„How transparent PVC-U turns green to produce food and fuel“

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teppfa
The European plastic pipes and fittings association
Channelling Performance

How PVC pipes can avoid this…

Source: O. Zuckerman; UniVerve; European Algae Biomass 2014

Providing food / feed / energy -

A global challenge:

- Corn and soybean prices up over 300% in 7 years
- 60-70% of the animal production cost account for feed (Reuters)
- World-population 9 Billions by 2050
- Intensive rise of fish farming
- Enormous need of energy and water for agriculture
- Threat for water & feed shortage
- Limited ground for agriculture
- Limited resources of fossile energy
- “Food vs. fuel”-competition
- Desertification, use of pesticides, erosion, loss of tropical forest, overfishing, intensive animal farming
- Unequal food-distribution

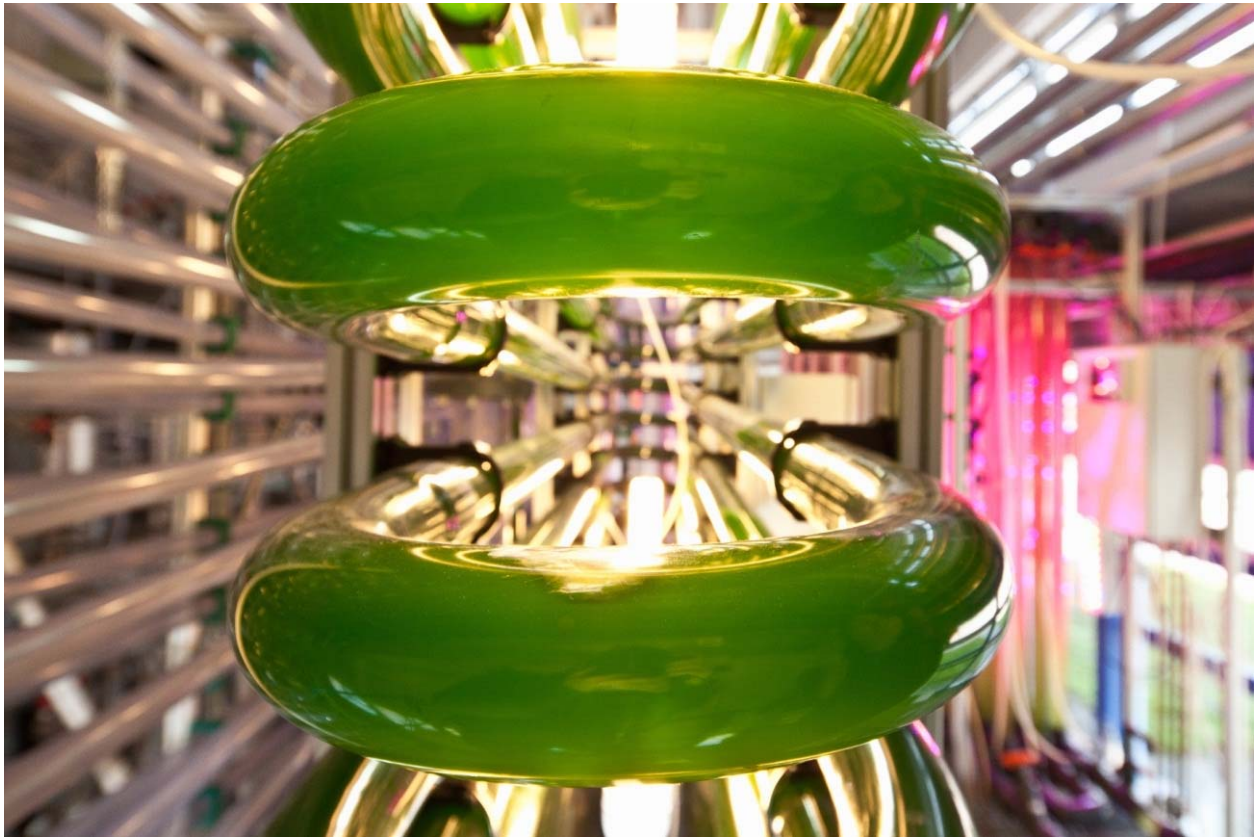
Chances of algae-cultivation

- Cultivation of microalgae is the only technology for biomass-production without using soil and reducing CO_2
- No competition to conventional agriculture
- Steadily increasing facettes / chances for large-scale-use

Strongly increasing demand for innovative non-soil-based alternative sources for biomass

Motivation: Aim of this presentation

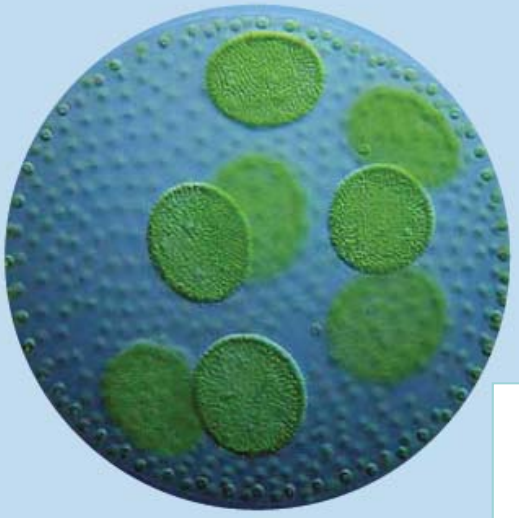
- Update on status
- Recapitulating the basics
- Tubular Photobioreactors (PBR)
- Status and perspective how PVC can support the technology



New phase: Out of the lab; up-scaling; closing circles, individual solutions using general concepts

