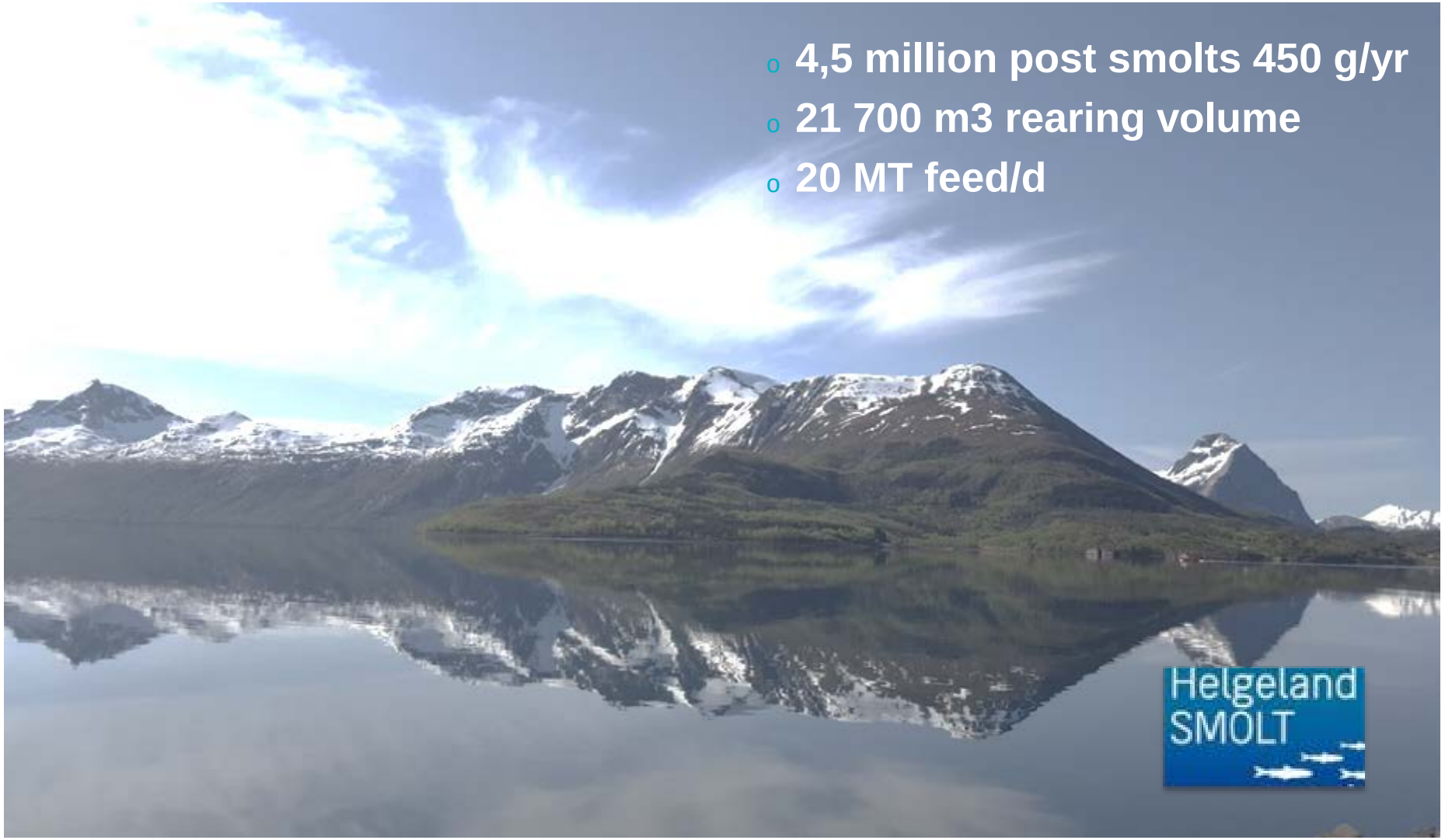
Helgeland smolt



- 4,5 million post smolts 450 g/yr
- 21 700 m3 rearing volume
- 20 MT feed/d

Helgeland smolt

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- 21 700 m3 rearing volume
