Assignment study for West Estonia 2020-30
July 1, 2021 Saaremaa Blue Economy Conference

Potentials of exploiting West Estonia coastal zone
Fish farming with aquaponic integration
Coastal circular economy
Action plan and way forward

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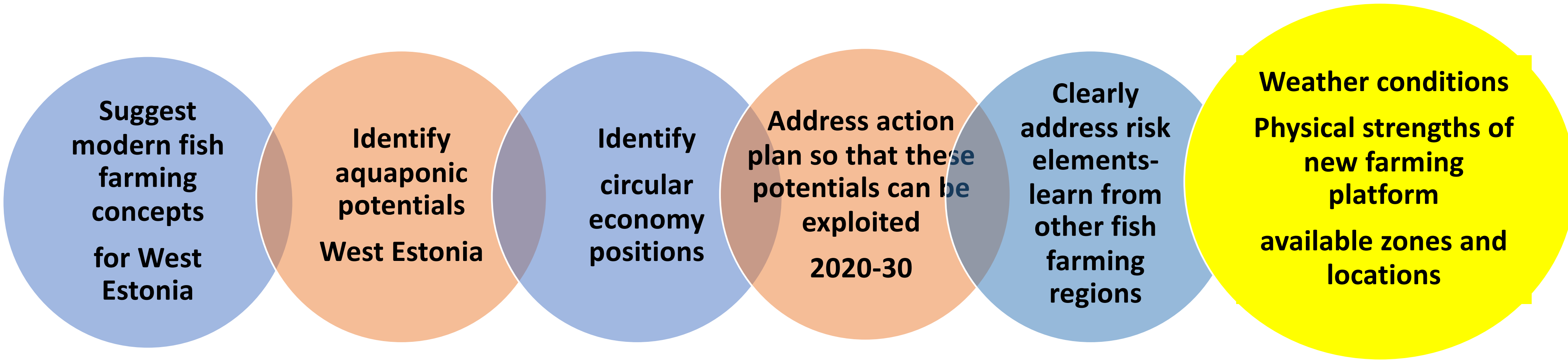
Content

A background - the Feasibility study West Estonia

The Saaremaa Rural Municipality Government arranged a public procurement to organize and receive a Feasibility Study of West Estonia coastal zone where the scope is;

- Identify the potentials of an eco-friendly sustainable strategy where the marine and coastal zones resources can be exploited with modern investment and technology

Focus is:

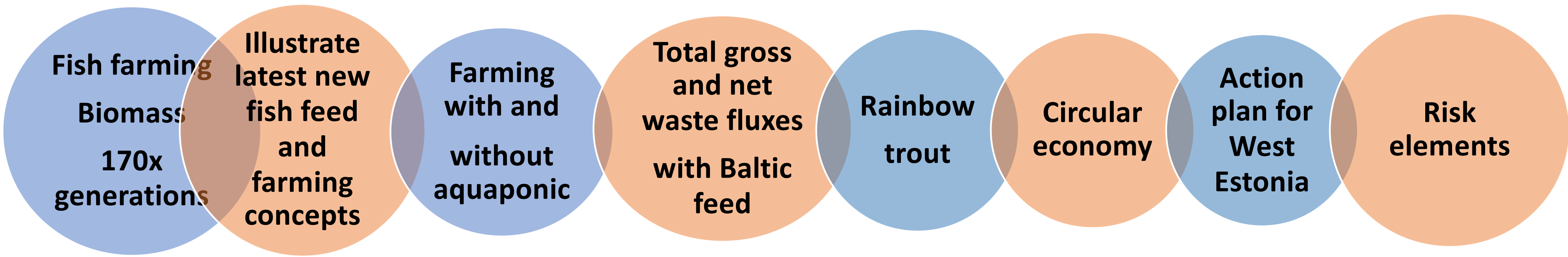


The report shall have a fact based and neutral format and reflect the conditions of the region as of today and suggest its' potentials for 2020-30.
The content of the Feasibility Report is the Saare- and Hiiumaa property and can be freely used.

B The authors and contribution – Fish farming

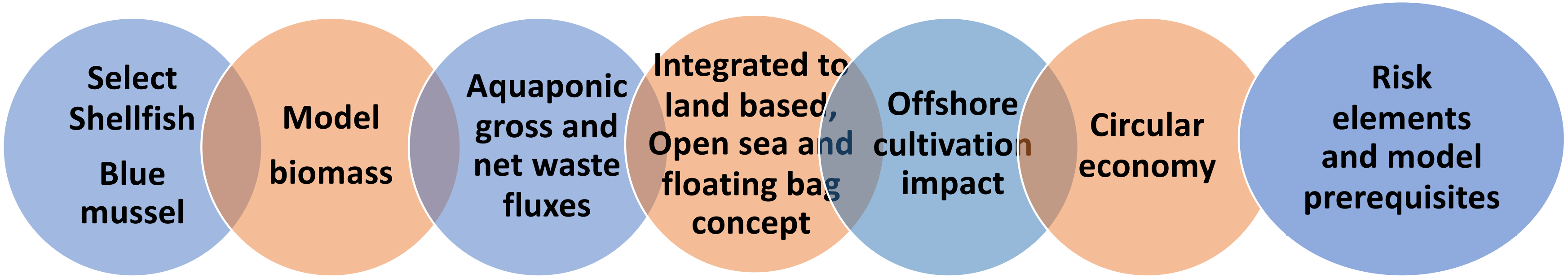
Knut Senstad, project leader, was rewarded the Tender and has conducted the study in co-operation with marine ecology professors Jonne Kotta and Georg Martin from the University of Tartu.

Knut has carried out the feasibility study for fishfarming production where

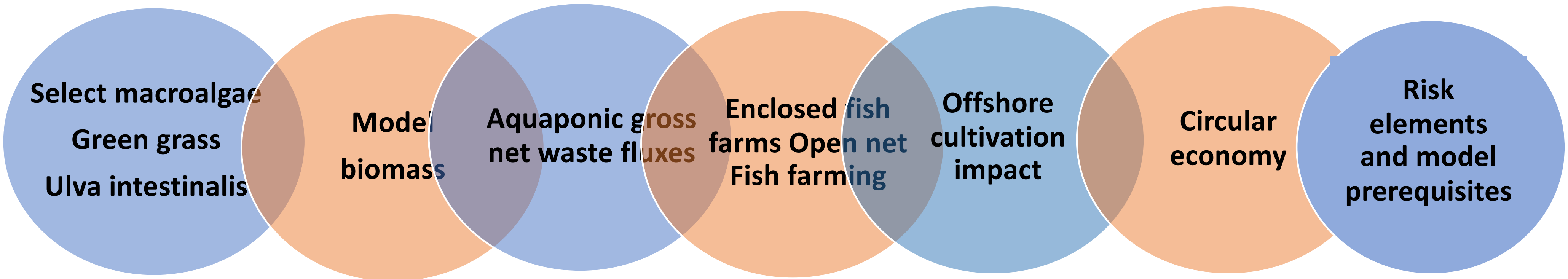


B The authors and contribution - Mussel & macroalgae aquaponic

Jonne Kotta has carried out;



Georg Martin has undertaken similar work tasks as J. Kotta, where he has:



C Executive summary

C Executive summary - Feasibility study targets

11x STEPS APPROCH

These environmental- and political- constrains => exploiting the coastal zone of West Estonia may look very difficult or impossible;

Fish farming do increase the nutrient flux to Baltic Sea - yes

How can we reduce these fluxes?

NO 1 - Use the latest modern Baltic fish feed- define new flux quantities

NO 2 Establish RAS on land- very expensive (> 75 M€ for 5 000 tons farm) but can be done

NO 3 Look for other land-based fish platforms that is less Capex demanding
How are these?, Who operate them? How functional are they? Can they reduce the waste fluxes?

NO 4 Consider a) traditional Open nets b)new Offshore fish farming platforms c)Floating enclosed bags - Which one? Where-to? What farming results? What advantages? What flux impact?

C Executive summary - Feasibility study target

Cont. - 11x STEPS APPROACH

These environmental and political constrains => exploiting the coastal zone of West Estonia may look very difficult or impossible;

NO 5 How can West Estonia aquaponic integrations further reduce fluxes?
If yes- what must be organized?

NO 6 What are the net new fluxes?