Photobioreactor piping for micro algae cultivation

Light



CO_2, nutrients

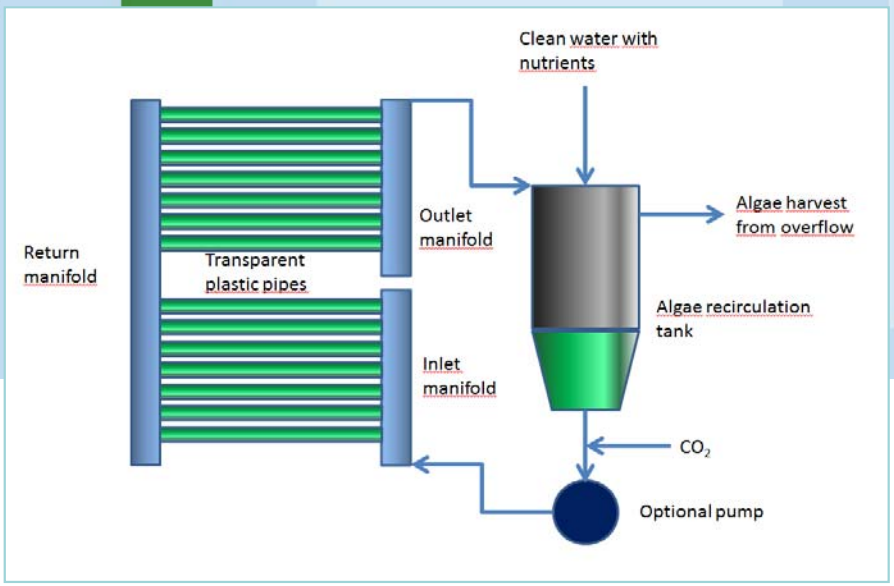
Biomass

Components of:

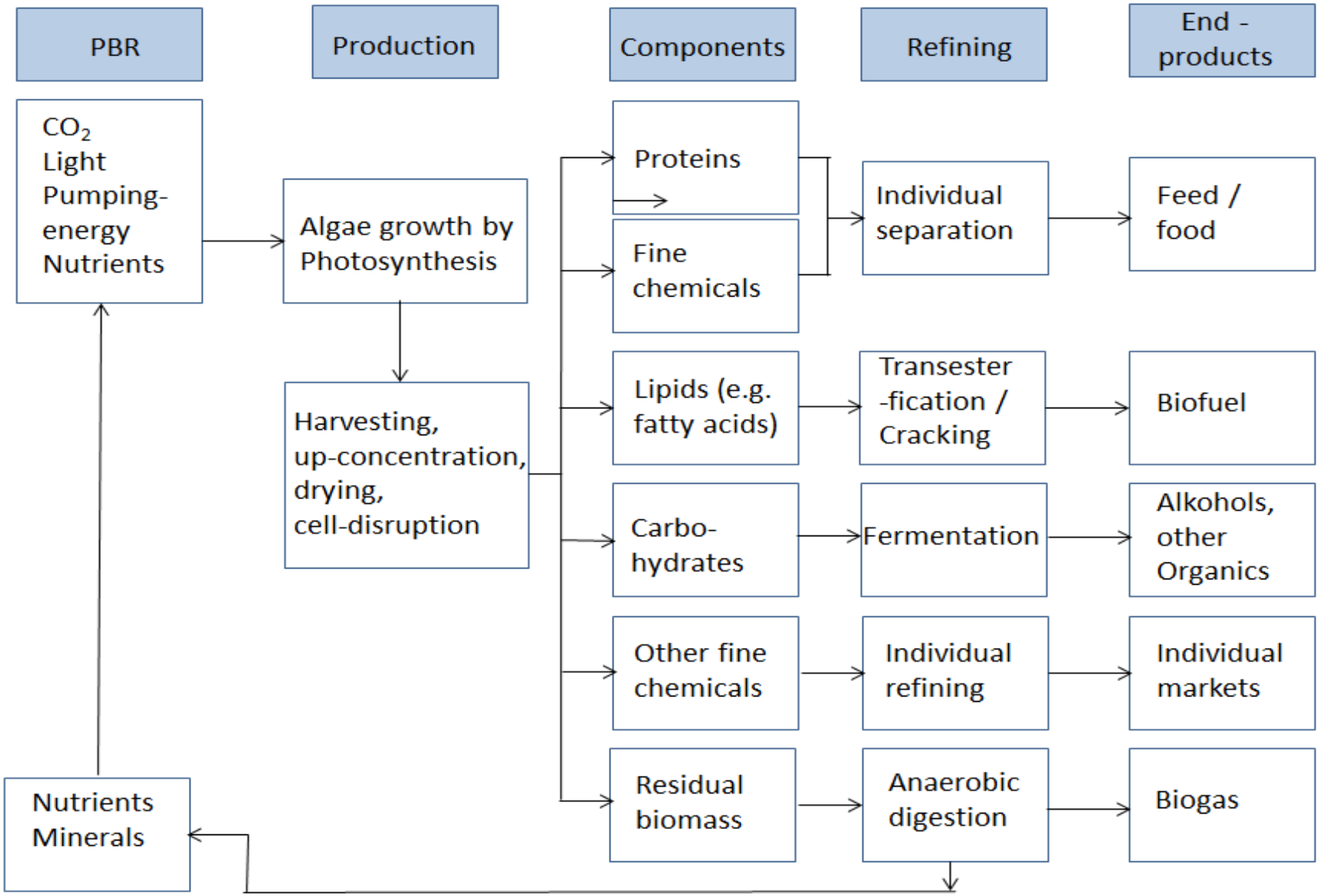
- Vitamins
- Oils
- Fatty acids
- Proteins
- Amino acids
- Dyes, pigments
- Polysaccharides

Algae Markets:

- Cosmetics
- Food
  - Food Supplements/ Nutraceuticals
  - Food Additives
  - Bulk Food Ingredients (Proteins, Lipids)
- Feed
  - Aquaculture
  - Feed Additives
- CO_2 -Sequestration & Fuels

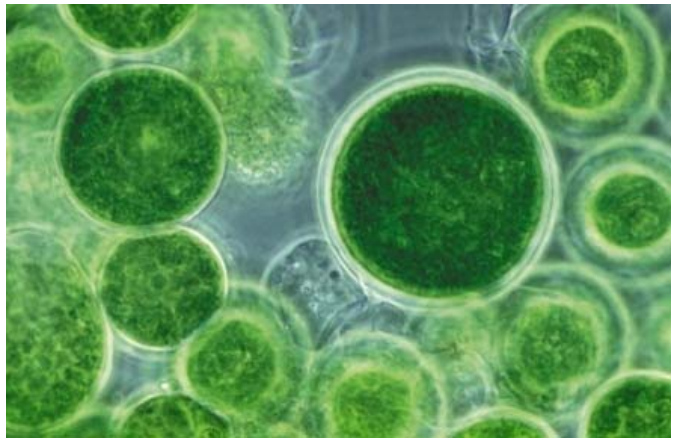


The supply - chain



Why Algae?