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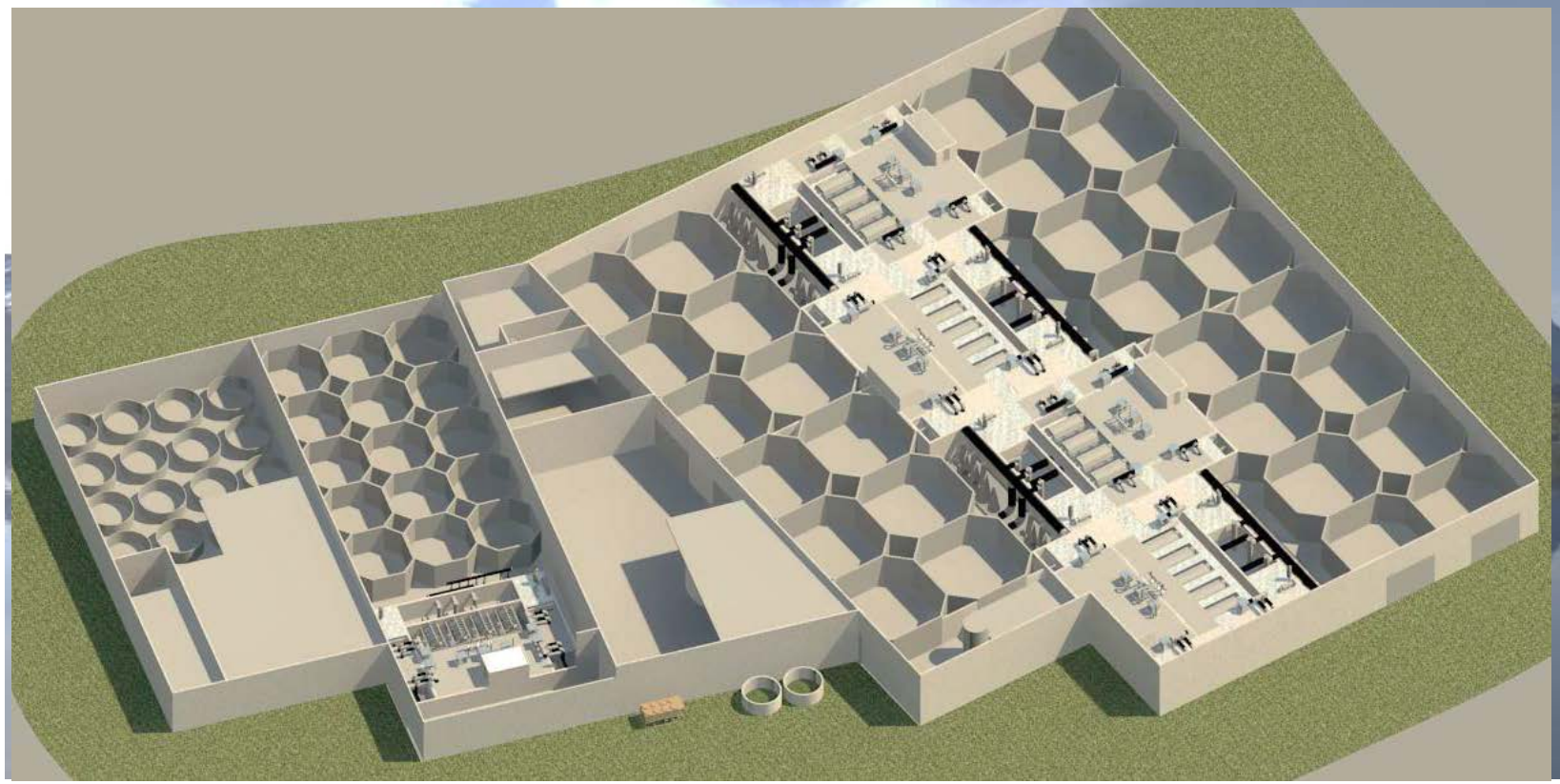
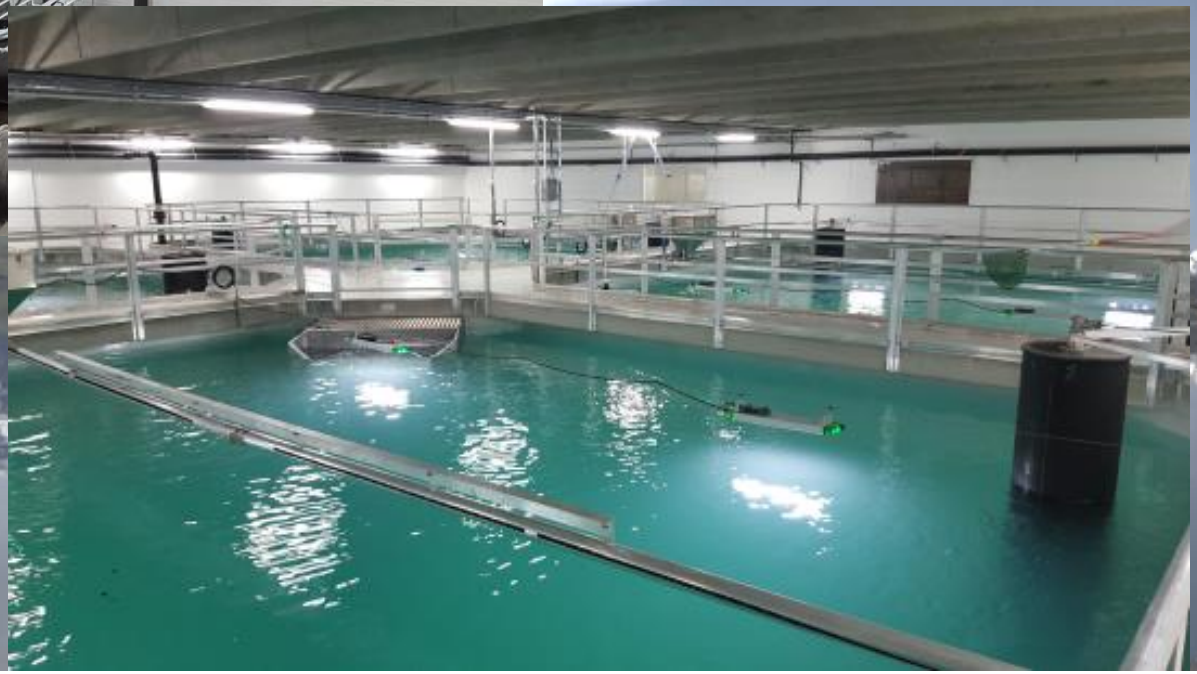


Helgeland smolt



Kaldnes® RAS in Practice

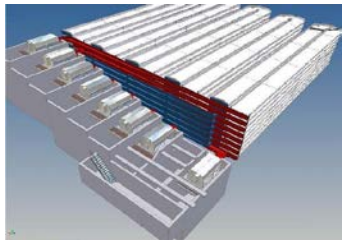
Valperca (CH)

