Resource recovery from organic waste by microalgae for global sustainability and space exploration

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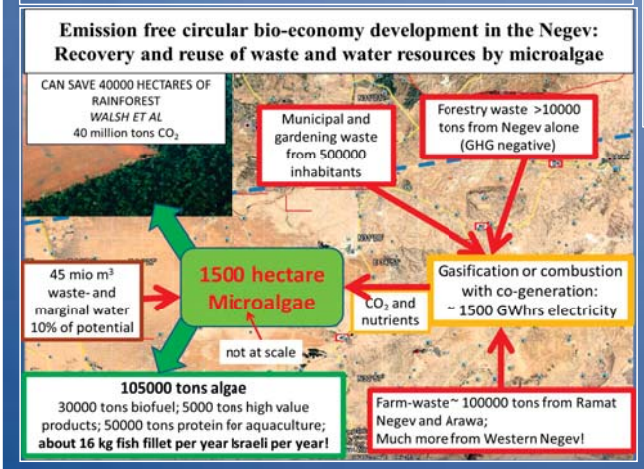
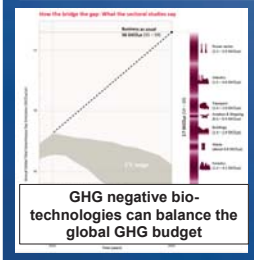
Algae for rural sustainable dryland bio-economy development:

The Microalgal Biotechnology Laboratory has developed and tested a complete set of technologies aimed at recovery and reuse of waste and waste water resources as substrates for large scale microalgae biomass production. Our findings provide the basis for wide scale application of microalgae as the centerpiece of closed loop biosystems for the highly sustainable waste free management of rural dryland regions and communities that can be the backbone of emerging **greenhouse gas negative** circular bioeconomy systems for the sustainable development of marginal dryland areas.

Main results

- Rural, arid agro-economies create large amounts of farm waste, waste water, municipal and forestry waste that need to be properly disposed off;
- Such resources may be funneled into centralized waste treatment facilities converting biomass into energy, CO_2 and nutrient rich residue;
- We have used such substrates successfully for the efficient cultivation of microalgae under exploiting and treating all locally available waste water;
- Such microalgae biomass could best be used for the production of high quality aquaculture feed and high-value co-products;





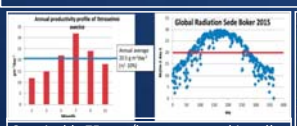
GHG negative bio-technologies can balance the global GHG budget

Stopping global warming!

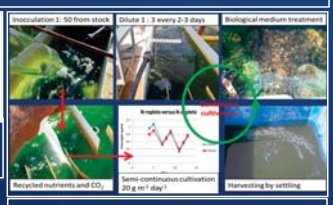
In this role, microalgae are a **greenhouse gas negative technology** contributing to pollution control, food security, and development of marginal dryland areas!

All components for such an approached are either commercially available, or have been demonstrated recently

- ✓ Robust high yielding species;
- ✓ Continuous year-round high yielding raceway cultivation;
- ✓ cheap harvesting, extraction, biomass processing and biorefinery;
- ✓ closed sea water cycle, allowing cultivation deep inside semi-desert territories;
- ✓ on site nutrient, CO_2 and renewable electricity generation – fully independent on fossil fuel inputs;
- ✓ avoided methane and NOx emissions, avoided eutrophication, avoided WW-treatment emissions;
- ✓ Cultivation on low-value desert land using marginal water;
- ✓ High yield production allowing to sequester massive amounts of CO_2 elsewhere;



Sustainable 75 tons/hectare year achieved!
- 30 tons of protein per hectare and year!
- Growth strictly depends on radiation!



Simple semi-continuous cultivation approach using recycled medium!