- Net-area productivity >> soil- based plants
- Option for microbiological tuning
- Efficient conversion of CO_2 into biomass
- > 50.000 species

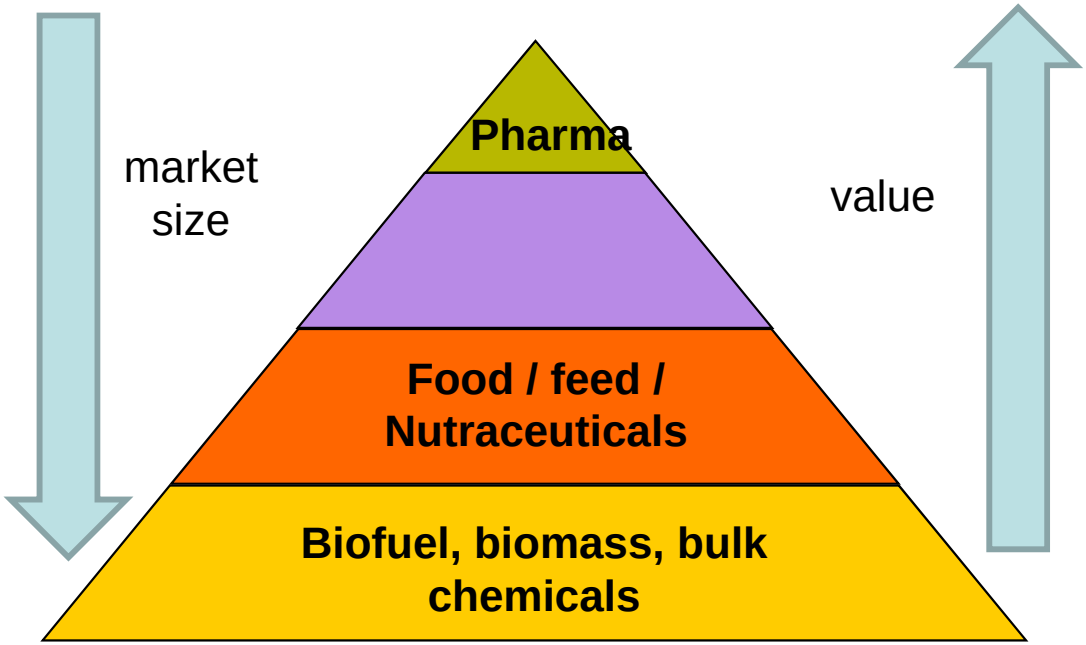


Component	Unit	Content per 100 g Algae Dry Mass		
		Spirulina	Chlorella	Dunaliella
Protein	g	57	67	35,4
Carbohydrates	g	24	1,1	29,7
Total fats	g	8	12,9	7
Beta Carotene	mg	0,34	119	8,800
Lutein	mg	0	503	97,6
Energy	kJ	1214	1600	1893
Fibers	g	4	8,7	0,4

Selection of strains according to individual need

Vieira, V.; Conference presentation; European Algae Biomass Sevilla, 2014

The current market for Algae:



- ~ 20 kt BDM/yr global production (~ 75% in China)
- Currently: Food / feed / health / cosmetics / pharma
- Emerging: Fertilizer, water-treatment, chemicals, fuels
- Estimated value 0,5 B€
- Strong differences regarding purity.

3 ways of commercial handling algae-based biomass:

Extracts

Pharma-Nutriceuticals
e.g. - β-Carotene
-Lutein
-Astaxanthine

Wet paste

Aqua-culture

Bio-drymass

Food / Feed

How to grow microalgae? Open ponds

- Currently 95% of commercial global algae production:

Beta-Carotene production from algae in 500 ha open ponds BASF/Cognis

- **Limitations:**
  - Water evaporation
  - Low efficiency
  - Contamination
  - No control of temperature
  - Photo inhibition
  - CO_2 loss
  - Low algae-concentrations
- **Advantage**
  - Cheap
  - Easy technology

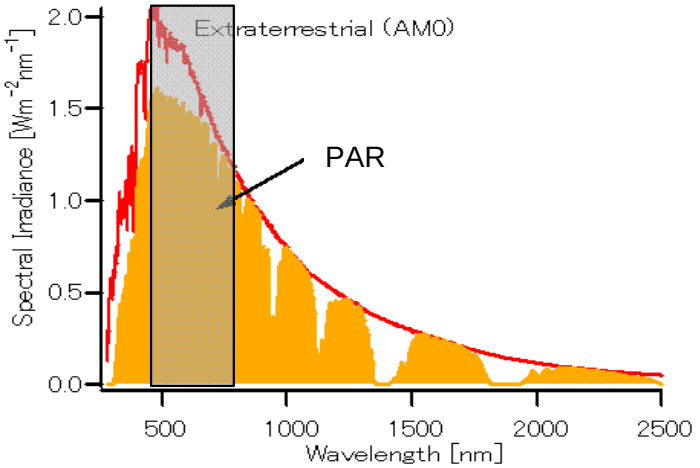
Alternative: Tubular closed Photobioreactors

- Increasing demand
- High potential for replacement of glass
- Advantages:
  - 3D possible
  - No contamination
  - High quality biomass
  - High efficiency, area productivity
  - Different designs

Request for: High quality, low energy consumption, affordable, long-lasting, efficient and robust PBR's

Decisive impact of the PBR-design

	W/m2	Tons / ha *yr
Global radiation	110	
PAR	50	
Theoretical Maximum	10	135
Practically achieved	5	68
Closed PBRs	1-3	14 - 40
Open ponds	1-2	14 - 27



Only < 5 % of the solar radiation energy can be transferred into energy stored in algae-based biodrymass (BDM)