500 kg feed/day

Seafarm BV (NL)

200 MT Turbot/yr

Multilevel shallow Raceways (8 layers)



Viet Uc (Vietnam)

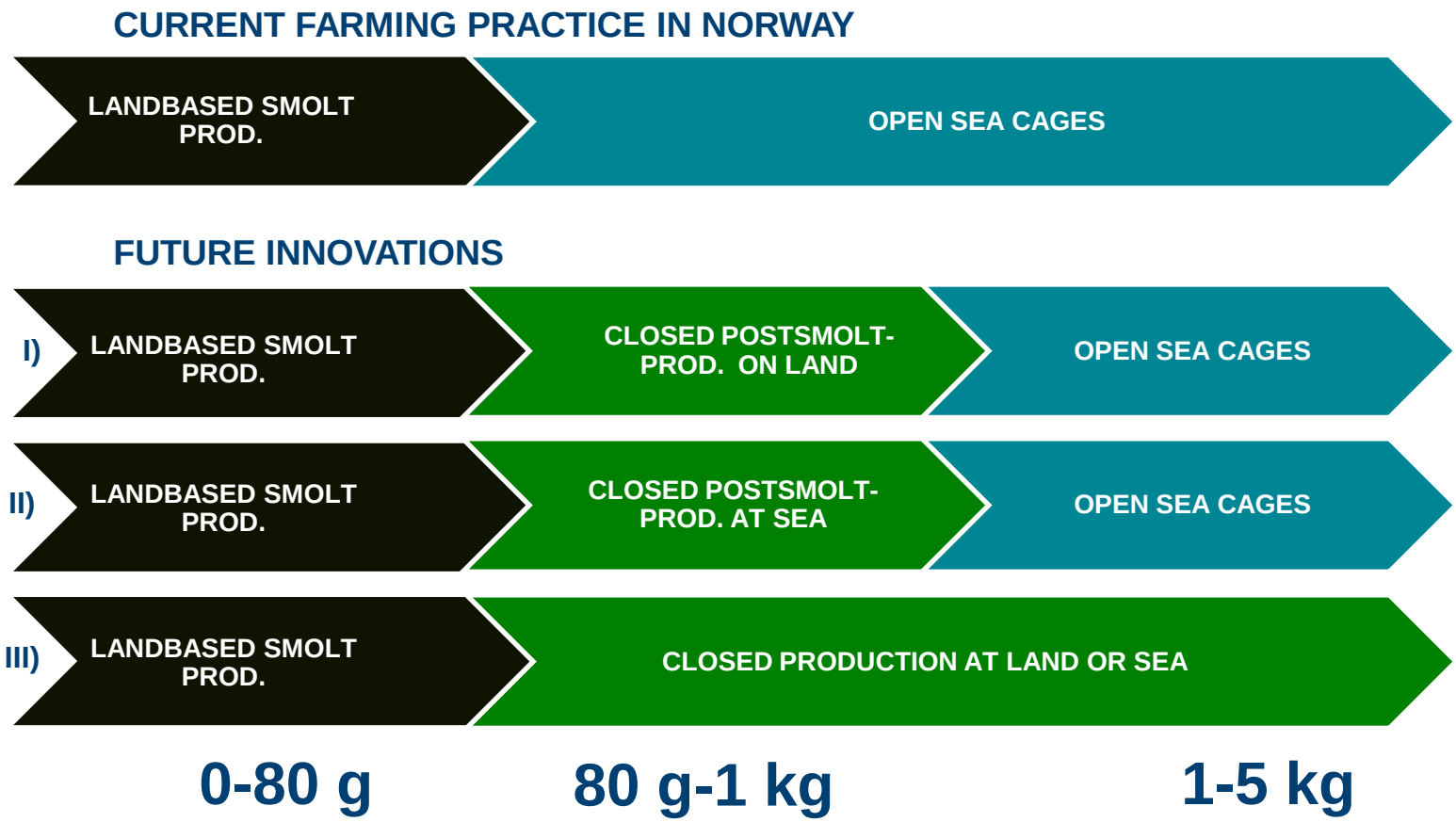
container RAS

150 kg feed/day

Macro trends in Salmon aquaculture

Kaldnes® RAS
Recirculating Aquaculture Systems

Macro trends in industrial Salmon aquaculture



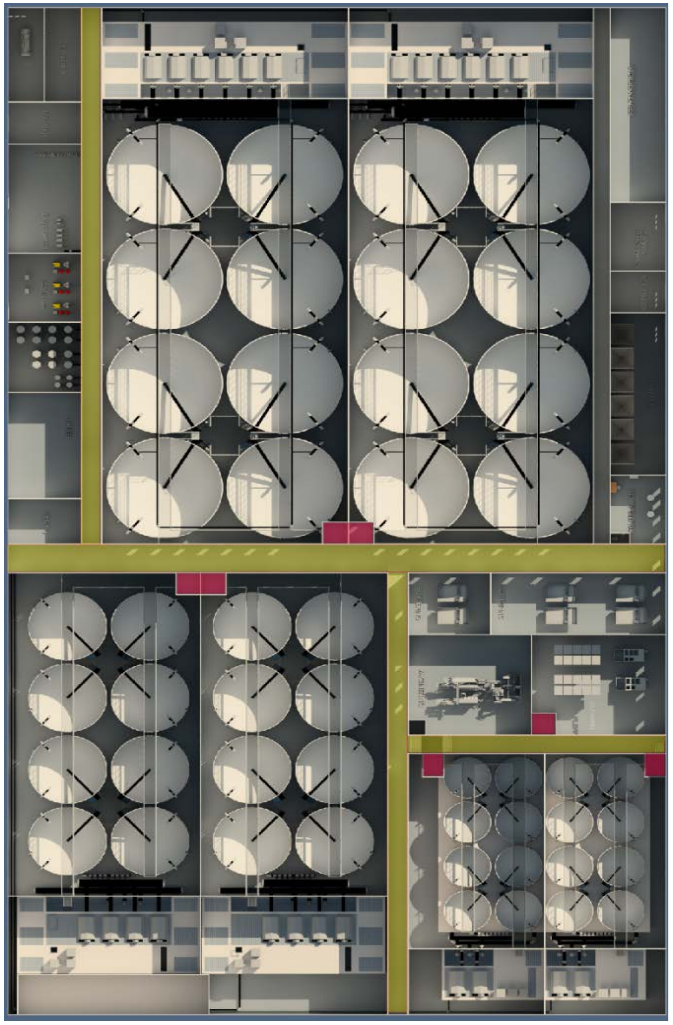
Terjesen et al. 2014

CtrlAQUA

Macro trends in industrial Salmon aquaculture

- Post smolt (0,25 – 1 kg) becomes «the normal»
  - Control of sea lice
  - Increased production capacity in excisting seawater locations
  - Better overall economy
- Strongly incrased production capacity in new smolt farms
  - more postsmolt
  - higher total number of smolt (>> 300 M/yr)
  - 2008: large RAS = 2 ton feed/d , 250 - 400m^3 fish tanks
  - 2016: large RAS = 20 ton feed/d , 750 – >1000 m^3 fish tanks
  - Requests for larger projects (100+ ton feed/d)
- More focus on closed containment systems (CCS) at sea
  - Both flow through and RAS
