

Land-based aquaculture is taking off in several regions

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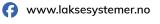
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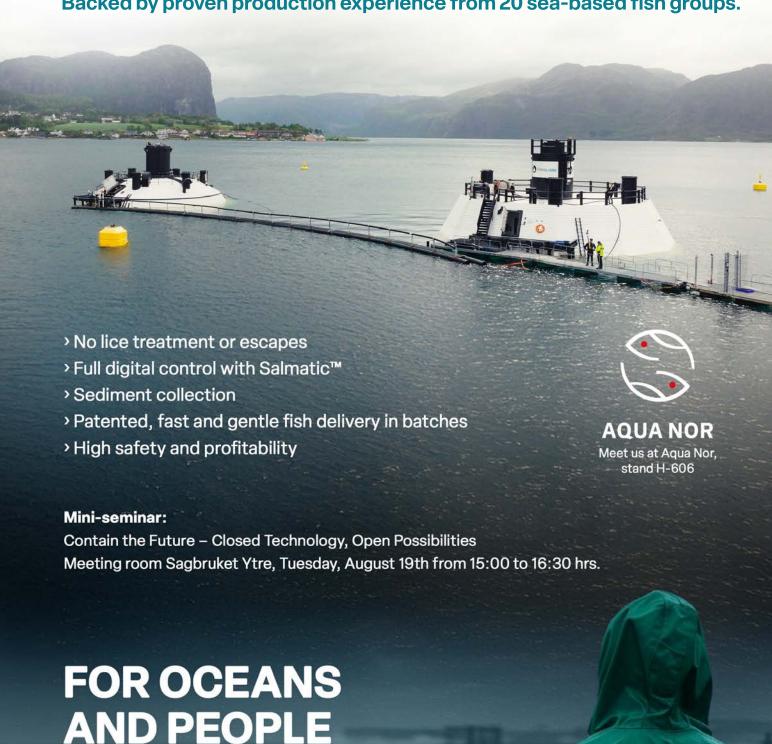
#### TAKING THE NEXT STEP IN GROW-OUT PRODUCTION

With AKVA group as technology partner, Laxey has developed a modern RAS smolt facility. Construction of the grow-out facility using reuse technology is well under way, and phase two has started.

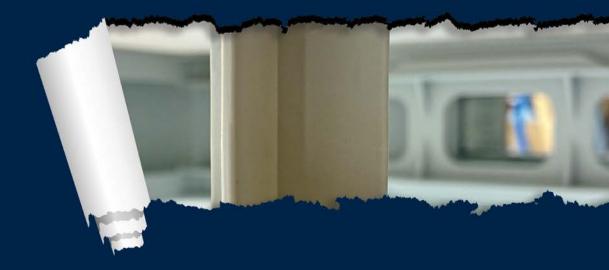


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Pål Mugaas Jensen

**Chief editor**LandbasedAQ

## Many land-based fish farming facilities are under construction in Iceland

Land-based salmon farms are being built in many parts of the world right now. One place where activity is surging is Iceland.

Iceland's production of land-based salmon was around 2,000 tonnes in 2022.

Since then, development has accelerated: several large facilities are now in operation, under construction, or in the planning phase.

Toward 2030, total capacity could exceed 180,000 tonnes. With access to filtered seawater, geothermal freshwater, and affordable renewable energy, the country has natural advantages few other regions can offer.

LandbasedAQ has visited key projects to explore how the initiative is being realised

in practice – technologically, biologically, and financially.

The plans and process of building in Iceland have existed for several years, but it's undeniable that foreign investment gained momentum after a temporary halt on new land-based aquaculture applications was introduced in Norway in December 2022. A new regulatory framework was needed, but it has taken over two and a half years before finally being adopted. The application freeze hit the Norwegian industry hard and created significant uncertainty. One of the key changes in the new rules is that all new facilities must disinfect incoming water, which will inevitably increase construction costs. It is therefore not surprising that some players continue to look beyond Norway.

In this issue you can also read about a new study presenting a comprehensive risk assessment of 21 land-based aquaculture facilities in Norway from the RM (Risk Management) Akva-project, using a standardised evaluation methodology developed by Akvaplan-niva, Norway. The study presents some interesting results on how to reduce risk in land-based aquaculture production.

For more news and insight on the land-based aquaculture industry, also check out our websites: LandbasedAQ.com, .no and .cl. •



#### >> AquaBounty has lost \$369m in its 33-year existence

Debt-laden former salmon farmer AquaBounty Technologies has made losses of US \$369 million since its incorporation in December 1991, it said in a gloomy update on its financial position in its report for the first quarter of 2025.

AquaBounty farmed fish that inherited a genetic modification enabling them to grow more quickly, and the company had ambitions to build a network of 10,000-tonne-capacity land-based facilities in North America.

But it ran out of money as building costs for the first such facility in Pioneer, Ohio, spiralled. It paused work on the site, and then sold off a smaller farm in Albany, Indiana, for a bargain basement price of \$9.3m to meet debts and raise money for the Ohio project.



» AquaBounty's site at Pioneer, Ohio, is estimated to be 30% complete. Photo: AquaBounty annual report

As of March 31, AquaBounty had \$1.4 million in cash and cash equivalents.

The company still owns the Pioneer site •

>> Bakkafrost's Applecross RAS facility. Photo: Bakkafrost Scotland

#### >> Bakkafrost Scotland's RAS and smolts are both getting bigger

The average weight of smolts transferred to marine sites from Bakkafrost Scotland's flagship recirculating aquaculture system (RAS) facility at Applecross in Wester Ross was 232 grams in the first quarter of this year - 80% higher than in Q1 2024.

Those fish pushed the average weight for all of Bakkafrost's smolts stocked in Scotland in the quarter to 169g, which is 40% higher than in the same period last year.

The Faroes and Scotland salmon farmer says that in the Scottish freshwater operation the main priority is to ensure a steadily growing output of large high-quality smolt from Applecross, which is in the ramp-up phase to deliver fish above 200g in 2025.

"Production volume and smolt release will increase throughout the year and into 2026. With the new Applecross 5 module now in production, the production capacity is around 3,500 tonnes of smolt annually. This capacity will be utilised to make Bakkafrost self-sufficient with around 14 million high-quality smolt of 250g."

