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

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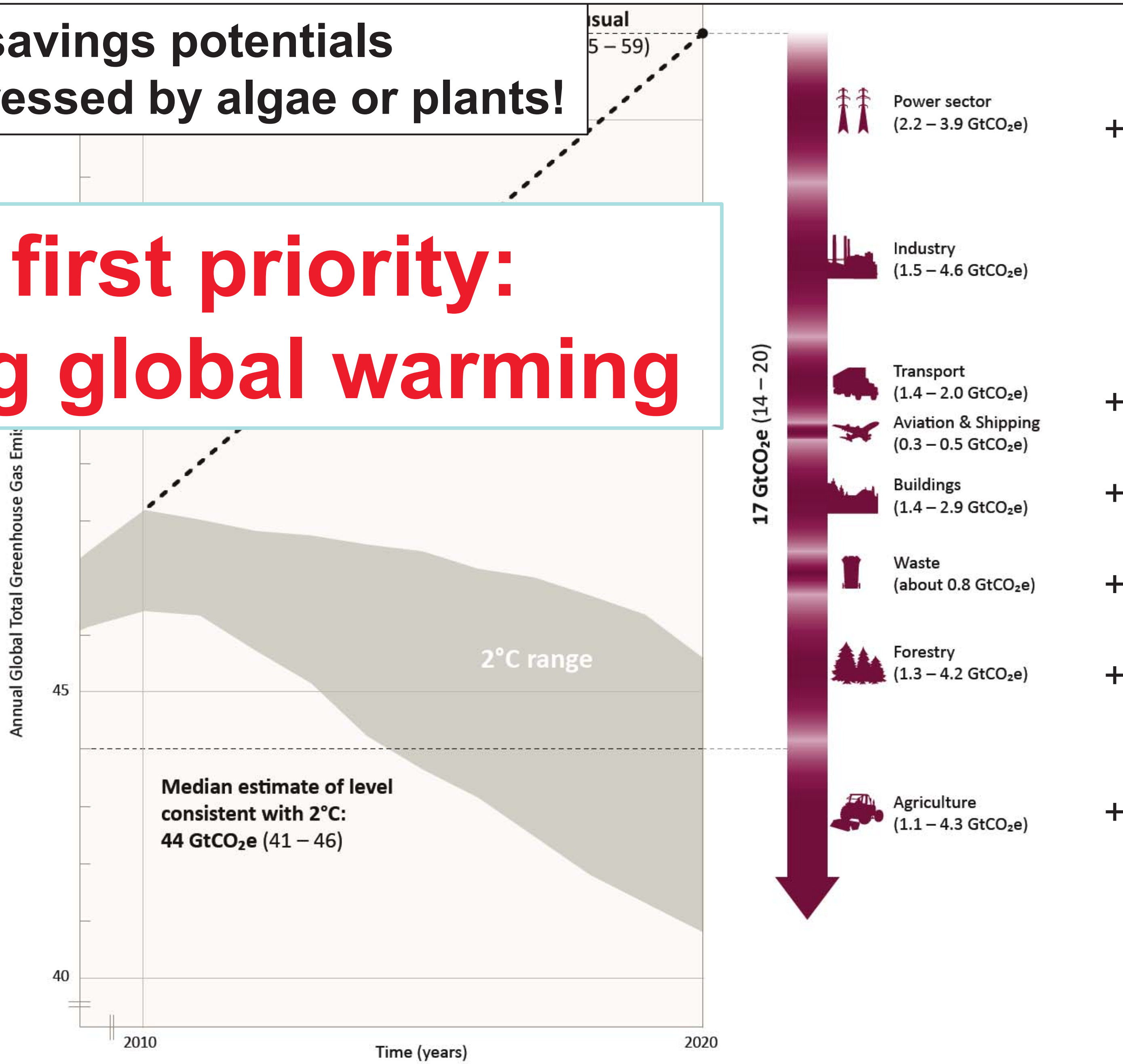
Earth – spaceship-space station

1. Same questions, same problems – different dimensions;
2. Biology is much simpler and much more efficient than engineered technologies;
3. No long term live support without photosynthesis!
4. Key challenge: convincing the stakeholders of that simple fact!