  - Sea lice control
- **Full production cycle on land is increasing**
  - High growth is expected
- Sludge capture and treatment
  - Sludge as resource (energy, fertilizer, spin off products etc)
  - Phosphorous recapture?

Norewegian outlook

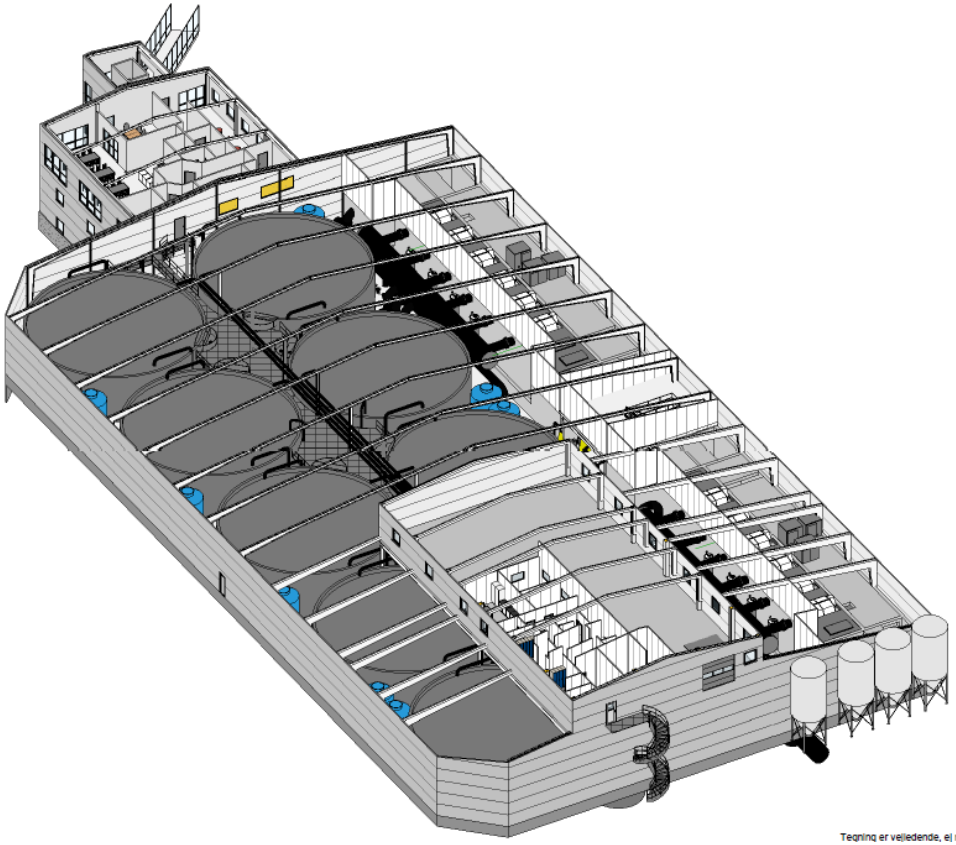


Smolt factories:

- Designed for efficient logistics
- Effective sorting og vaccination
- Central plants for feeding, heating/cooling, chemicals, dead fish collection, sludge handling etc
- Automatic control of all water treatment processes
- Automatic controls for valves and pumps
- Well-developed operations control systems with monitoring and alarm management

Some focus areas for RAS in Norway

- Defining optimal water quality conditions and fish welfare for postsmolt
- Biosecure production
- Scaling of production units (e.g. tanks and RAS modules)
- Water treatment efficencies vs energy consumption and adaptation of new technologies
- Wastewater and sludge treatment (e.g. saline sludge)



Rapidly increasing!