The percentage of sub-200g smolts stocked by Bakkafrost Scotland will decrease this year and next as Applecross increases its output. By Q4 2026, all smolt stocked at sea will be above 200g. When Applecross is operating at full capacity, it will produce 8 million smolts a year with an average weight of 500g. •

#### >> Home found for 'most sustainable' trout farm

Onnest, a Danish company planning to build the world's most sustainable trout farm, has announced that it has secured a site for the land-based facility.

The site is next to Egebakken and Hirtshals Transport Centre in Hirtshals.

"We have entered into a purchase agreement with Hjørring municipality for approximately  $85,000~\text{m}^2$  of land regulated for aquaculture," co-founder Samuel Muren wrote on the company's website.

"The Onnest site and its location have been discussed for some time, and the parties have now finally formalised an agreement that will mark the start of our development plans.



The Onnest site is next to Egebakken and Hirtshals Transport Centre in Hirtshals. Photo: Onnest

"The property itself is well placed for realising our vision on the future of aquaculture, and it can accommodate both our short-term development work and our long-term expansion plans. Moreover, we also hope its central location will spark curiosity and interest from both the local community and visitors alike. We think this is going to be a good home."

#### New milestone for South Korea's first land-based salmon farm

South Korean aquaculture company Eco Aquafarm has reached a new milestone in the development of its land-based salmon farm in Busan. The second batch of Atlantic salmon fry has now been transferred from the hatchery to the recirculating aquaculture system (RAS).

The salmon fry, having absorbed their yolk sacs, were recently moved to the facility's RAS 1 tank.

The transfer marks an important milestone in the facility's first year of operation. The company says that the salmon from the first batch, which was transferred to RAS 1 in February, and the trial batch transferred to RAS 2, are showing good and healthy growth.



The second batch of salmon fry is released into a RAS tank. Photo: Eco Aquafarm

Eco Aquafarm operates South Korea's first and only land-based Atlantic salmon farm. The facility, developed by GS Engineering & Construction and located at Pukyong National University's Fisheries Science Institute in Gijang-gun, is built over several floors and has an annual production capacity of 500 tonnes.

The facility was completed in December 2024, uses AKVA group's RAS technology and is part of the government initiative Smart Aquaculture Cluster Development Project, a programme to digitalise and modernise Korean aquaculture.

Eco Aquafarm plans a tenfold increase in production capacity in the next phase, and is seeking international investors to realise a large-scale RAS plant with 5,000 tonnes of annual capacity.

The first harvest from the facility is planned for the fourth quarter of 2026 •



## A glimpse of the future

The University of Stirling's Institute of Aquaculture has given an update on the progress of its £20 million, state-of-the-art recirculation and flow-through research facility, which was due for completion this month.

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The National Aquaculture Training and Innovation Hub (NATIH) marks a major investment in aquaculture research by the university, the Scottish and UK governments, and the local council.

More significantly, it provides the Institute of Aquaculture – one of the world's leading aquaculture research institutions – with modern facilities that enable it to carry out work on a wide range of aquatic species, for its own purposes and in collaboration with others.

Danish technology supplier Northern AquaCulture was due to hand over NATIH to the university in mid-August, IoA professor Trevor Telfer told a recent aquaculture conference in Inverness.

The most expensive equipment is the system that filters water from Scottish Water's supply to ensure its suitability for fish, said Telfer.

"We've got four (larger) constant temperature rooms here. And there are varying sizes, but they're all independent recirculating aquaculture systems, with different capacities. And all of them are capable of culturing fish or working with fish at anything between 6 and 28 °C. So there's a big temperature range within this.

"Everything's very well monitored and backed up, but each unit is completely independent."

NATIH also has four smaller controlled temperature (CT) rooms.

"These are more aimed at small tanks, behavioural trials, and maybe working with things like zebra fish before scaling up to larger trials."

Additionally, NATIH has three freshwater flow-through challenge facilities.

"Even though they're flow-through systems, they've got the same temperature range as the RAS systems. There's been a huge amount of work done on this, and it still fits into Stirling University's net zero ambitions – there's a lot of heat exchange and recovery," said Telfer.

Water used in NATIH goes through an outflow treatment system before it goes back into the public water system.

In all, NATIH has 48 tanks ranging in size from 25 to 500 litres in its four larger RAS zones and 40 tanks in its small CT rooms. "While the big RAS systems are very much fixed, the smaller CT rooms are ultimately flexible so they can be set up for any sort of research work," explained Telfer.

"Of course, we'll be doing work on many species of fish, including fish that we'll be importing, bringing in from overseas. We've already got plans to work with tilapia and pangasius, so we need quarantine units, and NATIH has got two."



The challenge area in NATIH. Photo: IoA



Controlled Temperature 1 with biolfilter. Photo: IoA



An illustration of the layout of the NATIH facility. Image: IoA

Commissioning of NATIH's systems is due to begin in September.

"Basically, everything is filled, some at more temperate conditions, some at more tropical conditions, so we'll be working with salmonids, tilapia and crayfish, and we'll be commissioning some behavioural studies with zebra fish in the smaller CT rooms," said Telfer.

"Everything will be full, so we can test the lot. Hopefully, everybody will be happy that the systems work, so then we can

CAD

drawing

start with the real research, the real trials work."

The new facility is not the only one the IoA can use for research. It also owns the Neil Bromage Freshwater Research Unit at Buckieburn, just outside Stirling, and the Marine Environment Research Lab at Macrihanish on the Kintyre peninsula near Campbeltown. Like the NATIH project, Macrihanish has also benefited from improvements funded by growth deal - in this case, a £70m Rural Growth Deal signed between Argyll and Bute Council and the UK and Scottish governments.

Dave Little, Professor of Aquatic Resources at the IoA, told the conference that another

> important part of the NATIH investment is looking at how the R&D facility plays out in its local and wider communities.

The university has been working with quango Developing the Young Workforce to show school pupils how aquaculture offered a pathway to many types of employment.

It is also seeking to use the facility to promote innovation, and is working with organisations to promote fish as a healthy ingredient, even for people who have to use foodbanks. Tinned fish is a now first choice for them, instead of a last option, said Little.

He asked: "How can aquaculture and seafood generally connect through to its role in our broader society? That's what this investment's about. The big money is going into building state-of-the-art facilities so that we can do joined up research across a range of species of global significance, but it's also about connecting through to people."