NO 7 Action point; Way forward- public stakeholders

C Executive summary - Feasibility study target

Cont. - 11 STEPS APPROACH

Another important element that we have considered;

NO 8 Selected new farming concept that is Capex friendly where waste produced can be collected

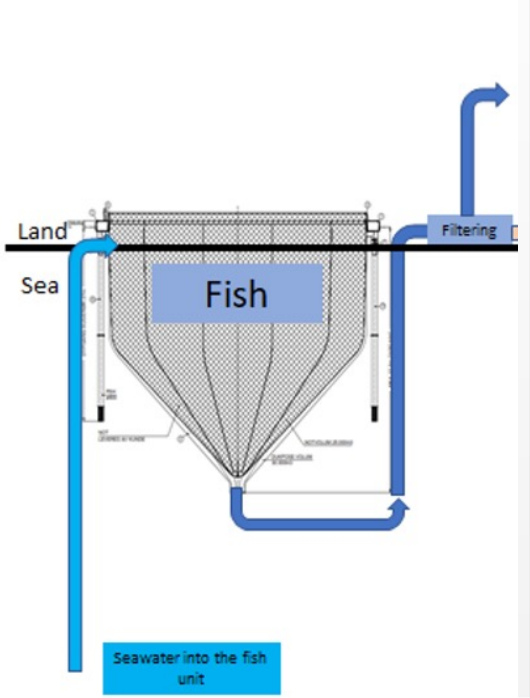
NO 9 Motivate public and private stakeholders to take decision

NO 10 Illustrated the aquaponic integrations - *state of the art* - raise the Nordic knowledge bar, if success may be very important for West Estonia => education, services, international brand (organic salmonid production/ sustainability/ fish welfare / environmental protection/ marketing)

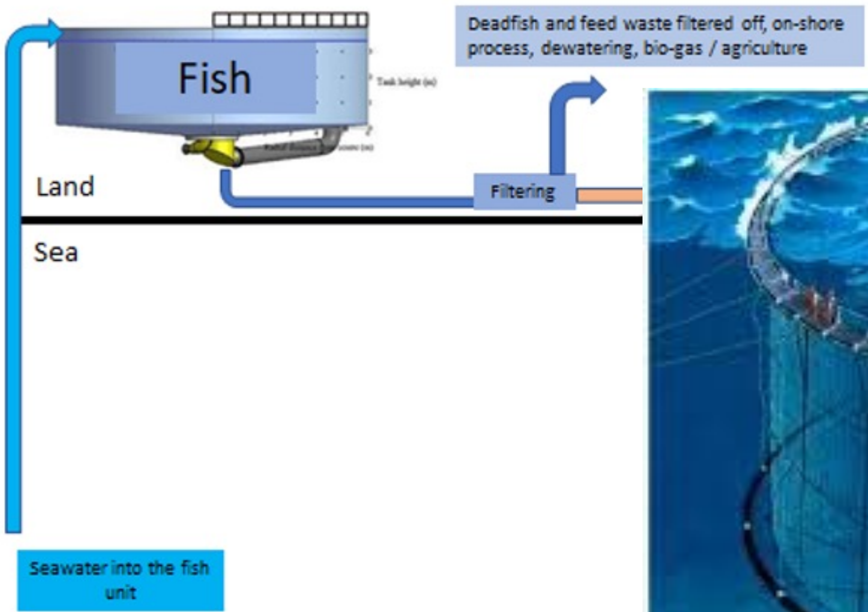
NO 11 Showing illustrations of circular economy impact West Estonia

C Executive summary- 3x fishfarming platforms

Floating bag



Tanks on land



Traditional Open net

C Executive summary – Types of wastes, their alternative routes

Flux to Water column,
Dissolved nutrient

N P

Comments- difficult to collect
Option 1- RAS biofilter and denitrification
Option 2- Aquaponic integration

Macroalgae/ Photosynthesis

Gjør fiskeslam til gjødsel med lyd og strøm

Flux as bound tp
faeces/slugde

N P

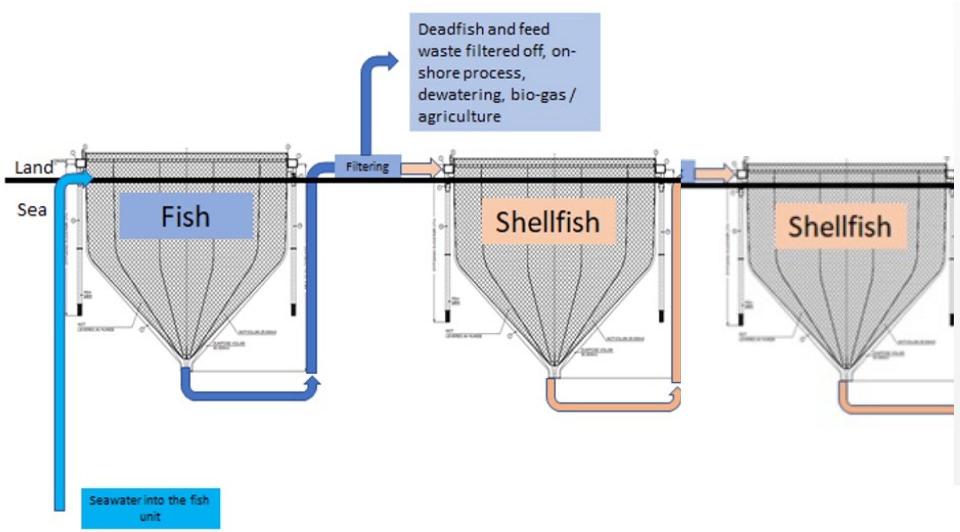
Comments- "easy" to collect
Option 1- Mechanical filtration
Option 2- Aquaponic integration

Shellfish

C Executive summary- Fish waste into closed loop

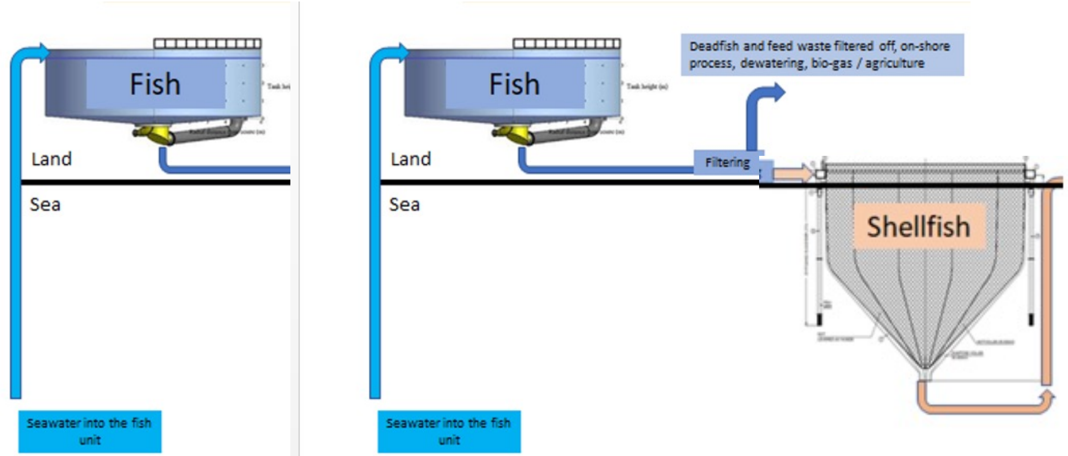
Wastes from fish production is entering closed loop pipes - possible to collect and treat wastes

Floating bag concept



Floating fish bags in the sea

Tanks on land



Fish tanks on land

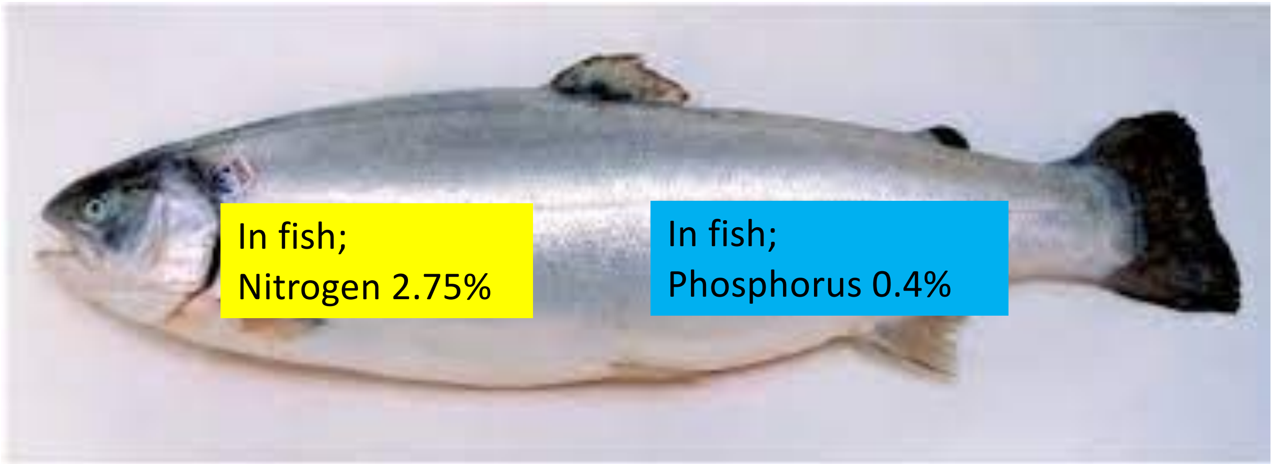
C Executive summary- Fish waste to open sea