Relevant features of transparent PVC-U for PBR – application

Optical properties

Variability of formulation

Thermoforming

Chemical resistance

Variable jointing

Thermo-mechanics

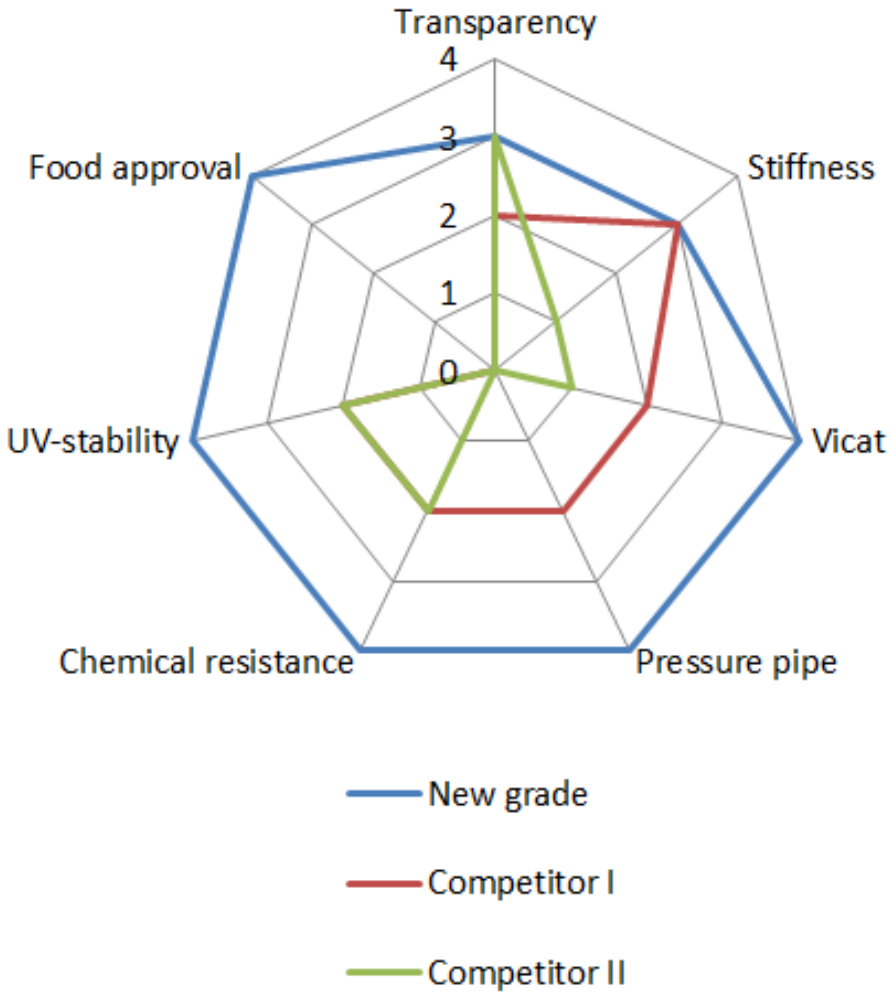
Low raw material price

DEKADUR G “Algae”-

Well-balanced transparent PVC-U components for tubular PBR

Advantages:

- Complies with DIN 8061/62 up to T=40°C → Easy dimensioning
- No acrylic modifiers, high MW, high Chlorine-content → Best chemical resistance
- Option for “very thin-walled” pipe → very low system-costs
- Outstanding optical quality and UV-protection
- One material grade for all components



Transparent PVC-U – One material grade for the entire “light-part” of a tubular PBR

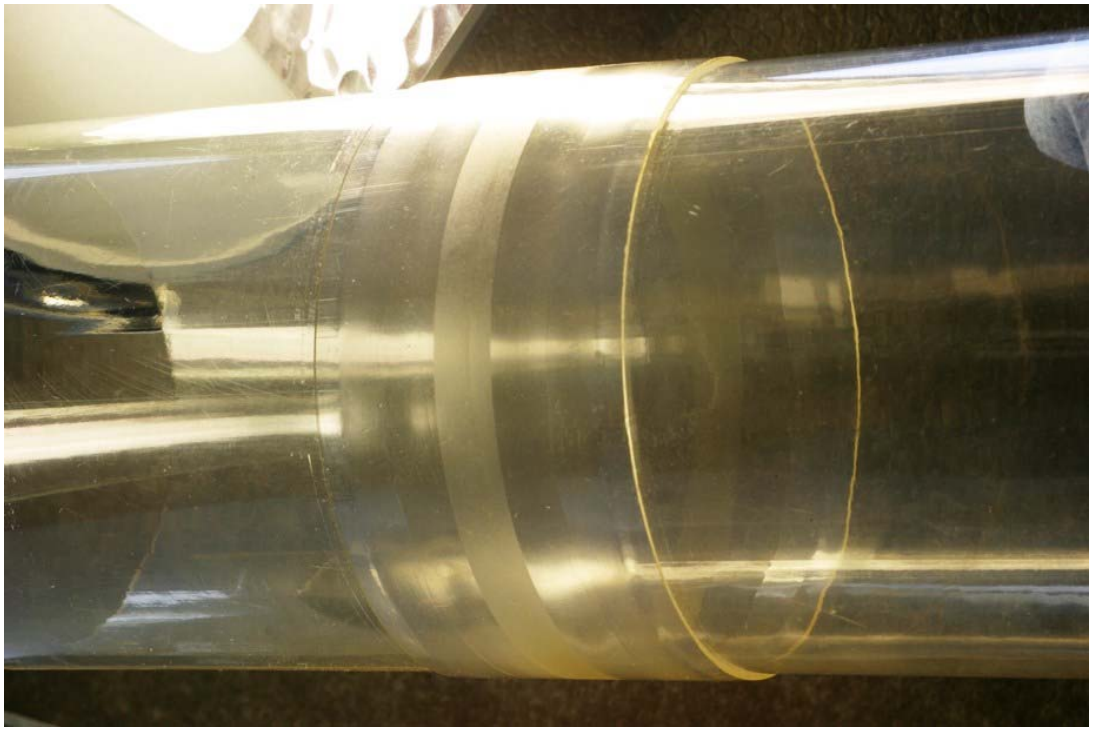
Variable jointing transparent PVC-U for PBR

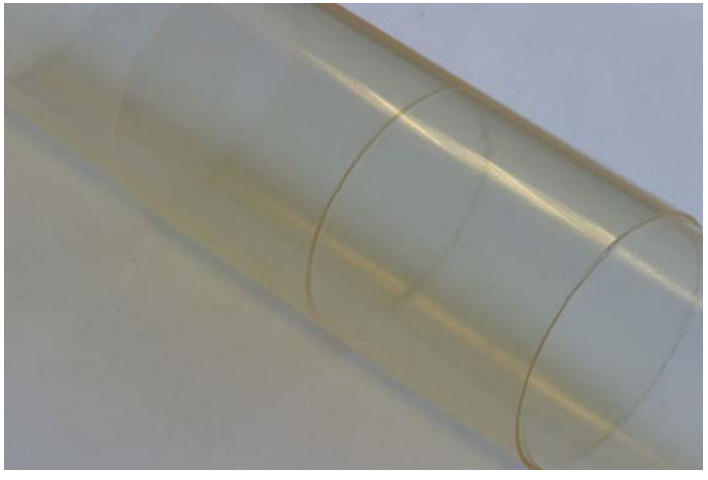
- Different levels of purity require different jointing - approaches
- Well-balanced and variable concept of cost vs. performance
- Can be adapted to any PBR-technology