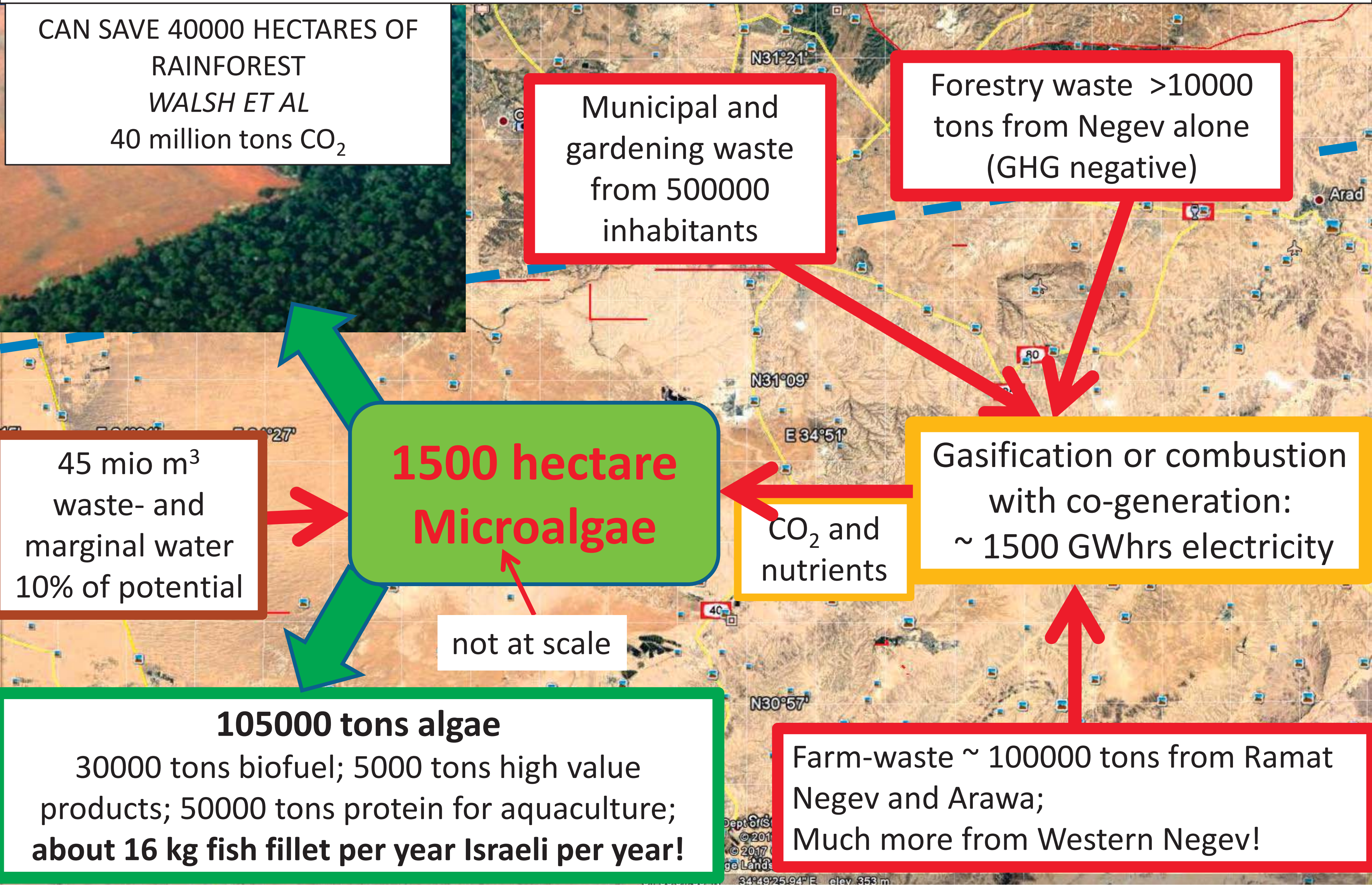
GHG negative technologies can balance the global GHG budget

Major savings potentials can all be addressed by algae or plants!