Wastes from fish production is entering the free water column

Open net farming

C Executive summary – Feed digestion, assimilation and waste fluxes

Uniform assimilation content in rainbow trout



BALTIC FEED 2021 – total flux to environmenet per 1 kg fish produced

OPEN NETS; total flux

Surplus none eaten FEED

TANKS /FLOATING BAGS; total flux

N

N 44.4 gram

N 37.6 gram

P 5.1 gram

P 4.0 gram

P

Flux to water column
Dissolved nutrient

N P

Flux as bound to
faeces/slugde

N P

C Executive Summary - West Estonian environmental impact

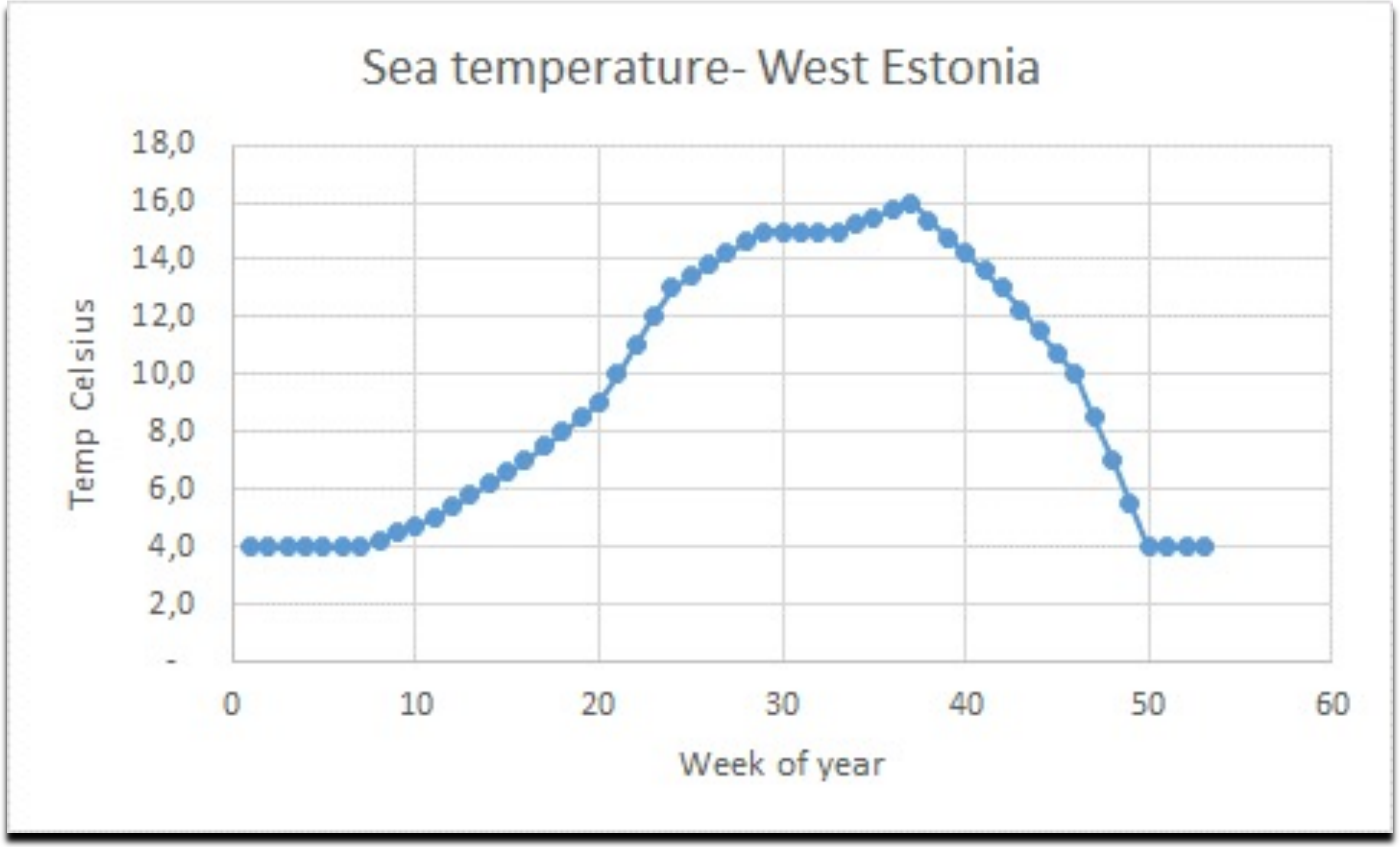
	Nitrogen gram/kg fish	Phosphorus gram/kg fish
Current Water Act per 1kg fish produced	50.0	7.0
Latest Baltic fish feed Open nets	44.4	5.1
Tanks/bags **excluding mechanical water filtration**	37.6	4.0
Tanks/bags **with water filtration 100 micro**	35.5	2.7
Tanks/bags with water filtration + **mussel**	33.7	1.6
Tanks/bags with water filtration + **mussel + algae**	**20.2 gram (-60%)**	**0.8 gram (-89%)**

Physical integrated aquaponic algae and mussel to traditional Open net farming is impossible

Organic waste can be fully captured by the filtering mussel for tanks on land and floating fish bags
Open sea cultivation of macroalga «green grass» is difficult to setup, the species is fragile, sensitive to weather conditions. Currently economically unfeasible.
Open sea cultivation of blue mussel is possible. But to counterbalance the fluxes from a large fish farming activity, cultivation dimensions have to be very very large

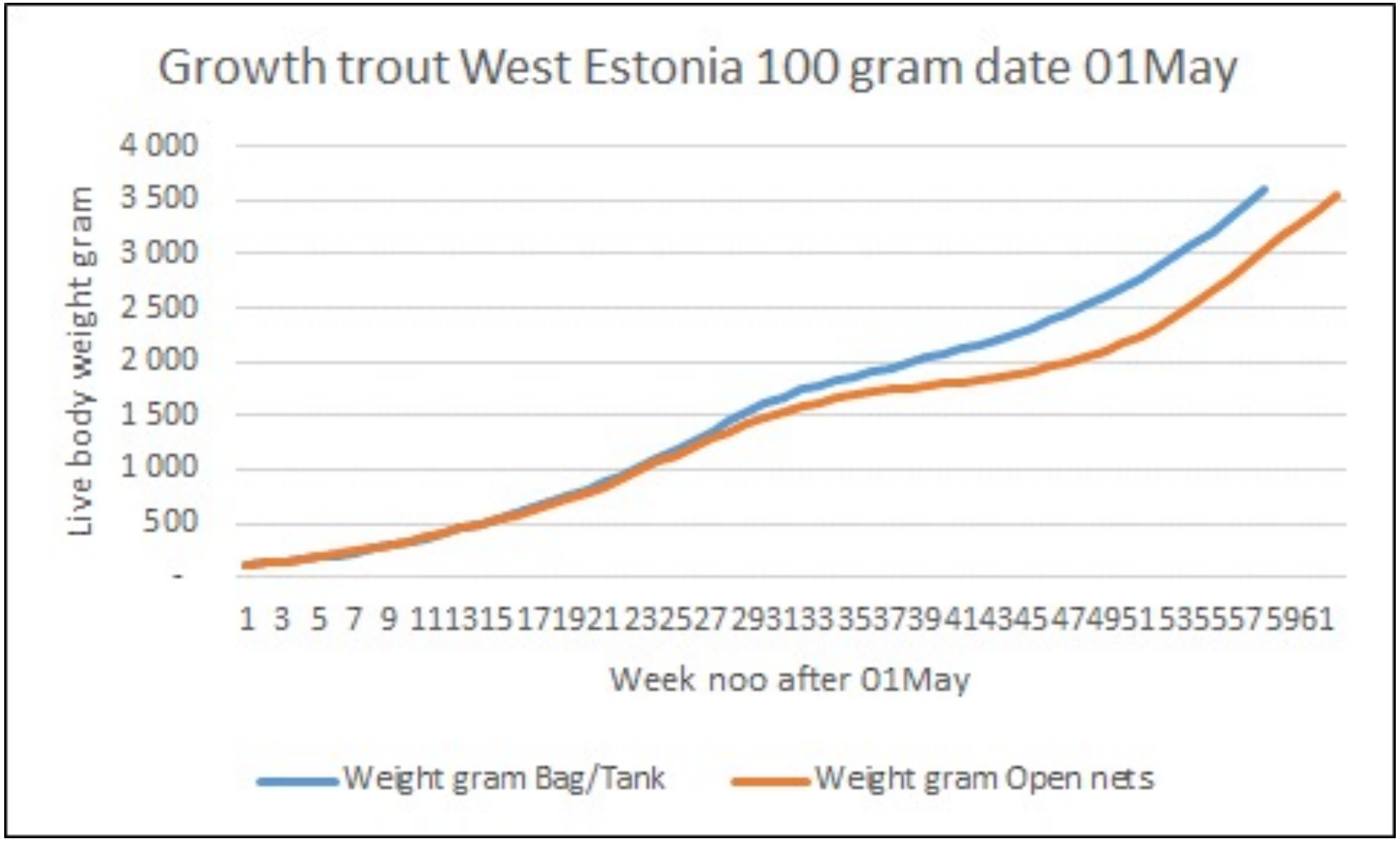
E Executive summary – West Estonia “optimum” temperature for rainbow trout

- Temperature conditions in West Estonia are good for the growth of seafarmed rainbow trout
- There is nothing wrong with the seawater nor Baltic Sea as such
- The selection of farming platform depend on weather conditions
- Severe cold conditions (+1-2.5 C) and drifting ice do represent risk factors



C Executive summary - Production planning rainbow trout

Rainbow trout is harvested after 58 weeks in Tanks on land and Floating bags and 62 weeks for traditional Open net



C Executive Summary - Circular economy potential West Estonia

		Landbased fish tanks	Floating fish bags
Egg and smolt production Rainbow trout 13 mill smolts per year 3-4 smoltfarms on land	Open net farming 20 000 tons live weight 20 sites, 220 cages Harvest; 2 000 tonnes from 10 sites/year	Landbased fish farm 20 large fish tanks a 200m^3 size, 10 farms, 200 fish tanks, Harvest 10 000 tons	Floating large fish bags 10 large units, a 6 000 m^3 on 10 farms 100 floating units, Harvest 10 000 tons

Jobs total supply chain and farming

Best guess

Open nets 270
Landbased and Floating bags 250
Aquaponic 175

Total 700 jobs

Circular economy value

Best guess

mEUR 175 Open nets
mEUR 100 Tank on land
mEUR 100 floating bags

mEUR 375

C Executive summary - Circular economy example Open nets

20 000 MT fish production Open nets per year

This farming volume would require the following staff that is directly and indirectly related to

270 jobs

- fish farming
- education and other services (fish health, water chemistry, logistic, harvest, processing, maintenance)

The table below shows how traditional Open nets farming without integration of aquaponic set up may look like.