Challenges

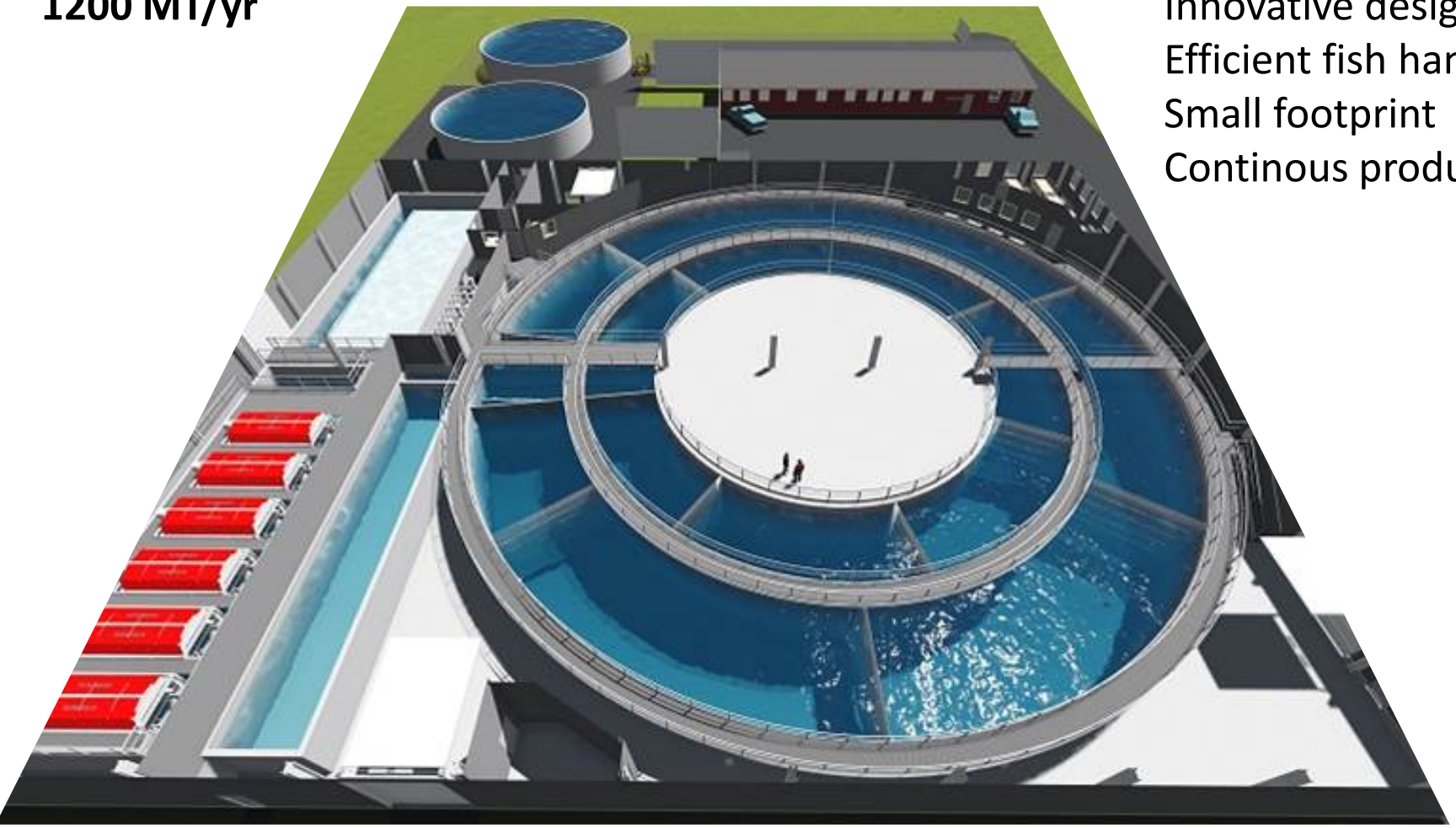
- Biological design and fish physiology competences
- Big fish logistics
- Cost-efficient solutions vs ocean based production
- Early maturation – detoriation of flesh quality
- Off flavor – detoriation of taste