Our first priority: stopping global warming



Emission free circular bio-economy development in the Negev: Recovery and reuse of waste and water resources by microalgae



Algae for space exploration

Even more than on earth, microalgae are the only sustainable option for long term life support in space!

BGU is developing an appliance highly suitable for space life support

Integrated microalgae biotechnology can significantly add to safe, comfortable and pleasant roundtrips to Mars, or Mars colonization :

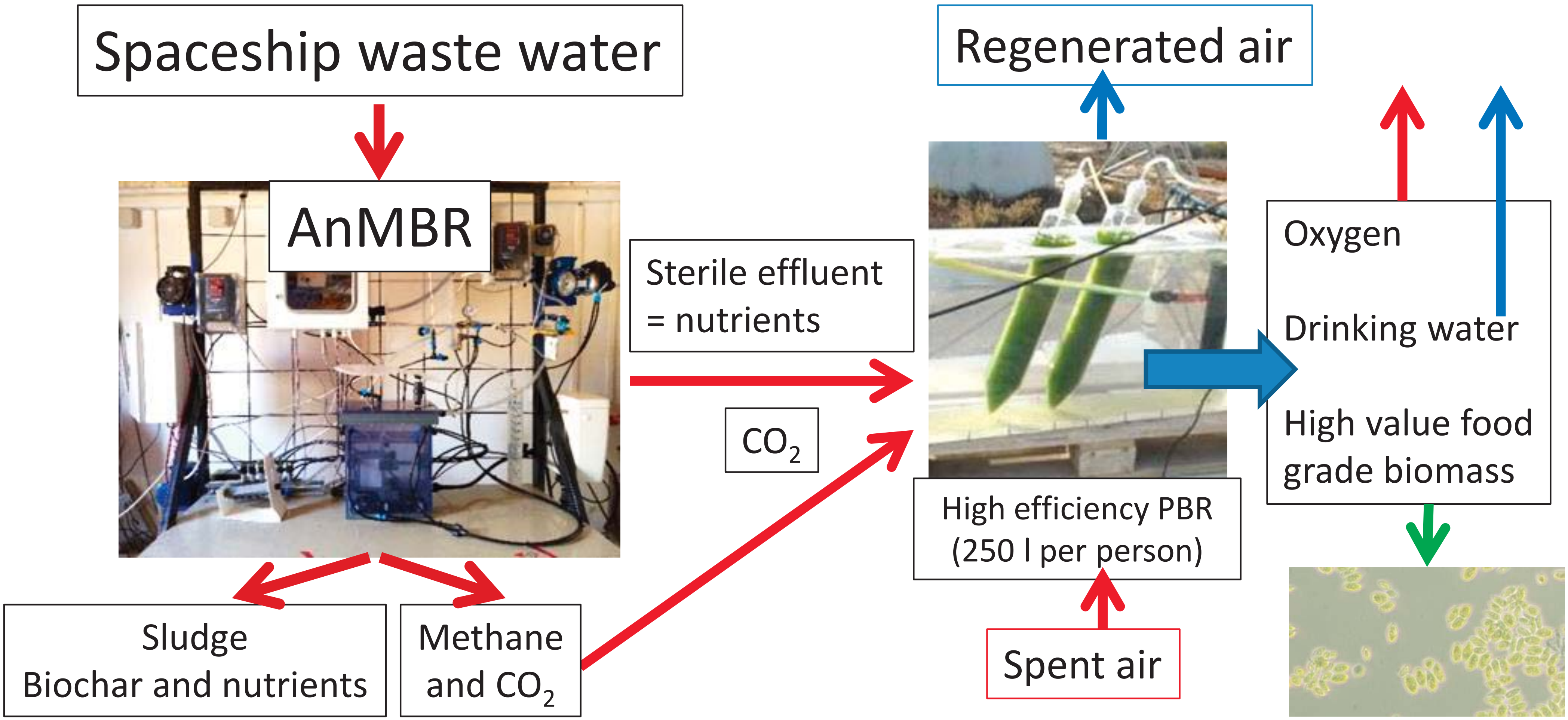
- Life support (air and water regeneration, integrated food production, waste recovery and reuse);
- Health: antioxidants, essential FA and AA, vitamins etc;
- Safety (PBRs can act as radiation shields, emergency heating or cooling, etc);
- Comfort, pastime and distraction;