Open net platform - Potential fish farming production and other sector services for West Estonia

Open net platform - no of man-year per year excl aquaponic smolt to market

production volume at sea	sum admin employees	no of farming staff	fish health	net service staff	cages and moorings adn logistic to sea sites incl fishfeed	mechanicl services	Processing gutted in box	wellboat jobs	styro box and transport	transport gutted fish to Tallinn, 18 MT/truck- n manyear per year on eperson 1x trip 250 days a year	foodsafety monitoring, weekly inspection of processing plants	total manyear per year
4 000	7	27	1,3	4	4	4	8	5	2	1	0,5	64
6 000	14	54	2,5	6	8	6	12	5	2	1	0,5	111
16 000	25	101	3	12	16	9	32	10	4	4	1	217
20 000	32	128	4,5	15	20	12	40	10	4	4	1	271

C Executive summary - Circular economy landbased and floating bags and aquaponic

20 000 MT fish production landbased and floating bags with aquaponic integration per year

Here including staff of aquaponic cutivation and harvest (jobs are just an estimate)

250 + 175 jobs

Floating bags and land based fish tanks - Potential fish farming production, aquaponic integration and other sector services for West Estonia																			
	number of farms	no of companies	management and admin for each company	sum admin employees	no of farming staff	Biomass live harvested per year MT	fish health	no of tanks bags	net service staff	logistics and fish feed	mechanicl services	Processing gutted in box	wellboat jobs	styro box and transport	n truck trips per year to Tallinn	transport gutted fish to Tallinn, 18 MT/truck- n manyear per year on eperson 1x trip 250 days a year	no of primary processing plants	foodsafety monitoring, weekly inspection of processing plants	total manyear per year
Landbased	1	1	3	3	10	2 000	1	20		1	2	4		1	111	0	1	0,5	
	2	2	3	6	20	4 000	2	40		1	4	8		1	222	1	1	0,5	
	3	3	3	9	30	6 000	2	60		2	6	12		2	333	1	1	1	
	4	4	3	12	40	8 000	3	80		2	8	16		2	444	2	1	1	
	5	5	3	15	50	10 000	3	100		3	10	20		3	556	2	1	1	
															-				
Floating bags	2	2	3	6	20	2 000	1	20		2	4	4	5	2	111	0	1	0,5	
	4	4	3	12	40	4 000	2	40		3	8	8	5	2	222	1	1	0,5	
	8	8	3	24	60	8 000	3	80		3	16	16	10	4	444	2	1	1	
	10	10	3	30	100	10 000	4	100		4	20	20	10	4	556	2	1	1	
Sum landbsed and floating bags - no of man-year per year - smolt to market, excl aquaponic activity																			
production volume at sea																			
6 000				9	30		2			3	6	8	5	3		1		1	68
10 000				18	60		4			4	12	16	5	3		2		1	125
16 000				33	90		5			5	22	28	10	6		3		2	204
20 000				42	140		7			6	28	36	10	6		4		2	281
Aquaponic integration to landbsed and floating bags; cultivation, harvest and processing																			
production volume at sea	No landbsed and floating sitesopen pen sites				no of aquaponic production staff	no of staff processing mussel	secondary processing no staff	producing and mussel seedling	staff number processing macroalgae	sedconadry processing no staff	producing and mussel seedling	black solider, waste cycle		fish health smolt and ongrowing					number must be verified
4 000	4		Aquaponic		8	4	4	2	4	4	2	3							31
6 000	6		Aquaponic		12	8	8	4	8	8	4	6							58
16 000	16		Aquaponic		32	16	16	8	16	16	8	12							124
20 000	20		Aquaponic		40	20	20	20	20	20	20	15							175

C Executive Summary - Potential aquaponic and fish feed impact

Potential Aquaponic impact

If the Feasibility study`s observations are within reach +/- %

- Including some adjustment on how the aquaponic integrations shall be sorted out

It may represent a game changer for the West Estonia region

SUSPENDED ORGANIC WASTE PARTICLES FROM THE FISH PRODUCTION DO NOT ENTER THE BALTIC SEA

A HIGH PROPORTION OF THE DISSOLVED NITROGEN AND PHOSPHORUS NEVER ENTERING THE BALTIC SEA

Water Act thresholds per 1.0 kg fish produced is reduced by

- **- 60% (N)**
- **- 90% (P)**

For Aquaponic integration

TO DO LIST

Baltic fish feed 2021

LATEST BALTIC FISH FEED SHOWS

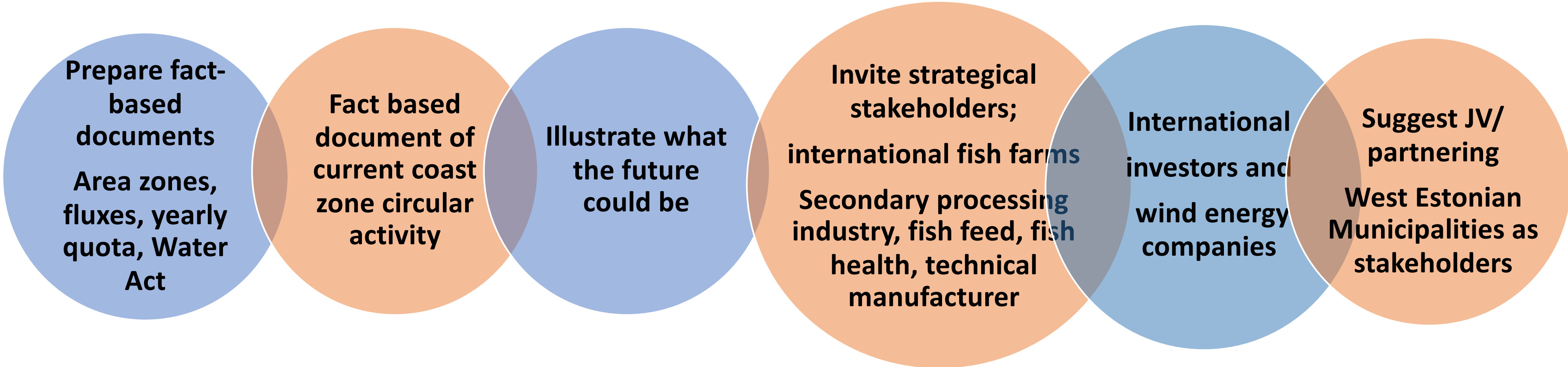
REDUCED FLUXES=> POSSIBILITY FOR OPEN NET FARMING

Water Act thresholds are reduced by;

- **- 11% (N)**
- **- 27% (P)**

C Executive Summary – TO DO LIST

Define yearly fluxes per zone/site and promote West Estonia potential localy and arrange international seminar



First movers will always have some benefits and will also have to sort out challenges - if you are not doing anything - nothing will happen

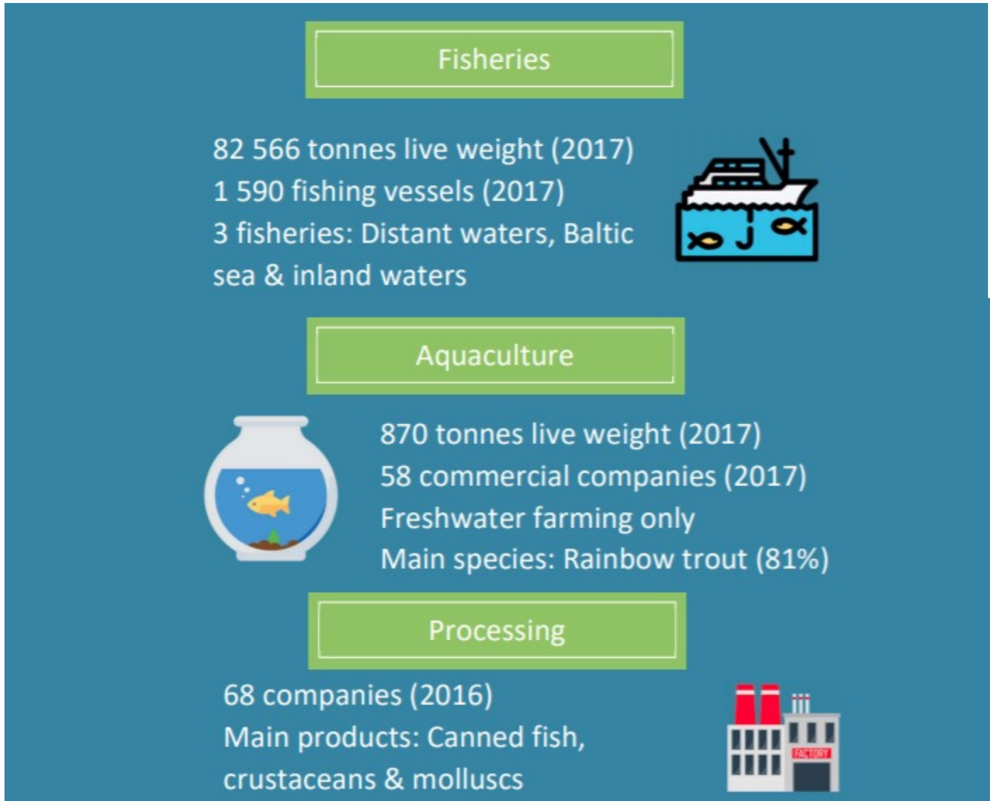
D Observations

D Observations - Marine exploiting today Estonia

Observation: many «small» companies that support the whole value chain

They should be well equipped to handle a much larger biomass, products and secondary processing activity

The value chain is fully in place - but needs more local produced marine raw materials



D Observations - Environmental EU rules and cross-country Baltic regulation

Observation; regulation and political challenges

Pressures to increase aquaculture production significantly in the Baltic Sea pose a significant environmental problem: many coastal waters most favorable to aquaculture are in ecologically poor or moderate condition, and the most used open-net rearing units cannot escape significant nutrient discharges to the sea [8,9].