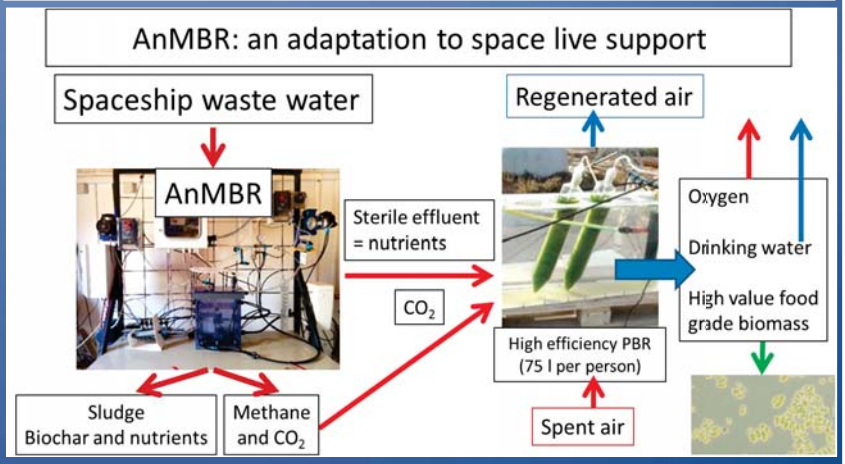
Biological seawater treatment on site:
- avoids pollution and eutrophication, and safes infrastructure costs!

Overview:

Microalgae are uniquely suited as the **central mediator** within circular waste free sustainable resource recycling or life support systems for GHG negative terrestrial or future space applications. We present here some recent experimental results demonstrating the validity of such approaches in remote desert locations and in outer space.

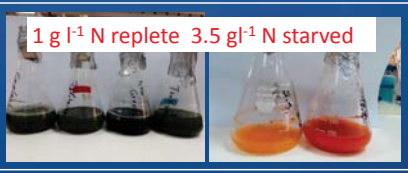
Space applications for MBL algae biotechologies

- An advanced development of those principles is an extremely simple, compact, but highly efficient life support system suitable for spaceships or Mars, developed in the framework of Israel-German joint collaborative project AnMBR.
- We have demonstrated the ability of this approach to convert all waste water, nutrients and CO_2 back into highly valuable food grade biomass, drinking water, energy and oxygen.
- The technology combines anaerobic digestion of organic waste in a membrane bioreactor, to create biogas and nutrient rich effluent, with microalgae mediated effluent treatment for recovery of nutrients, CO_2 and organic molecules for biomass production.
- First results indicate complete nutrient removal from the sterile effluent under creation of high quality algae biomass and high quality water. CO_2 for the process is sourced from biogas combustion.
- AnMBR sludge can be treated by HTC and is an ideal starter for Mars soil regeneration.

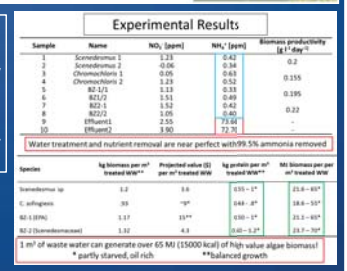


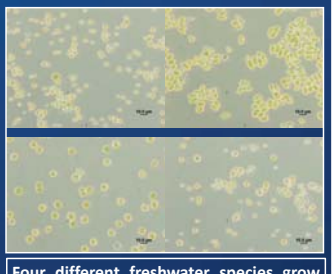
Results:

- 4 strains tested grow at around 0.4 g l^{-1} day^{-1} outdoors in AnMBR effluent;
- 4 different species with different biomass composition were successfully tested;
- 20 – over 70 MJ of metabolic energy (food for 1 week) can be recovered from 1 m^3 of municipal waste water;
- Quality of algae biomass is very high due to sterile effluent used for cultivation;



Initial growth assay of four algae species in adjusted AnMBR effluent and end point growth into carotenoid containing biomass





Four different freshwater species grow stable and very clean in An MBR effluent, completely converting N and P back into high quality biomass.

Why microalgae and not cyanobacteria in space (MBL has its own huge Spirulina collection):

- A mix of microalgae is nutritionally complete (AA, EPA, essential AA, FA profile, carotenoids;
- Microalgae grow in drinking water quality;
- Microalgae have superior stress survival strategies;
- Nutritional composition optimized to human (or fish) food requirements;

We are interested in collaborative projects:

- Horizon 2020 – circular bioeconomy call;
- Other related calls (biorefinery, protein etc);
- Demonstration of AnMBR in space/space simulations;
- Reviving Mars soil using AnMBR sludge;
- Contact: stefanleu3@gmail.com