Rjukan Akvafarm - Norway

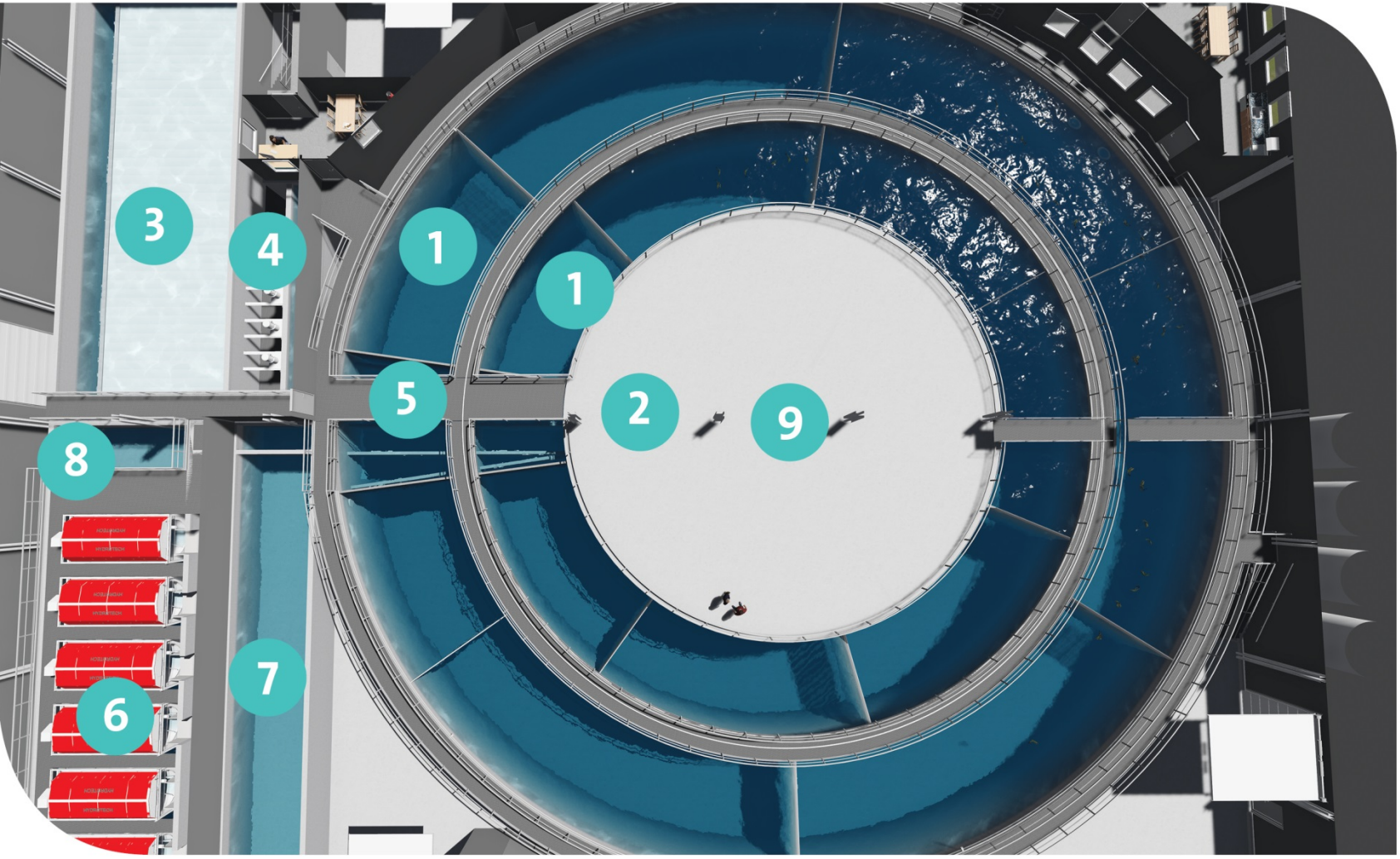
Modular farm – 10 000 MT/yr

RAS2020 – A new approach for cost efficient salmon production

1200 MT/yr



Innovative design
Efficient fish handling
Small footprint
Continous production



1. *Fish tanks with movable compartments*
2. *Biofilter MBBR reactor (Krüger Kaldnes – Veolia)*
3. *CO_2 and N_2 Degasser – (Krüger Kaldnes – Veolia)*
4. *Propeller pumps into level weir*
5. *Inlet channel and circulation propeller*
6. *Drumfilters (Hydrotech – Veolia)*
7. *Purging tank*
8. *UV filter*
9. *Denitrification chamber (optional)*

References for RAS2020

Swiss Alpine Fish – Switzerland – Start-up September 2016
Sashimi Royal – Denmark – Start up December 2016
Fredrikstad Seafoods – Norway – In design phase

R&D

a prerequisite for innovation

Our development strategy

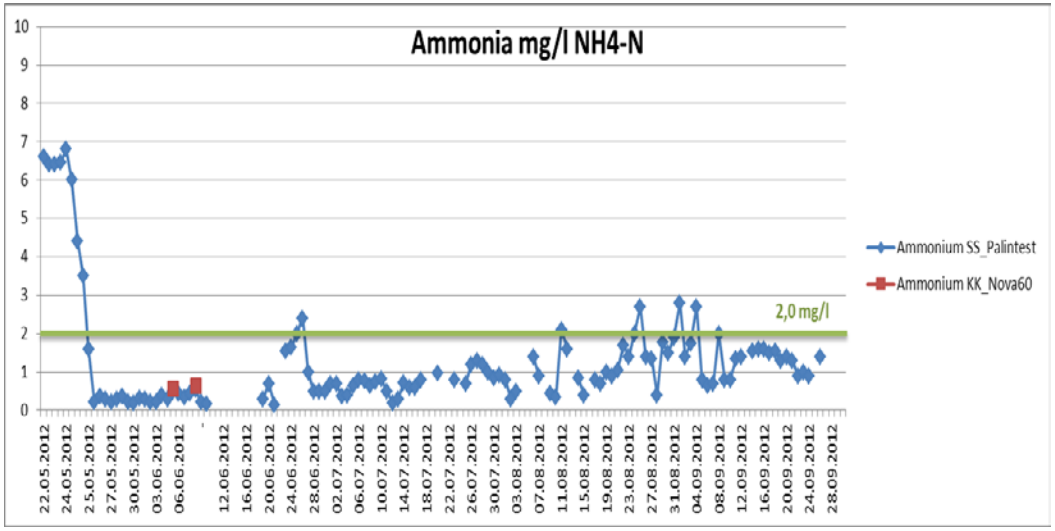
Development of exceptional RAS plants through technical know-how, innovation and validation