At present, the EU Water Framework Directive (WFD, 2000/60/EC) sets a binding legal obligation for the member states not to authorize projects that may deteriorate the ecological status of coastal waters or jeopardise the achievement of Good Water Status in waters up to 1 nautical mile from the baseline as set by the UN Law of the Sea Convention.

Similarly, the Marine Strategy Framework Directive (MSFD, 2008/56/EC) aims at Good Environmental Status of marine waters beyond the one nautical mile mark

In aggregated, these ecological goals present significant legal challenges for increasing nutrient loads in the EU member states around the Baltic Sea generally

D Observations - Aquaculture possibilities in West Estonia

If the West Estonia coastal zone can be exploited this represent good opportunities;

a) Located in Europe, there are modern smolt facilities already in the region

b) There is nothing wrong with the seawater in West Estonia other than the sea is eutrophicated, has low salinity and water >40m is sometimes stagnant and lack oxygen

c) Nordic culture, EU is probably the world's largest producer of portion trout < 1 kg

d) Eggs, fish feed, technical assets and farming knowledge is outside your door

e) West Estonia is in the middle of the EU market, medium labor cost and short logistic routes

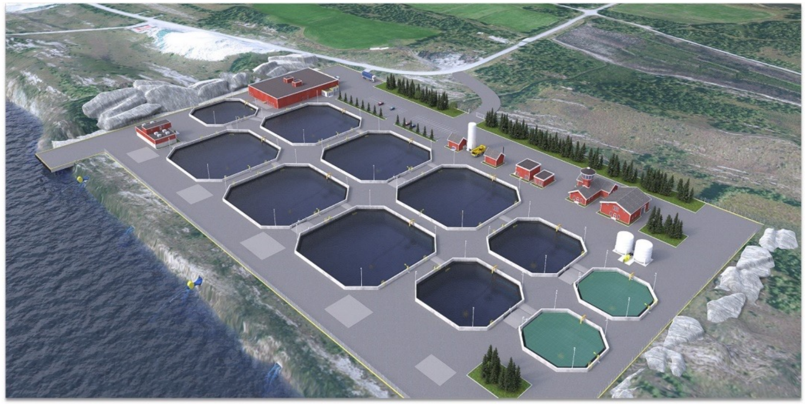
f) <u>Production cost of rainbow trout is similar to Norway and there is no costly license entry - unique!</u>

g) The worldwide center of secondary processing industry is outside your door (Poland)

D Observations - Open net farming

D Observations – Tanks on land

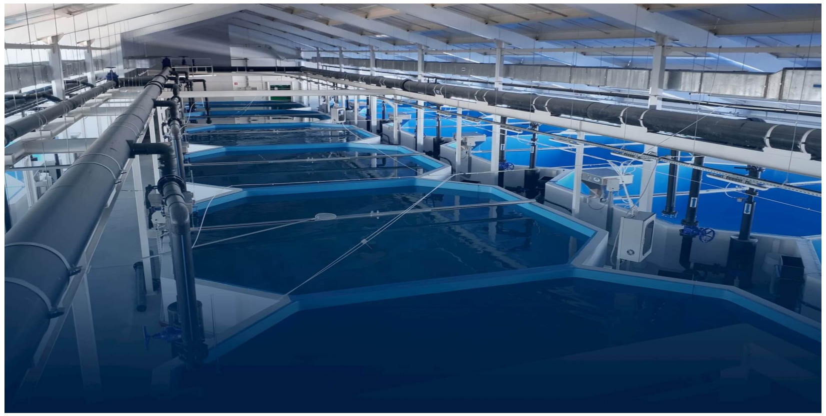
Conventional tank



Conventional tank

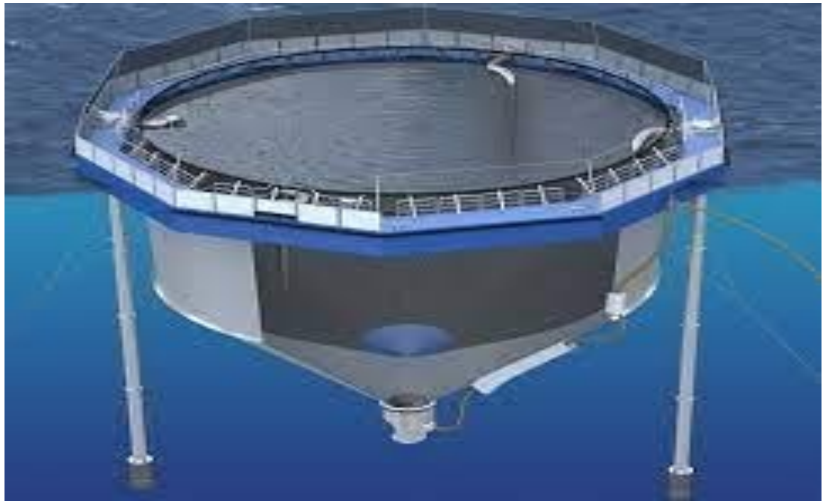
Raceway trout Denmark

RAS - recirculation



D Observations - Floating bag concept





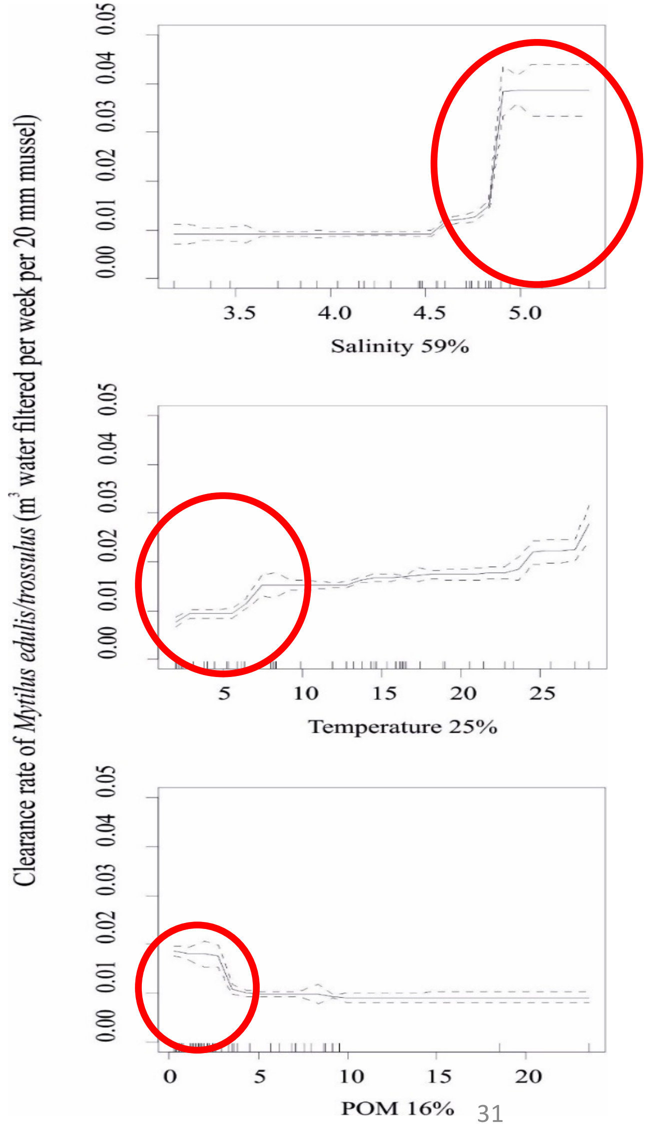

Illustration; Floating bags with dimension from 6 000m^3 to 30 000 m^3. Pumping cost is 1 kwh per 1 kg fish produced, the same cost in Tanks on land is > 300- 600%.