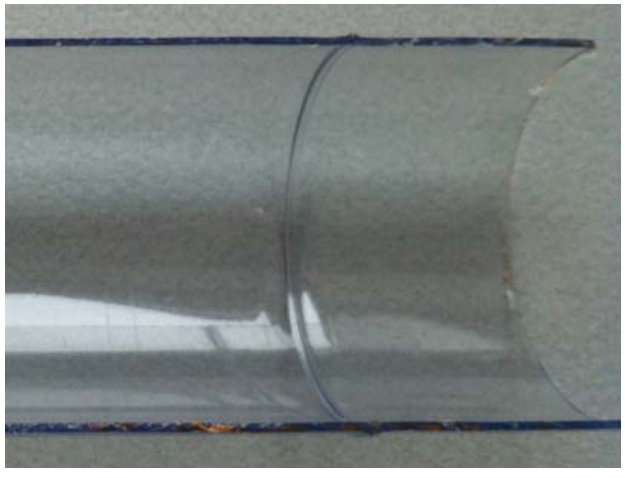
Concept	Advantage
Socket pipe	Easy, cheap, can be made up at site
Twin socket	Easy; fast installation, high-quality joint
Butt fusion welding	Easy; good for thicker walled pipe
IR welding	Reduced dead-zones; innovative
BCF welding	No dead-zones; ideal for (very) thin walled pipe
Clamping / flanging	Reversible jointing / universal jointing

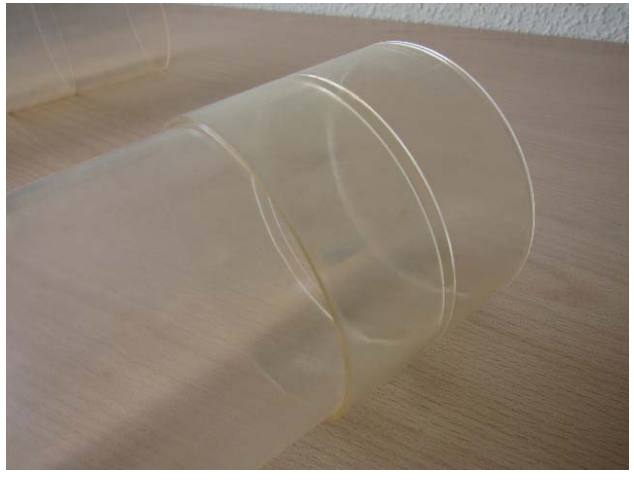
Innovative BCF-welding of transparent PVC-U

- Dead-zone-free welding of transparent PVC-U pipes with 0,5 mm wall-thickness
- Allows highest quality jointing of transparent PVC-U
- Strong argument in favour of PVC-U vs. glass



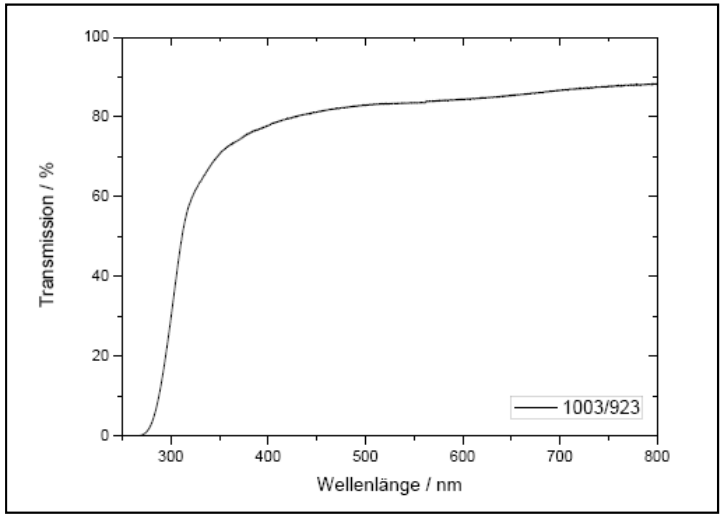


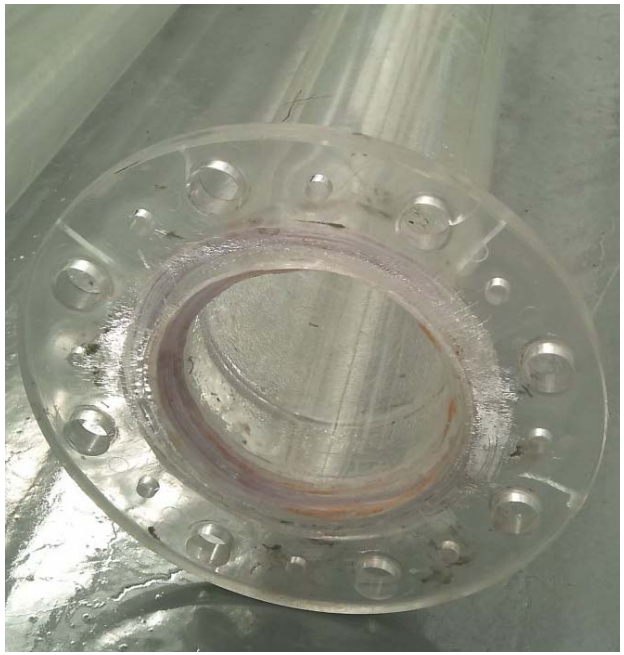




Actual assessment of transparent PVC-U for PBR's

- Important factor for system-cost reduction
- Customized PBR-pipes as technology-step
- Strong support to open doors for entering the food- / feed market and gain market shares for tubular PBR
- High interest for replacement of PMMA
- Huge potential for further system improvement
- Affordable further improvement of UV-resistance in progress
- Ideal material for thin-walled technology