Are you attending Aqua Nor? Find out more about NATIH's services from University of Stirling representatives at the Scottish Pavilion (D-337) •



## Slow and steady wins the RAS

Pure Blue Fish plans to produce thousands of tonnes in the United States but it's going to do it one careful step at a time

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The Israeli company Pure Blue Fish recently celebrated the sale of the first red drum grown at its 100% recirculating aquaculture system facility at Binyamina, about an hour's drive from Tel Aviv.

Next stop is Orangeburg County, South Carolina, where it has land and permission for a bigger facility. But unlike some of the land-based fish farming projects in the US, Pure Blue Fish isn't talking in the region of 20,000, 10,000, or even 5,000 tonnes – at least, not to begin with.

Instead, it will build one or two 300-tonne modules and add further modules once it has begun producing fish and selling them profitably. It envisages eight such farms in the US in the first phase, each with up to 16 modules, but expects the farms to take a decade to reach full size.

"This is by choice, not necessity," explains business development officer Ido Mann. "We believe 10 years is a good time frame to build a full farm, to grow gradually in terms of the team and manpower and partnerships."

Pure Blue Fish operates a zero discharge RAS that uses the local tap water supply and only requires top-ups to compensate for evaporation. And unlike the bigger US RAS projects, it won't grow salmon. The company is focused on marine fish, such as yellowtail kingfish and red drum, for commercial and conservation reasons.

"We know that in the market there are solutions for diadromous fish and freshwater fish that are pretty established," says Mann. "But when you're talking about marine fish, 95% of them are still being fished out of the sea. So, we believe the biggest impact you can have is by growing marine fish."

The US market for marine finfish is US \$15.6 billion, he points out.

The company's modules are self-contained, enabling it to grow more than one species of fish at a site. This will allow Pure Blue Fish to meet market demand, rather than trying to build it up or establish a complicated and expensive distribution network, says Mann.

"Because we have self-contained modules, we can change the temperature, the salinity, the acidity, everything, to grow different types of fish and then provide the consumer with a variety of products. We will be able to provide a restaurant with the three or four types of fish they need if we're to be their sole supplier, for example."

Pure Blue Fish's zero discharge and use of standard tap water means its farms can be built anywhere. Location will be decided partly on proximity to cities – the company aims to be within a sixhour drive of 80% of the population – and also on incentives offered by local governments seeking job creators.

"We've already started working on [plans for] our next farm, the second location in the US, and we're starting plans and reaching out to local governments to understand the incentives of other areas



Inside the Pure Blue Fish zero discharge RAS facility at Binyamina, Israel. Photo: Pure Blue Fish

in the US that are relevant to see where we're going next, our third and fourth farms," Mann tells Fish Farming Expert.

"We're agriculture and sustainable and we can be anywhere. This is a combination that local governments really love. We have the type of jobs they're looking for, which are middle tier and technical jobs for people who are sometimes uneducated, who are the mostly unemployed people that we can train.

"And so we're reaching out through our network of connections to local governments, and we're looking for the best incentive plans we can get. Sometimes we're getting discounts on land. Sometimes we're getting grants for construction. Sometimes we're talking about training."

Pure Blue Fish hopes to break ground in South Carolina in the next few months. It will take a year to build the facility and another year to grow the fish to market size, and after that the company expects

access to a lot more finance, as long as its bottom line can justify it.

"Once we have the profits in place, it will be much easier to get funding from agricultural banks," says Mann, who points out that Pure Blue Fish won't have any problems with the authorities and environmentalists about permissions because "we're years ahead of the regulation".

"Agricultural [financial] institutions are looking for projects to finance that are profitable and we just need to prove our profitability and our scalability.

"We have had talks with these types of institutions and they told us there is no limit on the amount of money, that what we need for the whole farm is not a problem for them, they just need proof of scalability and profitability." •



Water leaving one of the tanks at the Pure Blue Fish facility at Binyamina. Photo: Pure Blue Fish



### Land-based boom in Iceland

Iceland's production of land-based salmon was around 2,000 tonnes in 2022. Since then, development has accelerated: several large facilities are now in operation, under construction, or in the planning phase. Toward 2030, total capacity could exceed 180,000 tonnes – but this scale-up demands technological precision, biological control, and solid financing.

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Iceland is in the process of establishing a new growth industry: land-based farming of salmon and Arctic char. With access to filtered seawater, geothermal freshwater, and affordable renewable energy, the country has natural advantages few other regions can offer. LandbasedAQ has visited key projects to explore how the initiative is being realized in practice – technologically, biologically, and financially.

#### Technology and reality in land-based aquaculture

Several companies are now investing in industrial-scale facilities based on RAS, hybrid, and flow-through technology. Some have already started production, while others are waiting on capital or completing construction. If these ambitions are met, the industry could become a significant addition to Iceland's traditional export sectors.

#### Scaling up and corporate strategies

Over the past five years, land-based aquaculture in Iceland has moved from pilot projects to large-scale ambitions. As of 2025, five major grow-out facilities are in operation or under construction, targeting a combined annual capacity of around 180,000 tonnes.

- First Water (formerly Landeldi) is building in Thorlakshöfn and aims for 50,000 tonnes of annual capacity by 2029. The first harvest took place in 2023. The project includes 158 tanks of various sizes and is being developed in six phases.
- Samherji Fish Farming is building the Salmon Garden on the Reykjanes Peninsula in three stages. At full capacity, the facility is expected to produce 30,000 tonnes annually. The first phase is under construction and is expected to begin operations in 2027.
- Laxey is under way with phase 2 of its grow-out facility in Vestmannaeyiar.

- The plan is to reach 36,000 tonnes of annual production. Phase one is operational.
- Thor Salmon is developing a facility in Thorlakshöfn and recently raised €28 million. The project plans for an annual production of 20,000 tonnes. The first smolt facility is under construction and started operations in summer 2025.
- Matorka produces Arctic char in Grindavík. The facility was partially affected by a volcanic eruption in 2023, but operations have since resumed. The company plans to increase capacity from 3,000 to 10,000 tonnes.
- GeoSalmo has planned a fully integrated grow-out facility in Thorlakshöfn, with a capacity of 33,000 tonnes. The company has all permits and technical design in place but has decided to put the grow-out project on hold due to challenging capital access. However, its smolt facility has been completed.