Blue mussel - *Mytilus edulis/trossulus* – J. Kotta

D Observations – Mussel filtration capacity

Medium filtering capacity			Very High Filtering capacity					Medium filtering capacity			
Jan	Febr	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

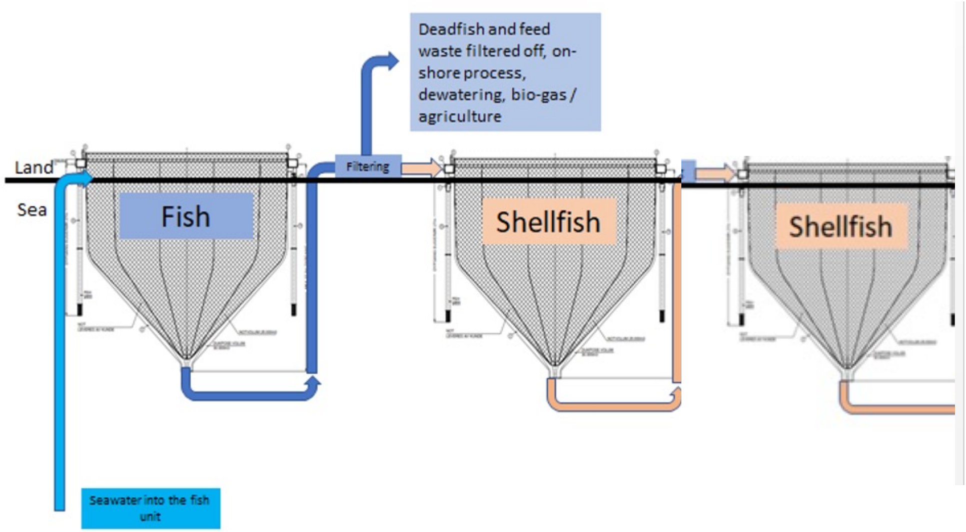
(light blue)	Medium
(dark blue)	Very high

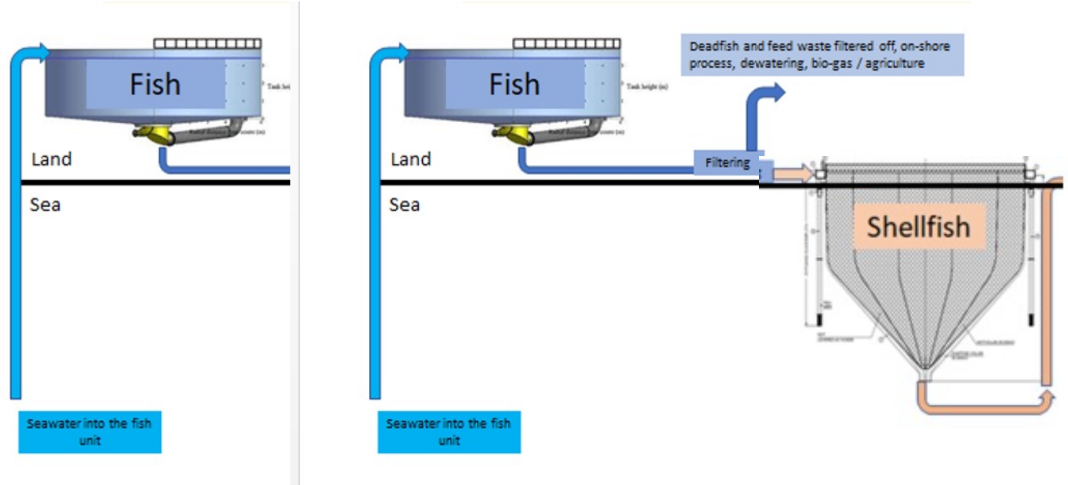


D Observations- Aquaponic mussel and organic waste position

Aquaponic mussel integration to fish farming by use of land-based tanks or the floating bag concept; possibility to filter out all organic waste = zero flux to the sea

Floating bag	Tanks on land





2 fishbags per 1 mussel bag
400 tons fish and 24 tons mussel per year

4 fishtanks per 1 mussel bag
400 tons fish and 24 tons mussel per year

D Observations – West Estonia conditions for the cultivation of shellfish

Conditions for shellfish growth are good in West Estonian environment

Why blue mussel?

- Extremely efficient filtering organism
- Native
- Abundant
- No diseases
- Harvest cycle 2.5 yr.

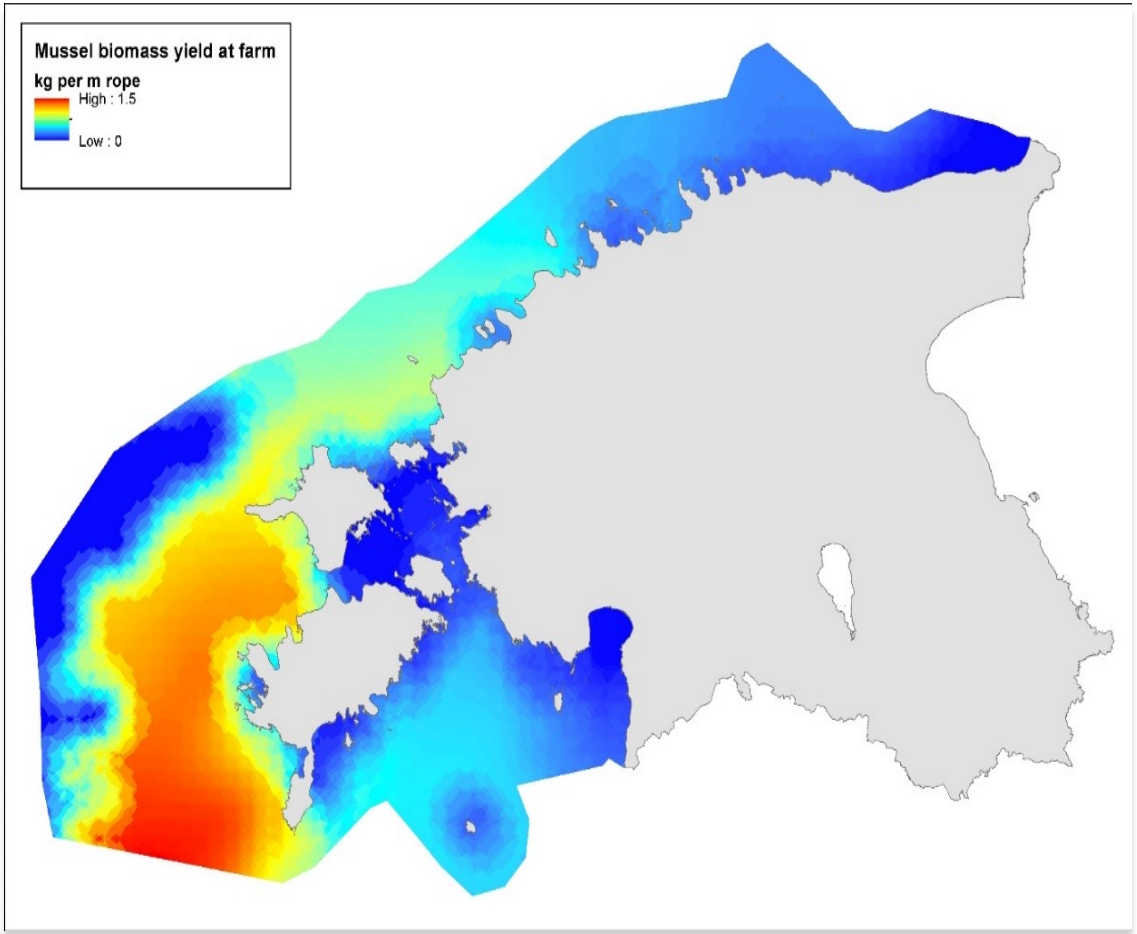
Seedling in May-June

- To reach optimum filtering size and capacity small musses need to be for 9 months prior being integrated to the fish farm (tanks on land and floating bags)
- This filter lasts >10 years, no need to harvest but can be harvested

Use traditional offshore cultivation techniques

- Trawler nets
- Integrate large floating mussel bags (including trawler nets) to floating fish bags/tanks on land
- No predation
- Control the flux of organic waste

D Observations – West Estonia conditions for cultivation of shellfish



The modelled growth yield of blue mussel in mussel farms in Estonian waters

D Observations – Circular economy mussel modelling

Aquaponic mussel modelling

Modeling

- Collating data on growth and filtering capacity
- Establishing relationships between mussel filter-feeding and salinity, temperature and concentration of suspended particles
- Considering seasonality in fish production, mussel mortality, predation

Harvesting is optional

- Harvesting every 2.5 yr
- But mussel populations can easy stay for a longer period
- Capturing suspended organic particles to avoid nutrient emissions to sea rather than optimizing the mussel biomass yields

Floating bags / fish tanks creates a steady and rich mussel food flow

Productivity is approx. 24 tons wet weight per mussel aquaponic unit per year (48 tons per 2 years) for every 400 tons live fish biomass

D Observations – Circular economy West Estonia - mussel

Circular economy Mussel

The aquaponic integration starts with a sea-based mussel seeding

- Best locations areas West to Saaremaa, Hiiumaa
- Seeding in May, early June
- Pick up optimal cultivation technique

Advantages

- Avoid eutrophication symptoms
- 24/7 food supply will result in a good winter growth
- Eliminate total organic fluxes and creates outfluxes of carbon

Risk factors

- No known diseases, predation unlikely
- How to ensure that the food particles are suspended in the water column
- Integration such cultivation technique in the mussel bags must be investigated

Circular economy

- Employment
- Harvesting and value-added processing line are not described in the report
- 20 000 tons fish production may equal to 1 200 tons mussel production

Mussels may act as feed ingredient for land animals and fish or processed as human food. Alternatively, may act just as a filter to capture fish farm effluents.