AnM-PBR is an appliance for waste water treatment under recovery of all resources!

First results at TRL level 4:

- The system works fantastically well when challenged to fluctuating weather and substrate composition;
- High value edible biomass with high nutritional value can be produced at 0.4 g l^{-1} day^{-1};
- high essential AA and FA, vitamins, antioxidants and caloric value can be varied at will;
- Ammonia and phosphate are completely removed, near drinking water quality is released!

AnM-PBR: an adaptation to space live support



- 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 can be optimized to human (or fish) food requirements by growth conditions (e.g. 30% of calories fat, 40% carbohydrates, 30% protein for maintenance);

Experimental Results

Sample	Name	NO_3^- [ppm]	NH_4^+ [ppm]	Biomass productivity [g l^{-1} day^{-1}]
1	*Scenedesmus* 1	1.23	0.42	0.2
2	*Scenedesmus* 2	-0.06	0.34	
3	*Chromochloris* 1	0.05	0.63	0.155
4	*Chromochloris* 2	1.23	0.52	
5	BZ-1/1	1.13	0.33	0.195
6	BZ1/2	1.51	0.49	
7	BZ2-1	1.52	0.42	0.22
8	BZ2/2	1.05	0.40	
9	Effluent1	2.55	73.66	-
10	Effluent2	3.90	72.70	-

Water treatment and nutrient removal are near perfect with 99.5% ammonia removed

Species	kg biomass per m^3 treated WW**	Projected value ($) per m^3 treated WW	kg protein per m^3 treated WW**	MJ biomass per per m^3 treated WW
Scenedesmus sp	1.2	3.6	0.55 – 1*	21.6 – 65*
C. zofingiesis	.93	~9*	0.44 - .8*	18.6 – 55*
BZ-1 (EPA)	1.17	15**	0.50 – 1*	21.1 – 65*
BZ-2 (Scenedesmaceae)	1.32	4.3	0.60 – 1.2*	23.7 – 70*

1 m^3 of waste water can generate over 65 MJ (15000 kcal) of high value algae biomass!

* partly starved, oil rich **balanced growth

Issues (true for any algae operation):

- **Many moving parts, sensors, filters, pumps, electronics;**
- **Maintenance intensive, biofilms and biofouling;**
- **Need for algae harvesting and processing;**
- **Risk of failure;**

