Fotosintetica & Microbiologica S.r.l.

Spin-off dell'Università degli Studi di Firenze

Large scale algae cultures: opportunities and limitations of artificial light

Fotosintetica & Microbiologica S.r.l.

AQUAFARM
Pordenone
19-20 Febbraio 2020

UNIVERSITÀ DEGLI STUDI FIRENZE
SPIN-OFF PARTECIPATO

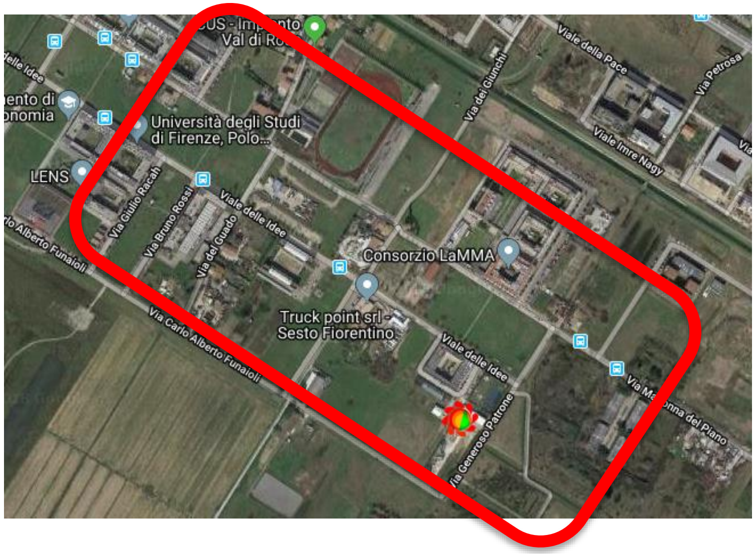
AQUAFARM

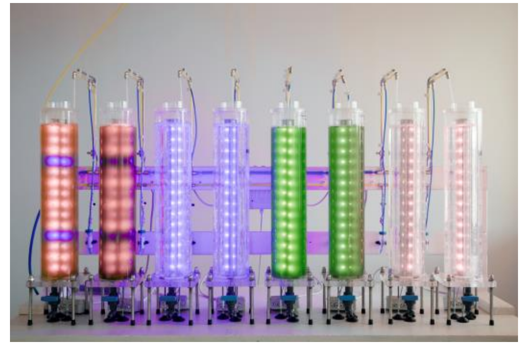
OUR HISTORY

Fotosintetica & Microbiologica S.r.l. (F&M) is a biotechnology company with more than 35 years of studies in algae cultivation and characterization.

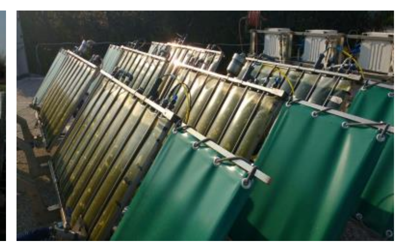
F&M was **founded** in **2004** to capitalize and improve the know-how on microalgae physiology and mass cultivation developed since 1980 by a research group coordinated by Prof. Mario Tredici.

COMPANY LOCATION





- INDOOR & OUTDOOR CULTIVATION SYSTEMS FROM 6 to 3000 L
- EQUIPPED WITH TEMPERATURE, pH, pO2 and REMOTE CONTROL ALARM.
- UPS & DPS: filters, centrifuges.



LABORATORIES






SERVICES & PRODUCTS

- ✓ REACTORS & PONDS PROVIDER
- ✓ R&D CONTRACT SERVICE
- ✓ CONSULTANCY
- ✓ ALGAE COLLECTION
- ✓ ENGINEERING
- ✓ TRAINING

MICROALGAE BUSINESS SECTOR IN EU

Europe has a long pioneering tradition in algae related knowledge development and innovation

- MICROALGAE *EU* MARKET VALUE > 700 M€ (Biomass +extracts + Services + R&D)
- EMPLOYED > 10.000 PEOPLE (Research & Production).
- +430 COMPANIES @ 2017 (Producers, Technology Suppliers, R&D)
- HIGH *TURN-OVER RATE*: Several companies open and several close every year.
- TOTAL BIOMASS PRODUCTION ~ 500 Ton. D.W/year