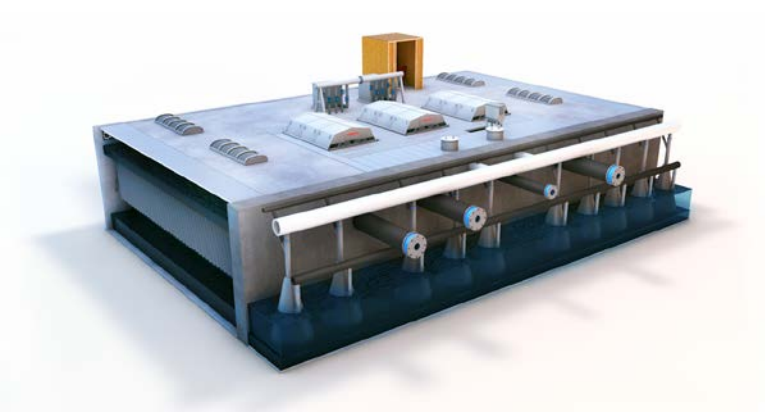
Strong focus on understanding fish physiology, water quality and technological performance enables us to apply the best solutions available

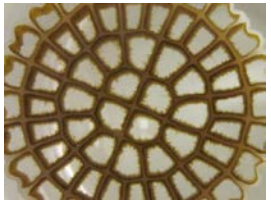
Planned and ongoing testing & R&D

- Some Ctrl AQUA projects
  - *Effect of suspended particles on fish health and welfare*
  - *Hydrodynamics in large fish tanks*
  - *AOP in RAS* (to be initiated)*
- Internal and partner projects
  - *Fine particle removal (filtration, membranes, oxidation, skimming)*
  - *Efficient gas removal/addition (CO2/N2, O2)*
  - *Wastewater & Sludge handling (filtration, composting,drying, biogas)*
  - *P recovery from sludge (Struvia)*
- Strategies for combating early maturation
  - *Temperature controls*
  - *Lighting regime*
  - *Stocking density*
- Efficient purging systems
  - *Removal of MIB/Geosmin in the RAS loop*
  - *Work-out regimes*

Testing og validation - Kaldnes® RAS

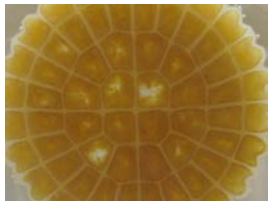






Documentation of Kaldnes® Moving Bed under various operating conditions:

- The effect of rapid load changes (e.g. at fish delivery)
- The transition from freshwater to seawater
- Influence of environmental factors



New technology - Kaldnes® RAS

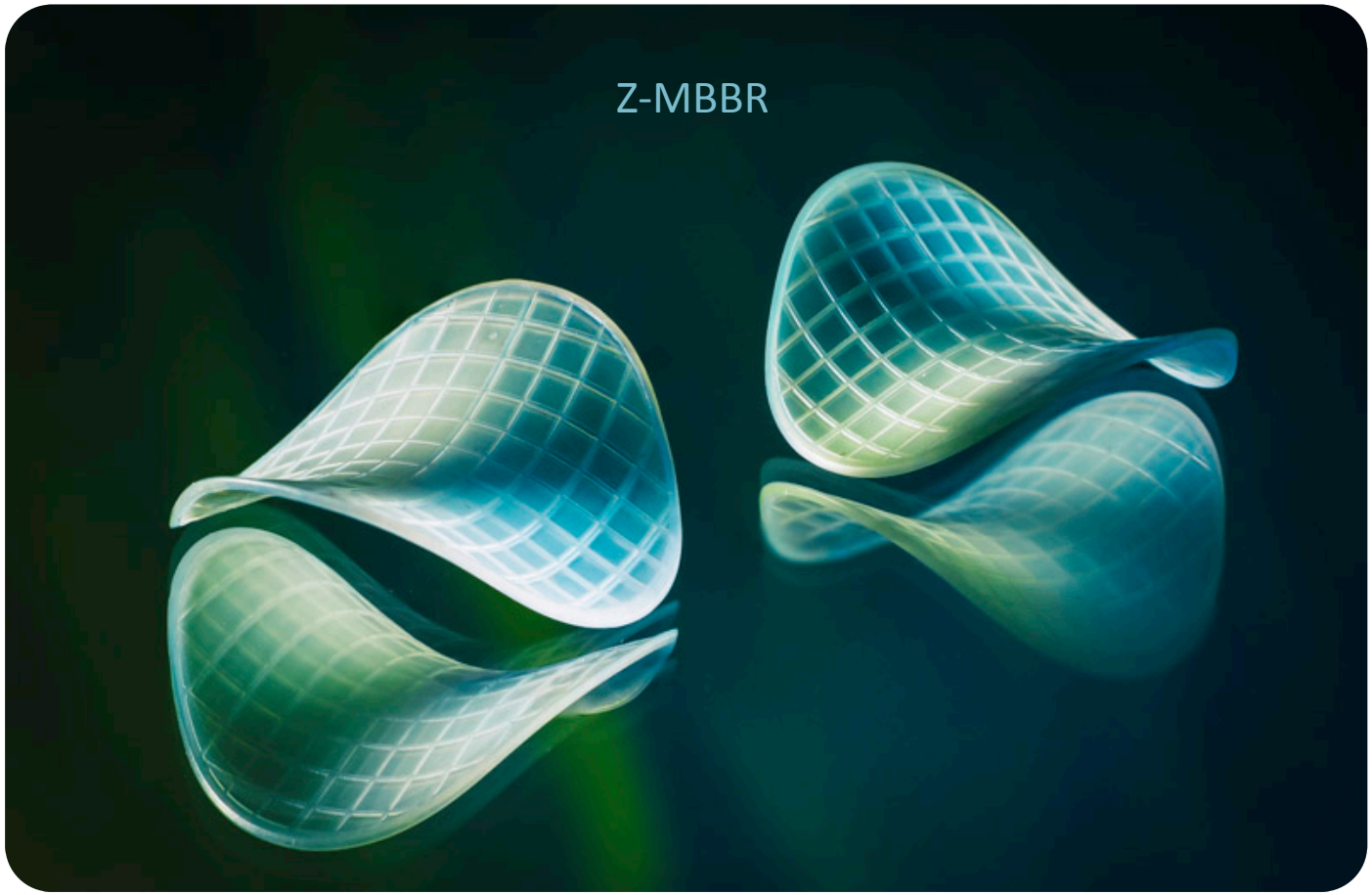
AOT (Advanced Oxidation Technology)