D Observations – Sea cultivation mussel

Traditional open net and open sea mussel cultivation

We predict that in order to reduce organic waste particles from Open net farming of equal fish production

we need a way larger amounts of traditional vertically hanging cultivation ropes/trawler nets (several hundred of km)

We assume that this is neither

practical nor economical feasible to capture all fish waste from a large Open net fish farm we need approximately

100 – 200 km of trawler nets for one large fish farm of 4500 tones per year

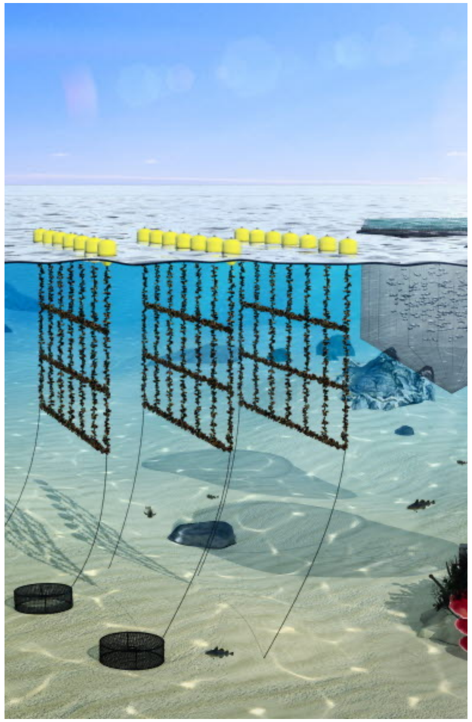
But apart of their NP content, **mussels may remove significant amount of nutrients from the matter flow in coastal systems.**

This needs to be further investigated.

Biomass yields in the mussel aquaponics may be higher than in traditional open sea cultivation due to constant food all year round

D Observations –mussel cultivation in sea either separate or integrated with traditional Open net farm

Dedicated near shore Offshore cultivation site



Near Open net fish farm

Aquaponic macroalgae «Green gras» - *Ulva intestinalis* G. Martin

D Observations – Cultivation elements West Estonia - macroalgae

Cultivation elements Macroalgae

Why *Ulva intestinalis*?

- Naturally present in West Estonia region
- Growth season, assimilation of nutrient, sunlight photosynthesis
- summer intensive growth
- winter hibernation and small growth
- winter fragmentation

Oxygen production and carbon dioxide reduction

Fragile algae

- Bad weather and wave forces damage the algae
- **Offshore cultivation is difficult**

Algae bags => advantages in form of

- is protected, conserve all nutrient flux and carbon dioxide to the algae
- circulation of nutrient rich water and algae inside the algae bag

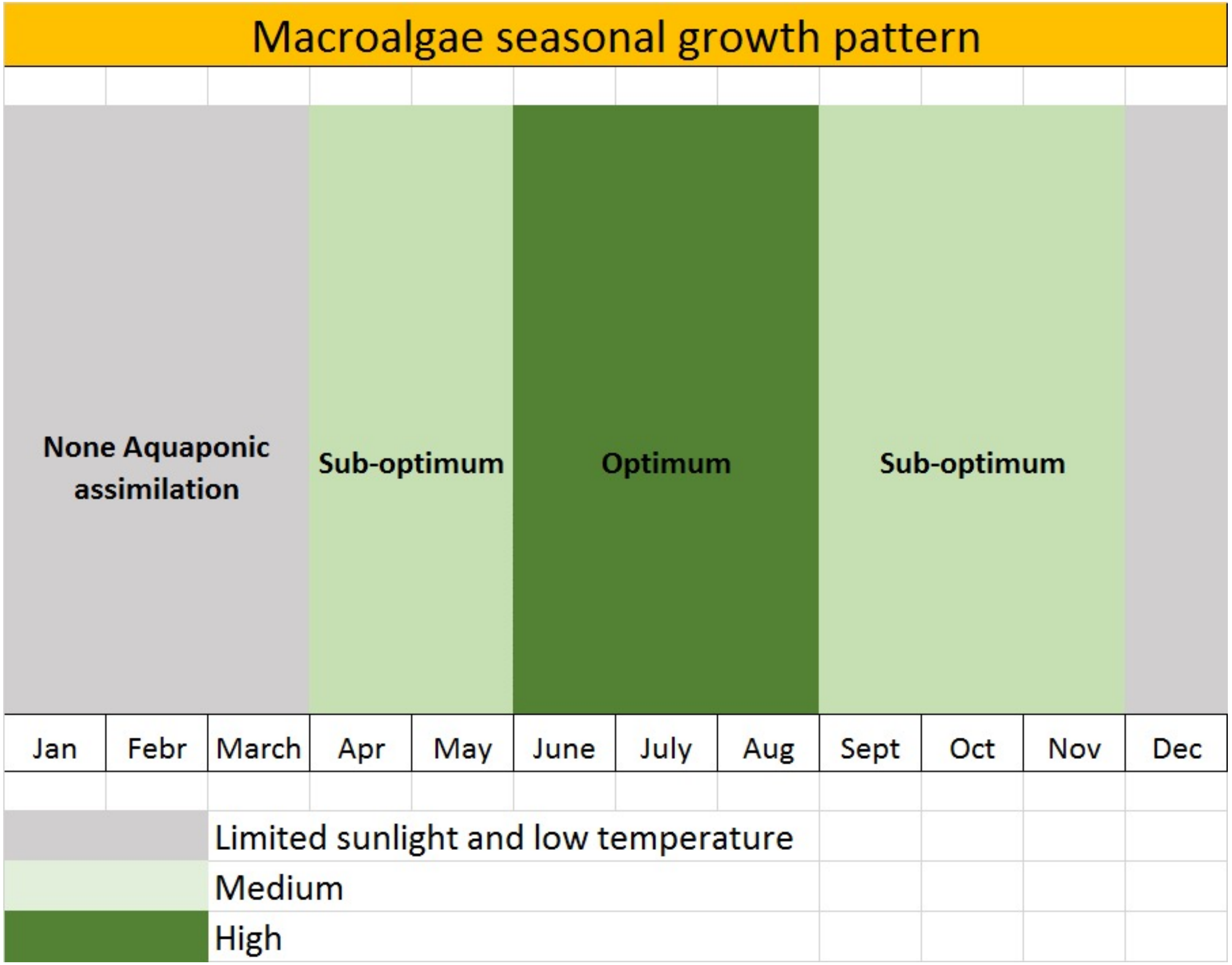
D Observations – Cultivation elements West Estonia - macroalgae

Cultivation elements Macroalgae

Technical challenges

- Sedimentation of macroalgae must be avoided
- Algae suspended in the water column must also avoid shadow effect/limited sunlight
- What is the actual growth rate?
- How to harvest?
- How to operate the units?
- How to avoid epizoon and predation?
- Intensive growth season, huge biomass volume

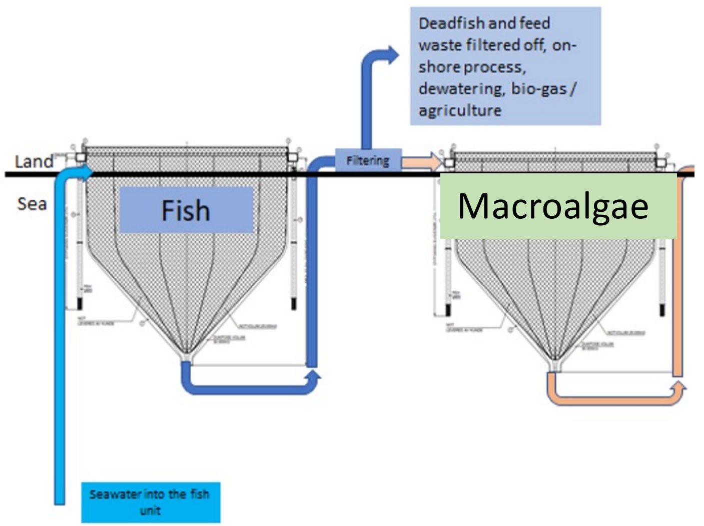
D Observations – Illustration of macroalgae growing season



D Observations - Aquaponic macroalgae nutrient assimilation

Aquaponic macroalgae integration to fish farms by use of land-based tanks or the floating bag concept

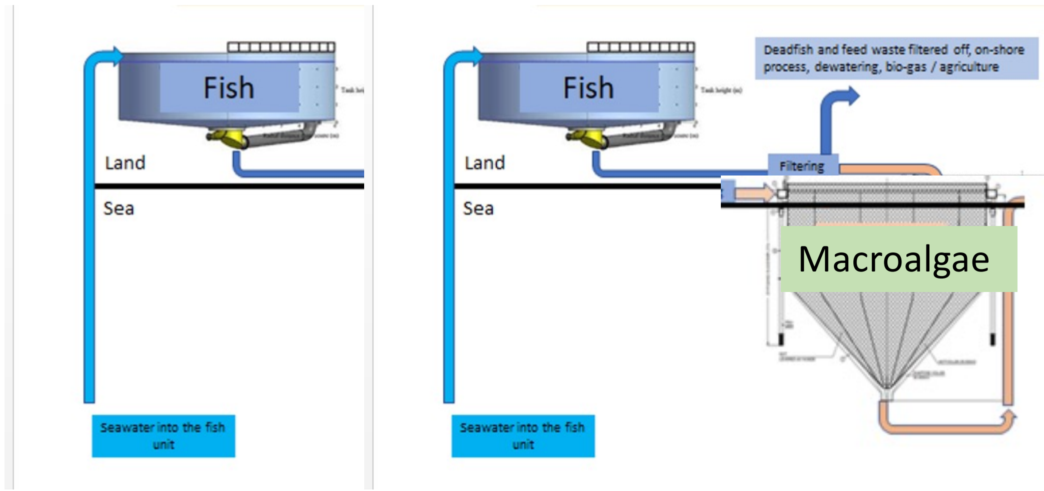
Floating bag



Best solution

4x fish bags for every 1x algae bag

Tanks on land



If good location is found we predict that floating algal bags represent a capex and cost advantage compare to land-based macroalgae cultivation