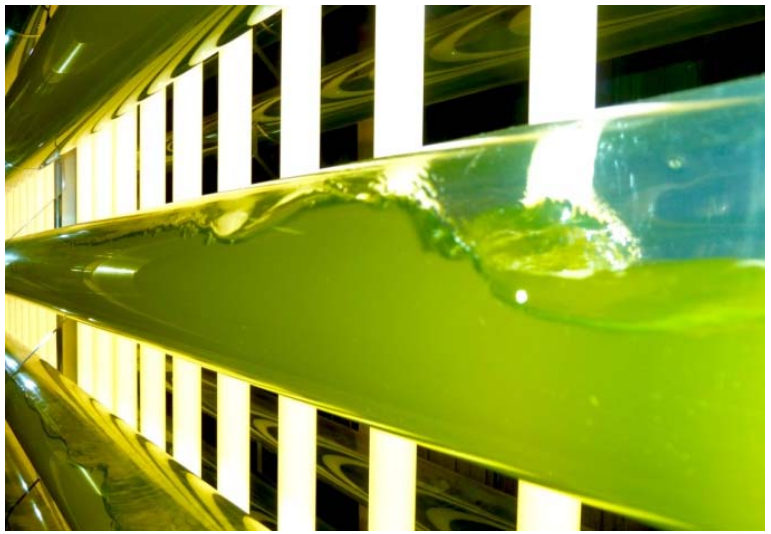




A new process technology for PBR

Features:

- No fouling on the inside of the reactor
- No growth-inhibition due to locally excessive amounts of oxygen
- Very large tube-length possible / unlimited upscaling
- Low energy use
- Thin-walled tubes with easy couplings
- Smart and easy process-steering
- CIP possible / low downtimes
- Maximum use of available light.



Bubble-Brush™-Technology

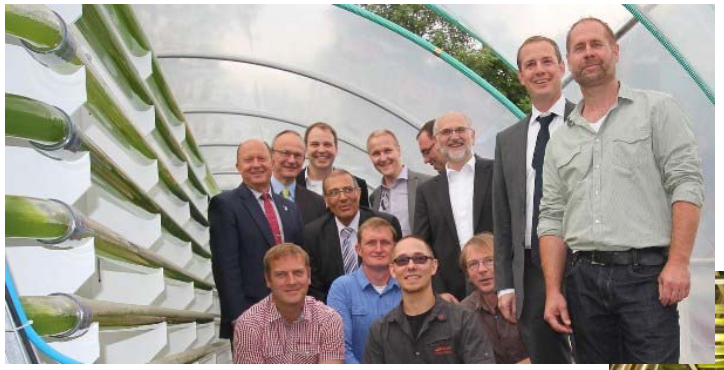
- 18.000 l volume; > 6 km 63 x 0,5 mm transparent PVC-U
- 130 m x 2 length

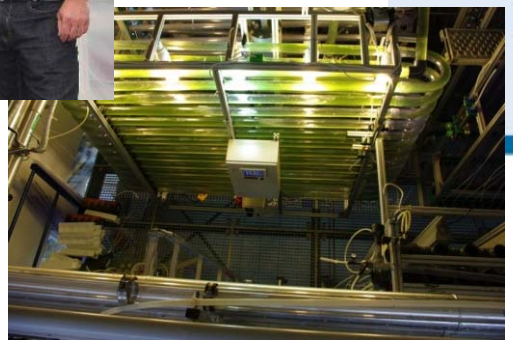
A new process technology for PBR / Custom made possible

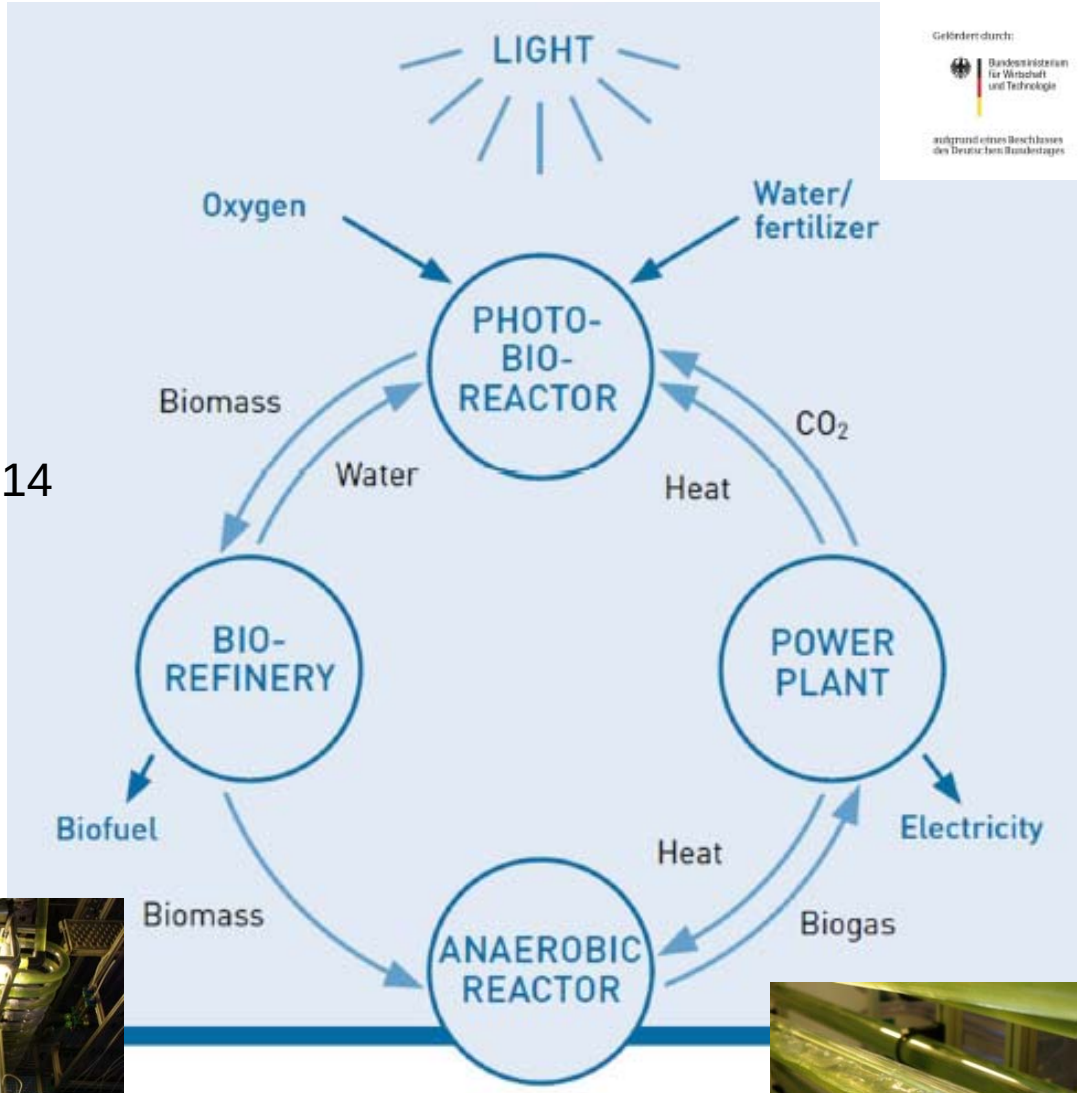
- Customized versions of GemTube reactors ready for research and production