#### **Advantages and bottlenecks**

Iceland offers several production advantages: stable water quality, low disease risk, and affordable renewable energy. This enables the production of salmon with a low environmental footprint, aimed at premium markets.

At the same time, as in many other parts of the world, Iceland faces several significant challenges:

- Operational technology: Large facilities require precise water chemistry and high-level technical control. Systems are continually adapted to local conditions.
- Expertise: Local experience is limited. Many companies recruit internationally for engineering, biology, and operations management roles.
- Capital: Investment needs are high, and many projects depend on external financing. Biological risk and salmon prices influence investor appetite.
- Logistics: Iceland depends on stable export logistics. An efficient cold chain and transport capacity are essential •



Photo: Therese Soltveit





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## Taking the next step in grow-out production

With AKVA group as technology partner, Laxey has developed a modern RAS smolt facility. Construction of the grow-out facility using reuse technology is well underway, and phase two has started.

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In May, LandbasedAQ visited Laxey's land-based aquaculture facility in Vestmannaeyjar along with a delegation of eight people from AKVA group. The visit included both the smolt production facility in central Heimaey and the ongoing construction of the grow-out site a few kilometres away.

The partnership between Laxey and technology supplier AKVA group was established in 2022, when an agreement was signed to deliver a modern RAS smolt facility - the first of its kind in Iceland - featuring what is referred to as zero-water technology.

#### **RAS-based smolt production**

Laxey's smolt facility is located in central Heimaey, surrounded by fishing boats and the harbour, and appears from the outside like a regular factory. But the interior reveals a modern and well-executed technical building. Chief opertaing officer Hallgrímur Steinsson welcomes us and takes us on a tour of the modern facility.

"Our owners already had a building previously adapted for the fishing industry, so we had to adjust the interior and systems accordingly. We've built the facility to be optimal for the smolt at all times. But it also needs to look good. That matters for the staff, for investors, and for our future." he says.

#### Control of water and growth

AKVA group delivered the smolt facility as a turnkey contract, including technology for denitrification and phosphorus removal - so-called Zero Water Concept. The result is a water recovery rate of 92-99.8%. The smolt plant has three RAS lines, two of which are based on AKVA group's zero-water principle.

The facility features AKVA group fixed-bed biofilters, and AKVA has also supplied the solution for oxygen integration via Laxey's own oxygen production.

"Daily monitoring and control of CO<sub>2</sub> stripping, ozone treatment, and water chemistry are some of the measures



 $Laxey 's \ under-construction \ grow-out \ facility \ at \ Vi\`olaga fjara, \ on the \ island \ of \ Heimaey \ in the \ Vestmannaey jar \ archipelago \ off \ Iceland's \ south \ coast.$ 

we use to ensure optimal water quality and good fish health," says freshwater manager Chris Malanka as he guides the delegation efficiently between departments.

Malanka points out several optimisations made over the past year and notes that in addition to RAS, Laxey also uses a reverse osmosis system from Hatenboer to produce freshwater directly from seawater, which then enters their system.

"This provides us with a stable, highquality water supply and makes us less dependent on external sources like municipal water, which is quite expensive," Malanka explains.

A smaller portion of saltwater is UV-treated and added back in to control salinity.

#### Smolt facility in full operation

The smolt facility is now fully operational, and an important milestone was reached on August 22 last year when the first batch was moved from RAS-2 to RAS-3 - the final stage before transfer to the grow-out facility. The site is designed to handle four batches per year, with an expected smolt production of about 4 million fish at 100 grams each.

The smolt station in Heimaey currently employs 10 production staff, including both a freshwater manager and assistant manager.

#### Reuse technology for grow-out

After the smolt site tour, the delegation boarded a bus to the grow-out facility just five minutes away. Five Laxey employees are currently working on site.

From a vantage point above the site, the scale becomes clear. Steinsson explains that once the smolts leave the RAS facility, they enter a separate growout facility with hybrid technology. This system differs clearly from the RAS setup, replacing 30-35% of the water and using mechanical filtration and degassing.

"Our reuse technology enables about 65-70% water reuse through mechanical filtration and degassing, and it's a natural



COO Hallgrímur Steinsson explains that the facility has three RAS lines and is designed to run four batches per year, with an expected smolt production of around four million fish at 100 grams each. Photo: Therese Soltveit



The smolt facility is located in the center of Heimaey, at the innermost part of the harbour in Vestmannaeyjar. Photo: Laxey

choice for Iceland, where we supplement with well water drawn from boreholes. This combines what is considered the lowest-risk technology with the lowest risk of disease or parasites," he explains.

AKVA group was also selected as supplier for implementing the hybrid technology in the first of six planned grow-out modules.

On January 14, AKVA group announced a signed contract with Laxey for module 2 of the RAS facility. The contract was contingent on financing, which Laxey secured on May 5 through a combination of equity and debt totalling €130 million. AKVA's delivery is valued at an estimated EUR 20 million.

The company currently uses four out of eight tanks in the first construction phase, and the COO expects the remaining four

#### Facts about Laxey

- Location: Grow-out facility in Vestmannaeyjar, Iceland. Smolt facility in central Heimaey
- Production capacity: Planned up to 36,000 tonnes HOG annually
- Phase 2 grow-out facility: Construction under way on module 2 under AKVA contract (€20 million)
- Grow-out technology: Reuse system with 30-35% water exchange, mechanical filtration and degassing
- Smolt technology: AKVA group RAS with Zero-Water concept (99.8% recirculation). Freshwater via reverse osmosis technology from seawater, controlled salinity
- First harvest: Planned for autumn 2025
- Financing: Approx. £101 million total (equity + loans)

to be in use within weeks. "When that happens, we'll have 45,400 cubic metres of grow-out volume available. We've also secured funding for an additional section with eight more grow-out tanks, and we're wrapping up another investment round for a post-smolt facility, which will increase both tank utilisation and system-wide capacity. These systems will be delivered in 2026," Steinsson says.

#### **Approaching two kilos**

The company has stocked two batches of fish in the grow-out facility, with the third to be introduced in early July.

"Our first batch is approaching 2 kg, and we plan to begin harvest operations later this year. So far, production has gone according to plan, and our design choices have proven sound," he says.