Photocatalyctic oxidation






New Technology – self regulating biomedia for MBBR



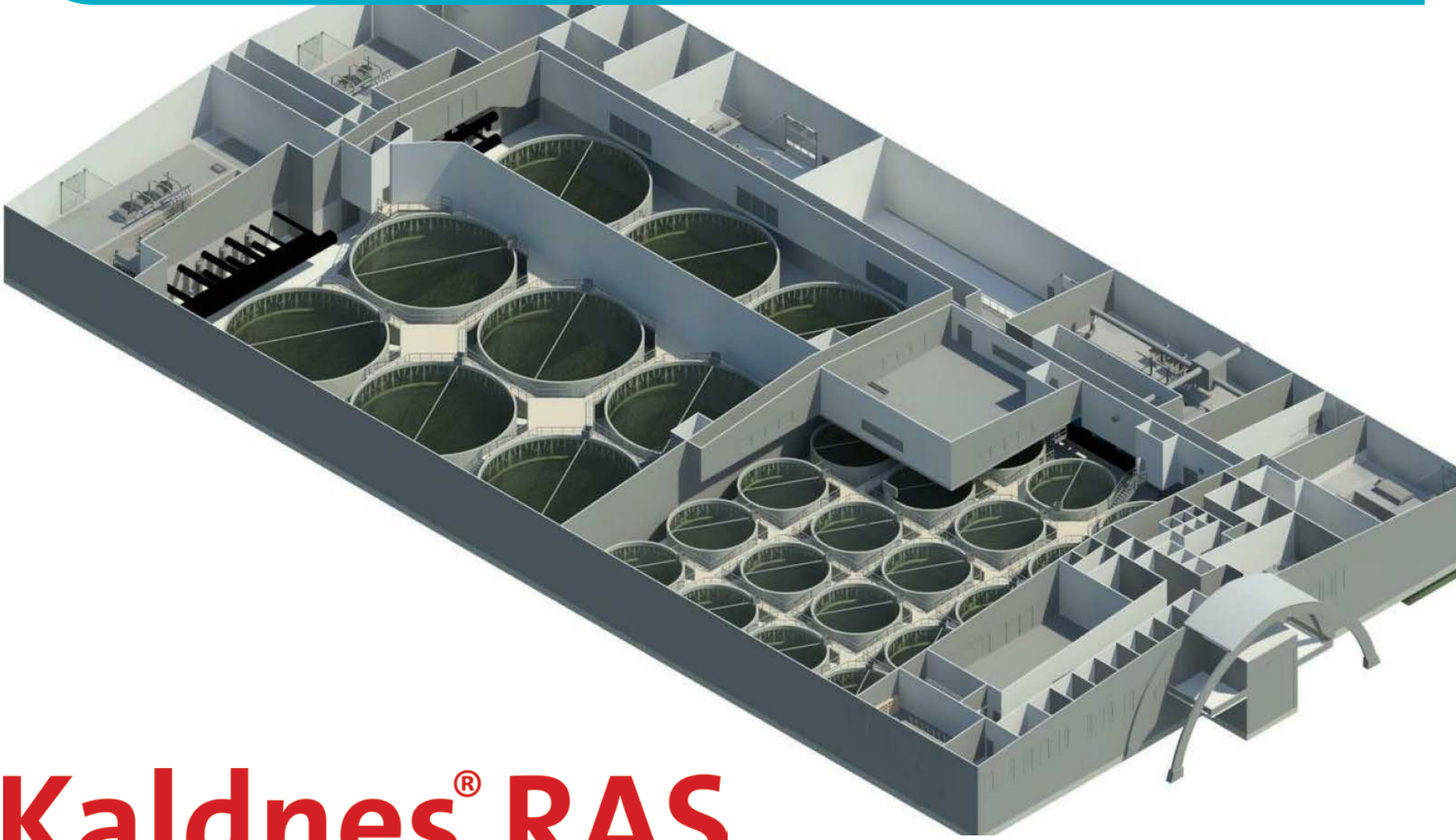
Concluding remarks!

- RAS has moved from being a **niche** to **State of the art** and **mainstream** production method for salmonids

- Development of smolt farms is towards **larger production** units for **larger smolts/postsmolts**. This causes changed conditions for how RAS plants are built and operated. Many challenges are addressed for efficient, predictable and cost efficient means of production.

- Salmon to full size on land is likely to increase dramatically in the very close future. Experiences from front runners are mixed, though lessons learned and new research and development address key challenges and and strategies to make land based salmon farms a viable production method in the future.

Thank you!



Kaldnes® RAS

Recirculating Aquaculture Systems