Application : Biophotonic combined energy system

- Important potential key application for the algae-technology
- Feasibility shown over 2 years using a 250 l reactor
- Additional second PBR-system built in 2 /2013
- Upscaling and field-testing launched in 5/2014
- Increasing public interest

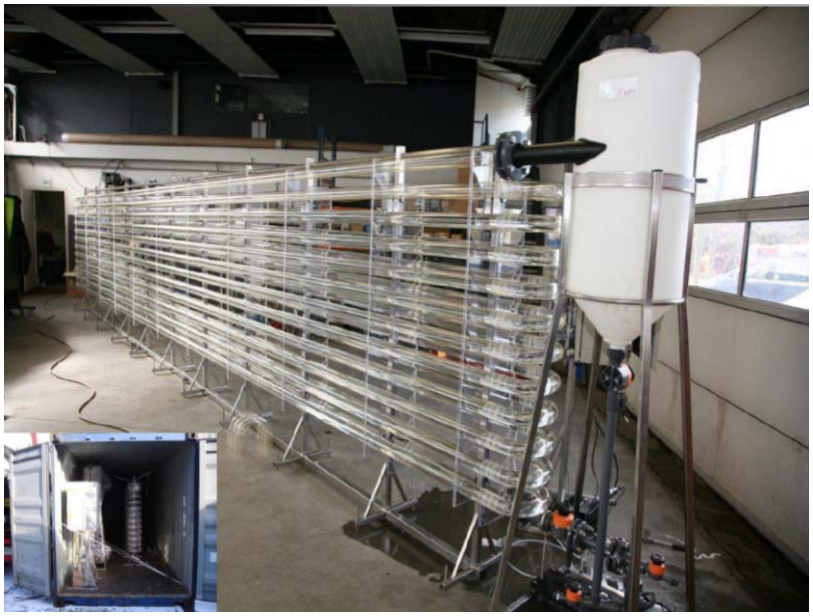






Commercialization “Generation One”

Geneva, Villes et Champs 2014



Synthetic Genomics (USA) / 3 - 2013

Case study: Solar Biofuels Research Center; Queensland; Australia

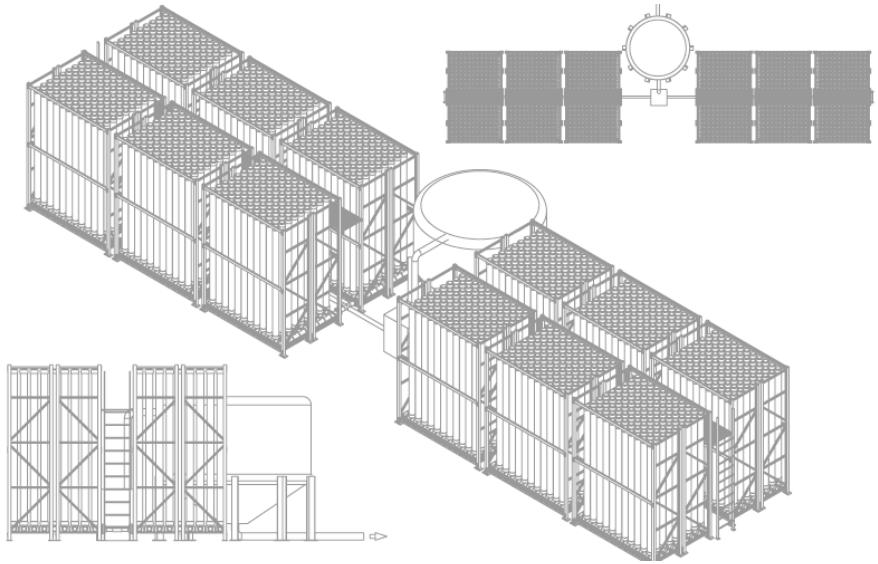
Segments

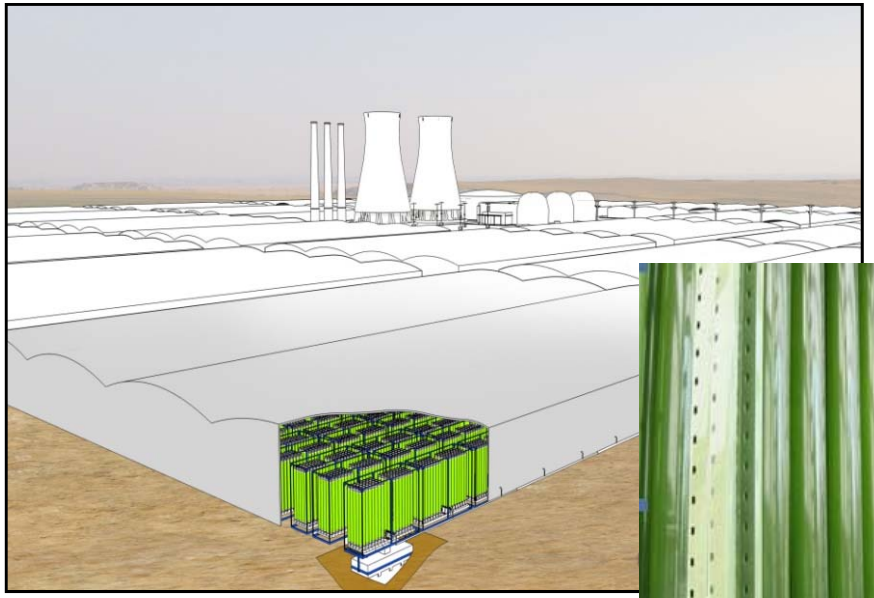
Green Technology

- Installation of two reactors with capacity of 1000 l as demonstration-unit
- Project aim: Optimizing the growth conditions for algae cultivation under real-life- conditions
- Bends, pipes, sockets: GF DEKA made
- Cooperation KIT Karlsruhe, Queensland University Neste Oil, Siemens, KBR, Australia Cement; Quantas
- Start: March 2013