#### **Deliveries in multiple phases**

When LandbasedAQ visited Laxey, phase 1 of the grow-out facility was nearing completion. Electrical and mechanical installations were in their final stages, and system testing was ongoing.

"We recently received certification for the intake water system and are now finalising installations in phase 1. The final commissioning begins in July," says Mads Skøtt, senior project manager at AKVA group Land Based.

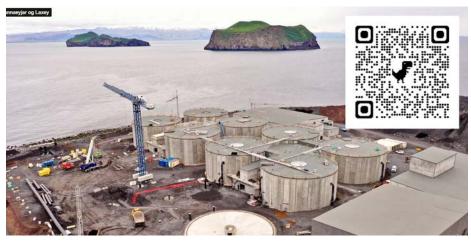
#### **Hybrid technology for salmon**

Laxey's grow-out facility uses a solution that reuses up to 70% of the water.

"Water from the fish tanks passes through mechanical filtration and  ${\rm CO_2}$  degassing before being re-oxygenated and sent back," Skøtt says.

"We use a high-pressure injector solution for oxygenation, as we handle large water volumes," he adds.

He explains that the system recovers heat from outgoing water. "Water not reused passes through heat exchangers before discharge. This allows us to recover residual heat and use it to preheat incoming water."



Eight tanks have been constructed at Laxey's grow-out site, with the bases for more under construction. Photo: Laxey



Hallgrímur Steinsson shows AKVA group's commercial director, Siri Tømmerås, the progress at the growout facility. Photo: Therese Soltveit

#### Ready for next construction phase

Preparations for the next construction phase are already well under way. The teams are working in parallel on design, engineering, and procurement.

"In phase 2, we will deliver two reuse systems for the grow-out facility and one system for post-smolt. We expect to begin installation by late 2025," Skøtt explains.

#### **Progress and production plans**

During the visit, Laxey was preparing to deliver its first post-smolt to an external customer - something it has now successfully completed - and has recently activated two new tanks.

"The next key milestone will be when all eight tanks are operational later this summer," Steinsson says. How is your current smolt/post-smolt production divided between internal use and external sales?

"At the moment, we have limited access to our own grow-out facilities, so most of the smolt we produce is sent to post-smolt. This creates good synergies that help advance the traditional industry in Iceland. With the planned expansion over the next year, the split will be about 50/50 in terms of smolt numbers," he states.

#### Phase 2: construction and new capacity

Phase two of the project doesn't involve major technology changes, but the design has been adjusted to reduce costs. The tanks are 5,000m<sup>3</sup> each, and the bases for the first two units had already been cast at the time of the Landbased visit.

"Project progress is going well, and we've already cast the foundations for the first two tanks and are preparing for their construction."

At the same time, a new post-smolt facility is being prepared to increase flexibility and tank utilisation.

#### From egg to harvest

While the long-term processing plant is still in the planning phase, Laxey is installing a temporary harvest and processing facility on site this summer. It will have a capacity of up to 15,000 tonnes (head on gutted) annually.

"This set-up will allow us to conduct our first harvest as planned in autumn 2025. With the harvest infrastructure in place, we'll be fully integrated from roe to harvest - a key element of our strategy to ensure consistent quality and control across the entire value chain." Experience gained in the transition from smolt to grow-out has clarified Laxey's operational priorities. For the COO, it's about staying focused on the fundamentals.

"There are many ways to do things, but the most important is to identify what's truly essential and not compromise on it."

Steinsson says open dialogue with other players and a continuous willingness to learn have been critical.

He also highlights two principles that have always been central to Laxey's approach: high-quality smolt production and strong biosecurity.

"These were priorities from day one, and I still believe they are the most important," he says •



These 5,000m³ tanks were due to soon be filled. Photo: Therese Soltveit





Construction work at First Water is in full swing in Thorlakshofn. Once completed, the facility will produce 50,000 tonnes of land-based salmon annually – making it one of the largest of its kind in Europe. Photo: Therese Soltveit

# Progress and fish welfare in focus at First Water

With an ambitious goal of producing 50,000 tonnes of land-based salmon by 2029, First Water is building one of Europe's largest and most high-tech aquaculture facilities in Thorlakshofn, Iceland.

Therese Soltveit therese@landbasedaq.no

With bright sunshine and almost no wind as a backdrop, LandbasedAQ visits First Water (formerly Landeldi) in Thorlakshofn, in the municipality of Ölfus in South Iceland. Here, 45 kilometers southeast of Reykjavík, one of Europe's largest and most technologically advanced land-based salmon farming facilities is gradually taking shape.

#### From Idea to production

Chief operating officer Stefan Agustsson has been involved since the beginning and shares insights from building the project from the ground up.

"It's been four and a half years of intense development, learning, and progress. We've gone from concept and drawings to actual operations with fish in the tanks," says Agustsson.

#### Six phases - phase one nearly halfway

First Water is building the facility in six phases, aiming to reach 50,000 tonnes of head on gutted (HOG) annual salmon production by 2029. The complete project will consist of 164 production and harvest tanks in various sizes – 20, 25, and 28 metres in diameter – as well as an on-site processing plant and a hatchery.

"We're still in phase one, but the pilot facility has been operating for three years already. As of now, we have 12 tanks in operation, all stocked with Atlantic salmon ranging from 500 grams to four kilos."

This summer, the company will put eight new tanks into operation, which will triple its current production capacity. This will bring the total number of active tanks to 20. "There are eight tanks remaining before phase one is complete, and then we move on to the next phase. We expect to achieve stable production once phase one is fully developed – likely next year," says Agustsson.

#### Production and fish welfare

The first fish were stocked in 2022, and the company has already carried out several harvests.

Only female fish are used in production, and Agustsson explains that research shows sex-separated populations of Atlantic salmon have a significantly lower risk of early sexual maturation compared to mixed groups.

"Males have up to a 15% likelihood of early maturation, while for females it's only 0.14%. Early maturation has major negative effects on fish quality. In addition, male salmon are often more aggressive and territorial – which is not ideal in a closed system," Agustsson explains.

First Water is now working toward its target of producing 5 kg HOG salmon by September 2025 – a goal the company expects to achieve.

According to Agustsson, their flexible tank system allows for partial harvesting.

"When we approach the density limits, we can harvest 25–30% of the fish in a tank and let the rest continue growing. It's a method we've already used several times.