D Observations – Circular economy macroalgae

Circular economy macroalgae

Best cultivation techniques for aquaponic

- Sun light/ suspended in the water column
- Not attached to substrate nor bentic

Final product

- chemical content
- added value
- food/feed chain
- Energy source

Productivity

A large fish bag may produce

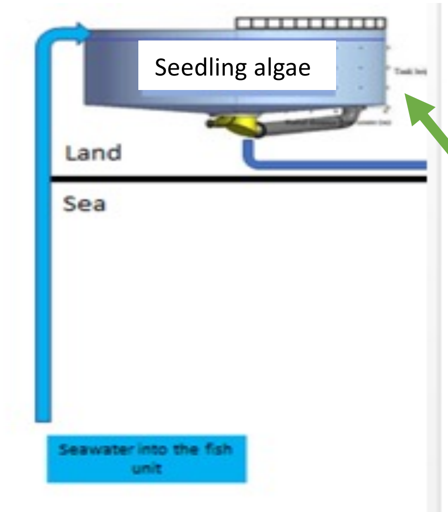
- 200 tons fish biomass per year
- 20 bags may represent 4 000 tons fish=> preliminary observations is that we here can integrate approx. 5 algae bags
- producing 5 x 1 620 tons wet weight algae per year (8 000 tons) i.e. 200% more than the fish biomass

These estimates are based upon

- Our assumptions as of today
- The large waterflow from the fish tanks can disturb the assimilation efficiency
- Should be verified under controlled cultivation

D Observations - Macroalgae Seedling process

Seedling production: pre-made juvenile macroalgae population prior to the early spring growth season



Juvenile macroalgae population needs to be cultivated (kept in a culture etc.) prior to the spring season every year and act as seedlings;

A dedicated land-based macroalgae seedling station located on the islands, example the Pilot station

Land-based macroalgae seedling station: temperature control and artificial light, supply to multi fish farms

Public decisions and TO DO LIST are the success factors

D Observations TO DO LIST 1

West Estonia has all options to

- **Issue farming licenses economy of scale**
- **Define zones and sites with flux quotas per year**
- **Create motivation factors for Aquaponic integration**
- **Adapt and create best farming protocols and fish health regime from Norway - do not copy, not all is perfect!**
- **Keep track of latest fish farming concept and waste techniques**
- **Establish pilot public R&D station with aquaponic- invite technical and R&D partners, lease with option to buy**

Test, learn

Education and sustainable platform - *state of the art*

D Observations - TO DO LIST 2

- Buy Egg, vaccines, fish feed international

  Do not spend time and money
- Initiate the process with hatchery and smolt farms
- Establish seedling stations
- Set up aquaponic fish integrations
- Exchange program in Nordic region; education, farming knowledge, University
- Probably one of the best sustainable fish farming techniques

D Observations – TO DO list 3

Do NOT have ambitions that you shall do everything yourself - do not invent the wheel in 2021

Establish a central pilot R&D station

- Buy or lease everything you need in the start
- Invite for JV and co-operations

Strategical create a lean plan

⇒ establish 2-4 modern commercial fish farms

⇒ and minimum 2 of them with aquaponic integration by 2025

Invite for

JV co-operations

Issue farming licenses and fact documentations that motivates private stakeholders to act

- Plan for a West Estonia investor seminar

D Observations – TO DO LIST 4 Pilot test station

Suggestion of **Pilot test station**

- Integrate universities within the Nordic/Baltic region
- Define exchange program for farming staff, education, show the Nordic region all about aquaponic integration
- Invite commercial fish farmers, feed fish producers, technical manufacturers

D Observations summary Fish biomass

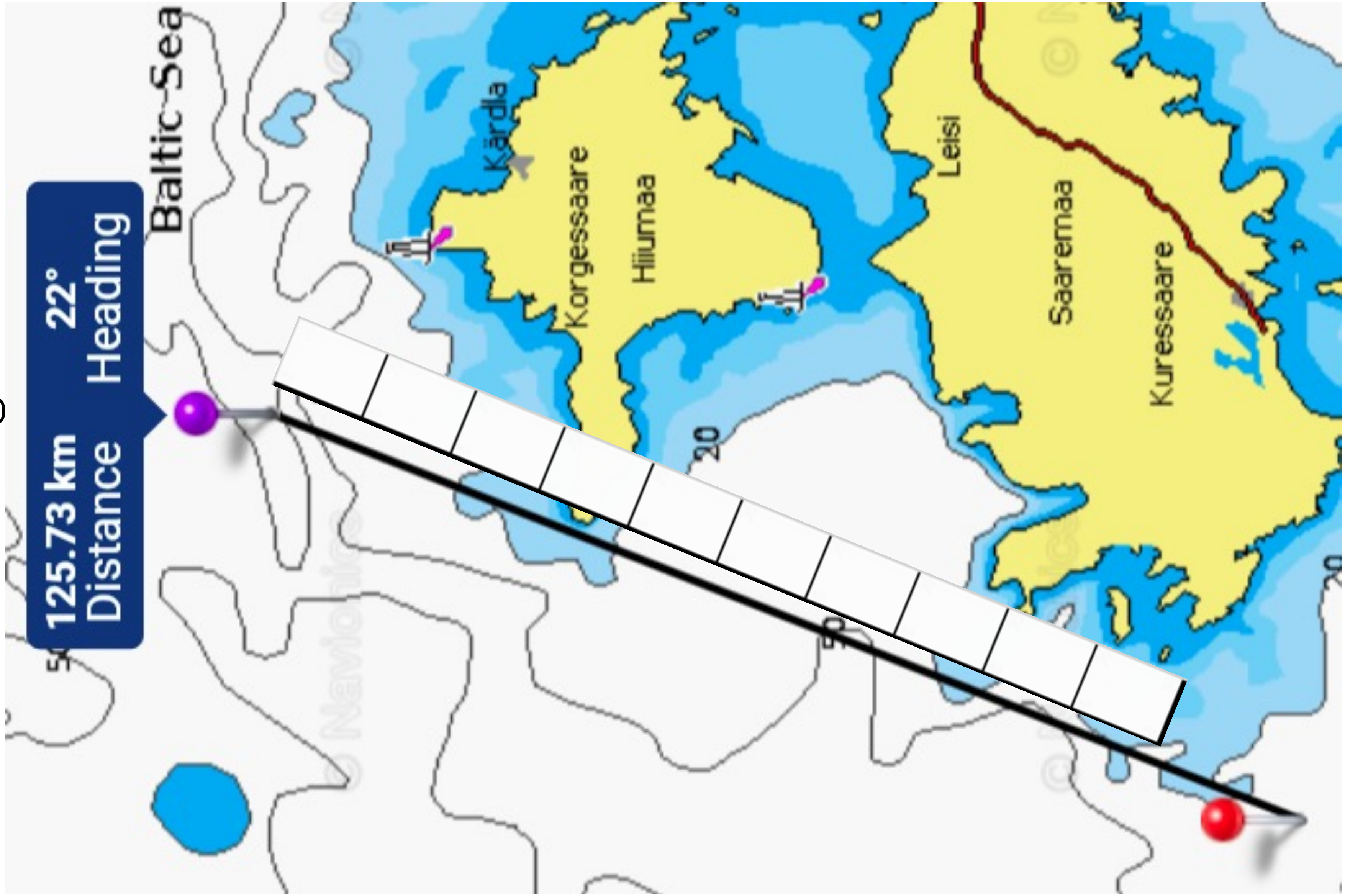
Theoretical production planning

Offshore area 100 km x 10 km

=> 20 000 000 kg on 1 000 km^2

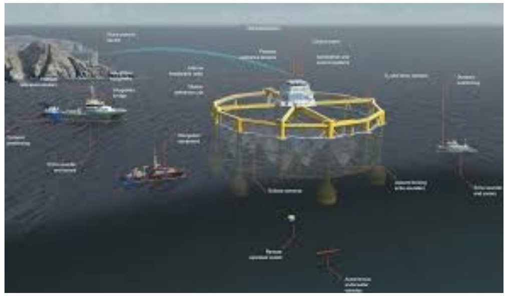
=> 20 mill kg on an area of 1000 mill m^2

=> 20 ton/1km^2



D Observations - Example of circular industrial partnership

Example – wind-energy company



Synergies;

1. Manpower - service operation
2. kWh supply and backup
3. Oxygen
4. Fish feed logistic and storage
5. Fish harvest and transport

West Estonia region could:
Grant Wind energy licenses combined with aquaculture integration, Offshore farming = win-win situation

D Observations – Risk & success factors

7x risk factors to pay attention to =>

No 1 Highest risks is the **weather conditions** where aquaponic integration can take place

No 2 **Define if Open net farming can be introduced without Offshore cultivation**

No 3 There is a need to investigate the details on how the aquaponic integration with the fish farms could be arranged

Cheap and functional mussel and macroalgae bags - technical layout and costs

No 4 - The initial investments of modern smolt plants - this must be linked to licenses for full outgrowth of fish to 3.5 kg

No 5 How West Estonia can establish aquaponic cultivation:

- juvenile seeding station of mussel - and macroalgae represent a key role in acting as seedings

No 6 Carefully consider good harvest techniques for both algae and mussel

No 7 Aquaponic products – their final product, market and economy