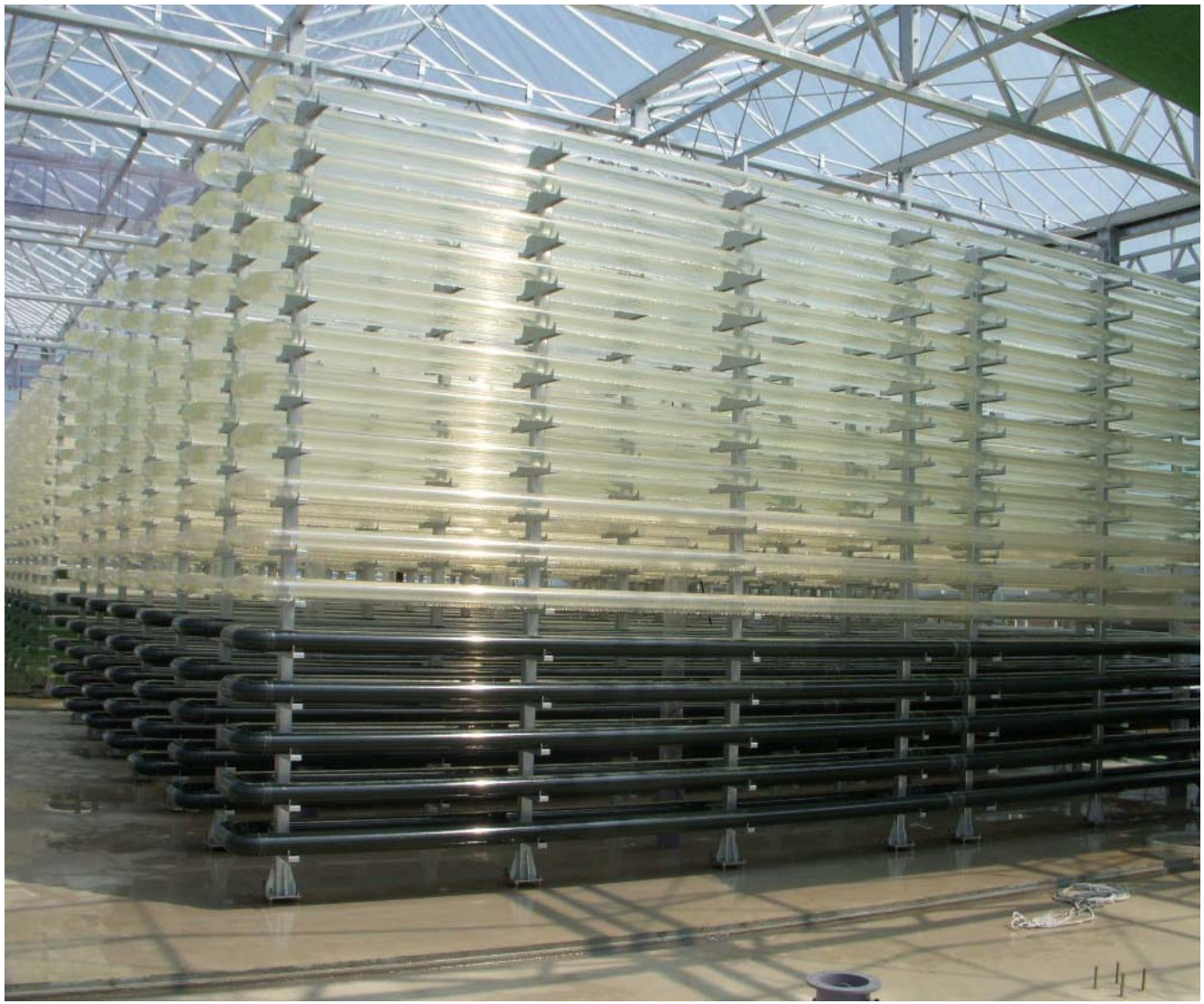
Alternative PBR-designs in transparent PVC

- General interest from other technology-owners in high-quality transparent PVC-U
- Same basic requirements for the formulation
- Strong request for optimized and long-lasting UV-protection





Alternative PBR-designs – “DEKADUR G Algae” transparent PVC



- GF DEKA made DEKADUR G “Algae pipe“ based PBR-plant; start in May 2013
- Commercial production of algae for hatcheries
- **20 km** of OD 110 mm PBR-pipe; **> 3000** bends

Thomas More Institute/Vito (Belgium)

- FP 7 – EU-funded project; 26 European partners
- Launched in 11/ 2013; duration 4 years
- Focus on “Recycling of media”
- Complete supply-chain optimization
- Semi-commercial scale (4000 l)

What are the trends in Algae-technology based on tubular PBR?

R & D	Commericalisation
• Go cheaper, gain efficiency • Development of outdoor-PBR • Smart harvesting • Modify strains • Think in circles • Integral use of BDM • Use algae as “tool”	• Upscaling, concept-testing, gain market-share • Out of the lab • Aquaculture • “Ceuticals”, WT, (fuel) • Request for high-quality BDM • Transparent PVC-U to replace glass / PMMA • Food approval, legal requirements • Chance for investors

Conclusion

- Algae cultivation is already established as THE key-technology for economic biomass-production and CO_2-capture
- The algae-technology has tremendous chances to gain significant influence on food, feed, (fuel) and for chemicals productions
- Algae-based biomass is already produced on large scale globally; “generation II” for polymer-based PBR ongoing
- Increasing interest in tubular PBR; ideal chances for transparent PVC-U for greenhouse-cultivation of algae
- Very dynamic technology
- PVC-U contributes significantly to establish the algae technology in large-scale.

Thank you all !!!

Special thanks to:

- **You** – for your attention
- SolVin – for granting the award
- LGEM – for mutual trust
- Our partners and the team spirit
- Our customers for being open to new technologies
- All GF colleagues contributing globally in many different ways
- Esp. the team at GF DEKA and GF NL
- Philipp Ruf and Jörg Wermelinger for elaboration of the BCF / IR welding parameters for transparent PVC-U