#### Adjusting the design along the way

The facility is modular, and the design is adjusted between phases based on operational experience.

"We've already implemented several improvements in the new tanks in phase one based on lessons learned from the pilot. Each phase, from 1 to 6, will include adjustments, but we are confident we now have a solid framework," says Agustsson.

During the tour, Agustsson shows the third tank line, which is scheduled to go into operation at the end of June. It's designed to house 75,000–76,000 fish, ranging from 1.2 to 3.4 kilos.

"This is line number three. We still have one more line with eight tanks to build before phase one is complete. Groundwork for this line is nearly finished, and tender documents for the concrete work have been sent to approved contractors," he explains.

#### Water and temperature

The facility uses seawater drawn from boreholes 60 metres below ground,

#### First Water

- 6 phases, expected completion in 2029
- 164 tanks 20, 25, and 28 meters in diameter
- 50,000 tonnes HOG annually at full operation
- 7–9 °C stable lava-filtered seawater
- Hybrid flow-through system
- €825 million budget
- 97% Icelandic ownership
- First slaughter in May 2023
- Low mortality (~3%)

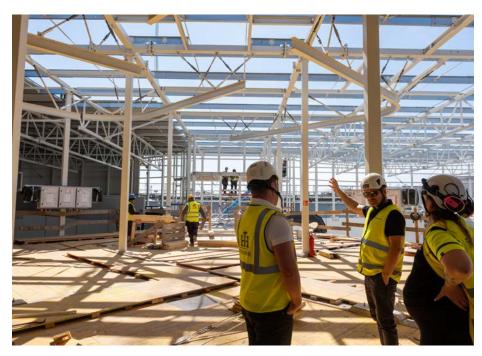
naturally filtered through lava. The temperature remains stable between 7 and 9 degrees Celsius. DNA testing has shown that the level of organic matter in the lava-filtered seawater is close to zero.

#### Hybrid flow-through system – continuously monitored

First Water uses a hybrid flow-through system in which around two-thirds of the water is recirculated.

The system is monitored with a range of sensors

"We continuously measure oxygen, pH, CO<sub>2</sub>, temperature, and salinity. We also conduct periodic testing, such as nitrite levels. It's critical to properly size the core



Chief Operating Officer Stefan Agustsson inside the new tank line under construction. Here, he discusses progress with the team. Photo: Therese Soltveit



COO Stefan Agustsson and construction manager Amelia Osk Hjalmarsdottir inside one of the water pipes, illustrating the scale of the facility. Photo: Therese Soltveit



Ongoing work at First Water: use of heavy machinery, piping, and tank assembly are taking place in parallel during the first construction phase. Photo: Therese Soltveit

systems, invest in quality sensors, and use mechanical filtration at all levels of water recirculation," the COO explains.

#### Energy, preparedness, and infrastructure

Power supply was a challenge in the early stages of the project, prompting the company to build its own infrastructure.

"We've experienced both planned and unplanned power outages. That's why we've installed our own generators and two transformers, each weighing around 80 tonnes. One of them could theoretically power all of Hafnarfjörður," says Agustsson.

The transformers, delivered from Italy, are built to step down the grid input from 66 kV to 11 kV.

#### Increasing exports to the US

Last year, the company harvested approximately 1,700 tonnes of salmon, primarily for the UK, Ireland, France, and Germany. Currently, only small volumes are shipped to the US, but the plan is to eventually export half of the production there.



Photo from an earlier stage of the project. Photo: First Water

"This year, we will produce 2,000 tonnes. Then 5,000–6,000 tonnes next year, and finally 8,500 tonnes in 2027," said chief executive Eggert Thor Kristofersson earlier to LandbasedAQ.

Phase 2 begins in November, and the entire project is scheduled for completion between 2029 and 2030.



COO Stefan Agustsson has worked on the project for four and a half years and says they've made significant progress this year. Over the summer, they will begin construction of eight new tanks, which will triple their production capacity. Photo: Therese Soltveit

#### Strong capital – and another share issue

First Water has received significant funding to date. In March 2025, the

company completed a €39 million private placement. In total, First Water has now raised €161m in equity, in addition to €80m in loans. A total of €240m is secured – €137m of which is already invested.

#### Sludge and side streams

First Water is working on solutions for treating and utilising sludge from production.

"We filter and dewater the sludge and obtain about 15–20% dry matter. We're exploring biogas and fertiliser as options, but this is still under development, as is the case for many others."

97% of the company is owned by Icelandic investors.

"That provides local anchoring, and the value creation stays in Iceland," says Agustsson proudly.

Once completed, the facility will consist of the six separate production phases, a hatchery, and a 30,000 square metre processing plant.

In the meantime, a temporary slaughter facility is in operation, with a capacity of 18,000 tonnes per year •



#### Science

# Risk assessment of 21 land-based aquaculture systems in Norway – what can be learned?

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The RM (Risk Management) Akva Project

- **Scope:** The RM (Risk Management) Akva- project included risk assessments of 21 land-based aquaculture facilities in Norway, covering Atlantic salmon, rainbow trout, and lumpfish.
- **Methodology:** All evaluations used a standardized procedure developed by Akvaplan-niva.
- **Objective:** The project aimed to reduce mortality, improve fish welfare, and strengthen insurance support through improved risk management.
- **Key Finding:** System complexity (e.g., RAS) does not automatically result in higher risk effective design and operations are key.
- **Stakeholder:** Funded by Gjensidige Insurance, which also provided a large dataset for analysis.
- Workshop: During Aqua Nor (Wednesday, August 20, 9:30–10:30 AM) a workshop will be held in connection with this study. Location: Meeting room Munkholmen. Here there will be an opportunity to ask questions about the survey.

A new study presents a comprehensive risk assessment of 21 land-based aquaculture facilities in Norway from the RM (Risk Management) Akva-project using a standardized risk evaluation methodology developed by Akvaplan-niva, Norway. Facilities varied widely in age, technology (FTS, HYB, RAS), and production scale, with assessments focusing on technical and operational risk factors affecting fish mortality. The results showed no clear correlation between system complexity and overall risk. Instead, effective design, good operational routines, and built-in safety margins were key factors in reducing risk.