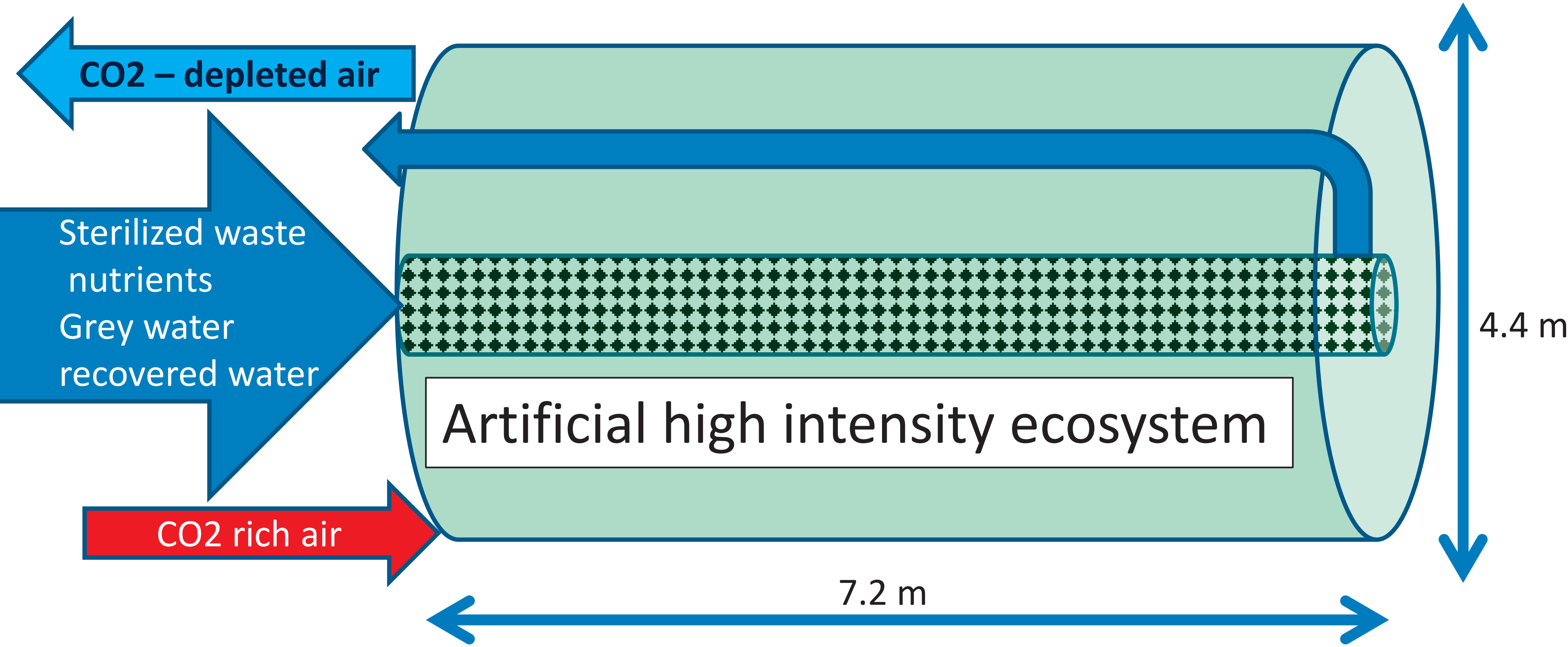
- **Much better than a heavy engineerig approach**

However:

an artificial ecosystem approach based on Permaculture principles may be far superior in all relevant aspects:

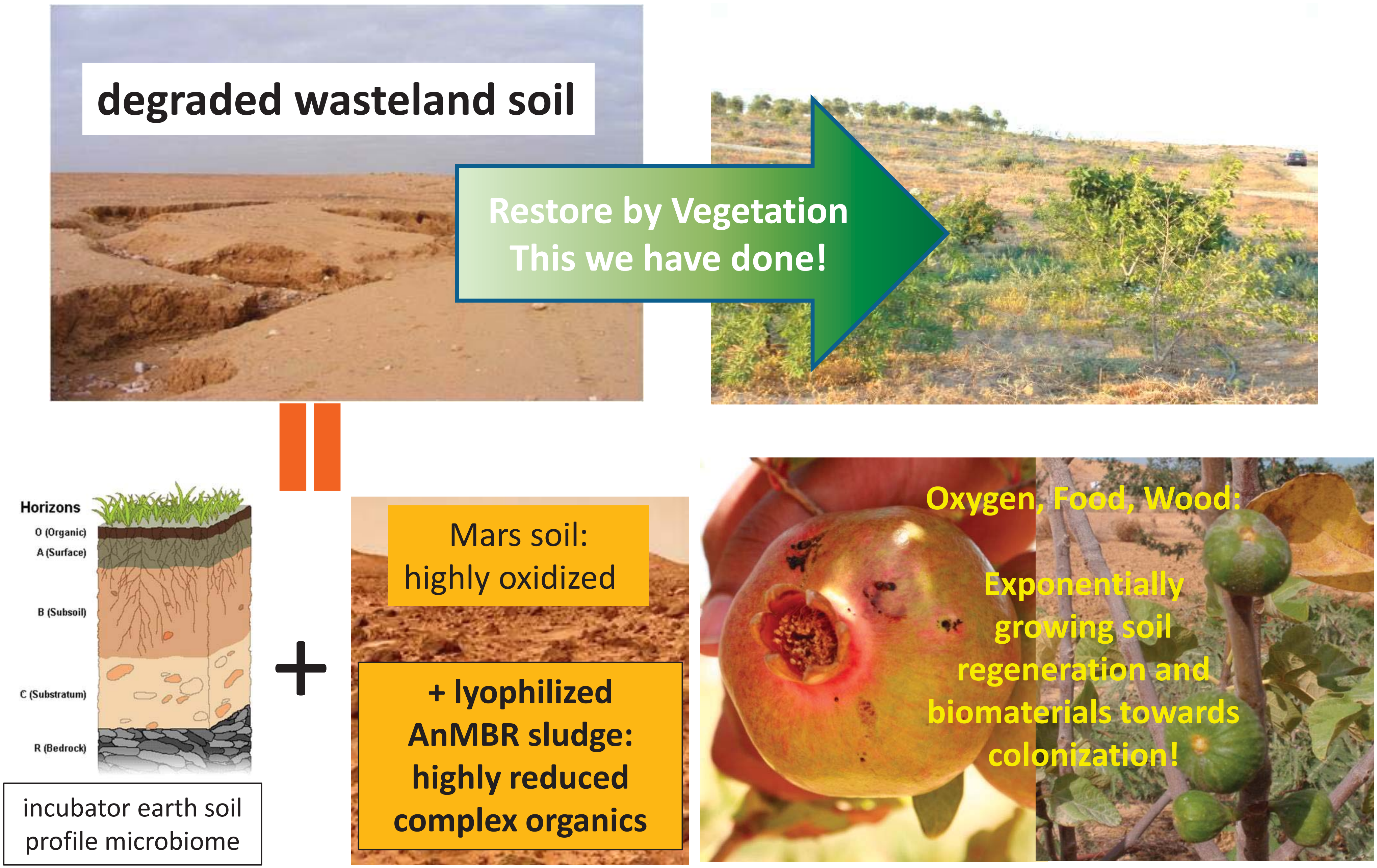
- weight
- investment and maintenance cost;
- reliability;
- durability etc

A higher plant based alternative may be profoundly simpler



- **Such a module has 120 m^2 illuminated surface, estimated 1.5 tons CO_2 sequestration per year (about 5 astronauts);**
- **no moving parts!**
- **no supervision, electronics etc required;**
- **lighter, cheaper, simpler;**
- **radiation protection feasible;**

Ecosystem approach to creating Mars or Moon based agroecosystems (we also work on rehabilitation of degraded dryland ecosystems)



Conclusions

- Highly sustainable circular dryland agroecosystems can be created using microalgae;
- Similar principles can be applied for life support in spaceships, or for creating exoplanetary agroecosystems;
- Only microalgae's unique unmatched properties can fully close all relevant cycles and mass balances;
- Higher plant based greenhouse modules can provide food, CO_2 and nutrient recovery cheaper with less weight and far lower cost!
- One of each would provide sufficient redundancy for safe space travel!

- We will be happy to demonstrate all possibilities at any of your research or demonstration facilities;
- Relevant upcoming H2020 opportunities can address various options;

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