In recent years, the aquaculture industry in Norway has faced challenges related to undesirable events and mortality in landbased systems for Atlantic salmon. These incidents, which predominantly occur in land-based smolt production facilities but are also expected to occur in land-based facilities for larger salmon, pose serious concerns for fish welfare and may result in high mortality and substantial economic losses.

To address these challenges, the industry is focusing on risk-reducing measures such as improved system design to avoid dead zones and particle sedimentation, as well as efforts to bridge the gap between planned production capacities and achievable production. The importance of technical assessments and risk evaluation in land-based aquaculture systems cannot be overstated, not only for ensuring operational efficiency and fish welfare but also for securing assets and enabling farmers to adequately insure their investments.

The insurance industry has an important interest in this area, recognizing the high

value of both the facilities and the biomass they contain. The Norwegian insurance company Gjensidige, which is the owner of the RM (Risk Manage¬ment) Akvaproject, has contributed significantly to this field by sharing an extensive dataset from risk assessments of 21 land-based aquaculture systems from the The RM (Risk Manage¬ment) Akva-project, all evaluated using a common standardized methodology developed by Akvaplanniva, in colaboration with NIVA.

The primary objectives of these risk assessments and subsequent analyses are to reduce mortality, improve fish welfare, and mitigate economic risks. By increasing fish farmers' awareness of potential risks and enabling them to implement corrective measures, this approach aims to create a more resilient and sustainable land-based aquaculture industry.

#### **Results**

The assessments of 21 land-based aquaculture facilities, varying in size, technology, and water treatment intensity, revealed no consistent pattern linking

increased complexity, water reuse, or specific system types (FTS, HYB, RAS) to higher overall risk. While more advanced systems like RAS were associated with greater operational complexity and production intensity, both low- and high-risk scores were observed across all facility types. Notably, the two highest and two lowest overall scores were found among facilities using RAS or FTS+RAS, demonstrating that effective risk management is achievable even in highly complex systems.

The somewhat high proportion of medium-risk scores among FTS facilities may reflect the influence of fewer departments, where isolated risks have a stronger impact on the overall average. RAS facilities, while more frequently linked to deviations in water quality, typically involved parameters expected to accumulate with water reuse, such as nitrogen compounds and metals. Lowrisk outcomes in some RAS facilities were associated with robust system design, adequate treatment capacity, and strong operational routines.

System resilience also depends on design and operation. FTS facilities often rely on gravity-fed intake water, making them less vulnerable to power outages. RAS, with minimal use of intake water, are less exposed to external water quality issues but are more sensitive to internal failures. Mechanical breakdowns, sensor faults, or power loss can escalate rapidly due to their integrated nature.

Most facilities showed good redundancy and backup systems for critical resources like water, oxygen, and electricity. However, personnel at facilities with a longer operational history typically exhibited greater awareness and had progressively refined their practices over time. In contrast, higher risk was more common during start-up phases, implementation of new technologies, or shifts in production strategies, stages that require time to build system understanding and improve design.

The key risk factors related to water chemistry were more critical for the overall risk score in RAS facilities compared to FTS/HYB, because of the increasing complexity of water treatment and the

Process

Collect relevant documents
Identify Key Performence Indicators
Plan inspection schedule

Facility inspection
Compare documentation with actual situation
Interview Key personnel
Collect samples for lab analysis

Assess risk areas
Evaluate risk by applying risk matrix
Calculate overall risk
Identify necessary risk mitigation
measures

Standardised Risk report
Updated and expanded knowledge
base
Bench marking

Figure 1. Flow diagram for the risk evaluation method based on principles from the Akvaplanniva procedure.

accumulation of some compounds. The risk of H2S production was higher in RAS and increased with more use of seawater, but our results also indicate that this risk can be mitigated by proper water treatment, good measurements and good routines, since several seawater RAS did not have problems with H<sub>2</sub>S.

There were several mortality cases where H<sub>2</sub>S was suspected as the cause. All of these cases were in facilities with MBBR systems and involved design and mixing issues causing particle accumulation. These observations highlights design and operational challenges with MBBR. However, it is often difficult to draw definitive conclusions in cases where H<sub>2</sub>S may be involved, as suspicions are typically based on the exclusion of other plausible causes. These assessments are often supported by the absence of other abnormal parameters and the nature of the mortality pattern, which is usually acute and without clear clinical symptoms.

Finally, increased awareness around chemical use is needed. In many cases, chemicals were applied to resolve acute issues like particle buildup or foam, but all potential consequences were not adequately assessed. While chemical treatment may offer short-term relief, addressing root causes, such as improving solid removal or using physical foam control are generally a more sustainable and effective approach.

#### **Acknowledgement:**

The authors gratefully acknowledge Gjensidige Forsikring for funding this project and for providing the technical reports that form the foundation of this study.

The findings emphasize the importance of robust system design, informed operational practices, and continuous monitoring to ensure good fish welfare and reduce economic losses in land-based aquaculture.

For the full article with details about the findings, scan the QR-code in the fact box •

#### Full article:

This article is a summary of a longer article that contains detailed results from the study.

Article reference: Veberg Larsen, S., Jonassen, T.M., Steigum, E., Hess-Erga, O.-K., Stuve, H., Worum, B.H., Nikolaisen, J., Kvalsvik Stenberg, S., Egeland, S. (2025). Risk assessment of 21 land-based aquaculture systems in Norway – what can be learned? LandbasedAQ.com 2025.

**URL:** https://www.oceanspacemedia. com/files/2025/07/10/AkvaRisk%20 eng2.pdf

Alternatively scan the QR code to read the full article with details about the findings:



#### Science

# Successfully switched off immune genes in salmon – could lead to better vaccines

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"Fish immunity is far less understood than in mammals, yet it is crucial for improving health and welfare in aquaculture," says marine researcher Rolf Brudvik Edvardsen in a news release from the Institute of Marine Research.

B cells are the body's defence cells. Some of them, called IgM-positive B cells, produce an antibody that helps salmon fight off disease and stay healthy – immunoglobulin M.

Researchers at the Institute of Marine Research successfully knocked out both genes that code for the antibody immunoglobulin M in Atlantic salmon.

"Deactivating these genes means immunoglobulin M is no longer produced in the fish's body – a molecule that normally protects against pathogens," Edvardsen explains. For the first time, scientists have managed to deactivate immune-related genes in salmon. This will help them better understand the immune system of the species.

The scientists used the CRISPR method, a technique for altering the DNA structure of an organism.

This is the first time that immunerelated genes in this species have been specifically deactivated.

The results provide new insight into how the salmon immune system works and may contribute to the development of improved vaccines.

#### Salmon survive with a weakened immune system

The researchers measured the effect of the gene editing by analysing the B cells in the blood.

Results showed that the proportion of IgM-positive B cells, which produce immunoglobulin M, was reduced by an average of 78%.

In some fish, there were almost no IgM-positive B cells left – yet they survived.

"That these fish survived even in a nonsterile environment was surprising," says Edvardsen.

"It means they can tolerate a weakened immune system."

This opens up new opportunities to investigate how salmon defend themselves without the help of immunoglobulin M.

#### **Produce a different antibody**

The researchers also found that fish with low levels of immunoglobulin M appeared to increase production of another antibody – immunoglobulin T.

"This could play a complementary role in the immune system, essentially replacing immunoglobulin M," says researcher Mari Raudstein. The project formed part of her PhD

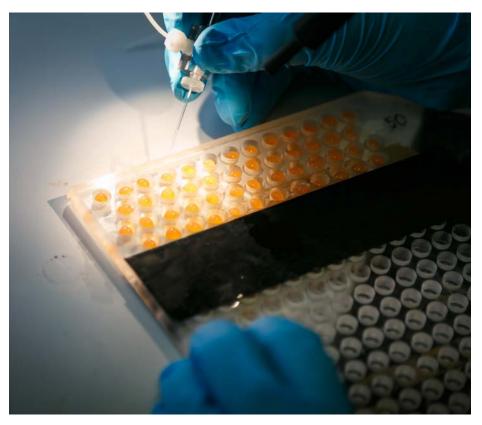
Immunoglobulin T plays an important role in the mucosal immune system – in the gills, intestines, and skin – areas where the fish encounters many microorganisms.

"This helps us understand how the different components of the fish immune system work together, giving us a better foundation for developing vaccines that protect against a wider range of diseases."

The next step is to breed a generation of salmon where immunoglobulin M is



For the first time, immune-related genes in Atlantic salmon were specifically deactivated. The findings offer new insight into how the salmon immune system functions. Photo: Tomasz Furmanek / Institute of Marine Research



Will CRISPR-modified salmon pass on the modifications? Anna Wargelius, Rolf B. Edvardsen and team investigate. Anne Hege Straume prepares roe for CRISPR injection. Photo: Erlend Astad Lorentzen / Institute of Marine Research

completely removed. This will provide deeper insight into the fish's immune system and create opportunities to develop better vaccines and improve fish health in aquaculture.

#### **About the project**

The study is part of the Research Councilfunded TUNESAL project (2019–2025), and Mari Raudstein worked on it as part of her doctoral thesis. Rolf Brudvik Edvardsen was the project leader and supervisor •

#### Reference

Raudstein, M., Peñaranda, M.M.D., Kjærner-Semb, E. et al. *Generation of IgM+ B cell-deficient Atlantic salmon (Salmo salar) by CRISPR/Cas9-mediated IgM knockout*. Sci Rep 15, 3599 (2025).



#### Science

## New genetic breakthrough in the fight against CMS

AquaGen has been selecting for resistance to CMS – also known as cardiomyopathy syndrome – for nearly 15 years. This long-term effort is now showing clear results: an increasing proportion of fish are nearly free of the virus after infection tests. This marks an important breakthrough in the battle against one of the aquaculture industry's most serious viral diseases.

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#### CMS - a virus with serious consequences

- CMS is caused by piscine myocarditis virus (PMCV).
- The virus attacks the heart muscle and can lead to sudden and extensive mortality, often late in the production
- The disease has long been a challenge for farmers, with major economic consequences.

In 2018, AquaGen began using genomic selection in its work on CMS resistance. This method involves reading over 70,000 DNA markers in the salmon genome and makes it possible to select broodstock based on genetic similarity to resistant fish. During this process, a QTL on chromosome 23 with a very strong effect on CMS resistance was identified.

When AguaGen first discovered this QTL in 2018, it marked the start of a long-term, targeted breeding program. Since then, other actors in the research community have also reported the same QTL.

We have now succeeded in increasing the frequency of the favourable gene variant to a level that allows for commercial use - giving it significant relevance for the industry.

## A QTL with a strong effect

A QTL (Quantitative Trait Locus) is a gene with an especially strong effect on a trait in this case. CMS.

Resistance to CMS can be measured through challenge testing. In such tests, fish are infected with PMCV and the virus load is measured using PCR nine weeks after infection.

More than half of the variation in virus load is due to the fish's genetics, making CMS resistance a highly heritable trait. The specific QTL on chromosome 23 alone accounts for over 70% of this heritability in our salmon strain.

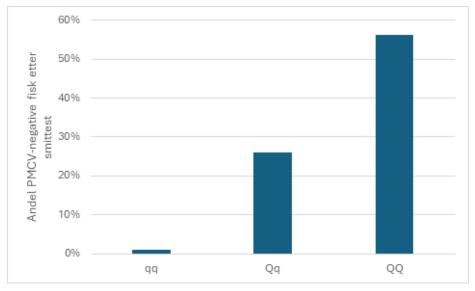
This means the QTL largely determines how resistant each individual fish is - making it a key factor in the genetic resistance strategy (see figure).

#### The road ahead

Through systematic use of genomic selection and targeted breeding, we have taken an important step toward reducing the impact of CMS in Norwegian salmon farming.

The documented effect of the QTL on chromosome 23 provides a strong genetic foundation for further improvements in both fish health and production performance.

With the increasing frequency of the favourable gene variant in the breeding stock, conditions are in place for this knowledge to benefit the entire industry in the near future •



Percentage of challenge-tested fish that are free of the virus (PMCV) after infection, grouped by the number of copies of the resistance-associated gene variant: 0 (qq), 1 (Qq), or 2 (QQ).

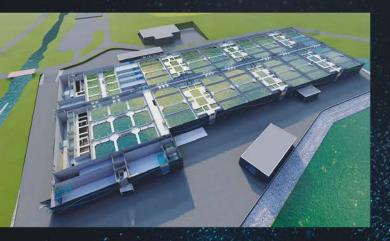


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