MICROALGAE PRODUCTS AND MARKETS

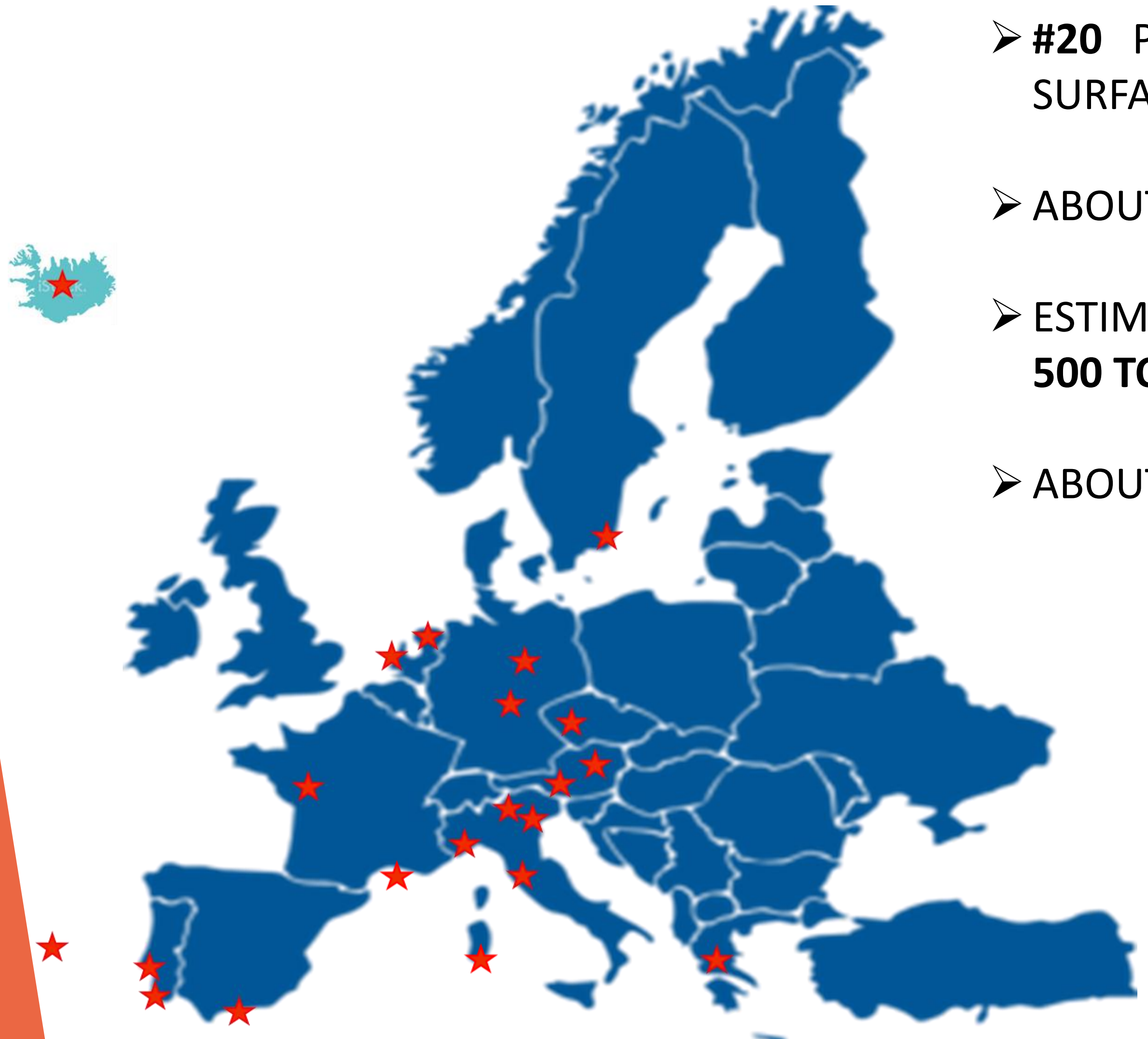
Products from microalgae have currently only three possible forms:

	PASTE	DRIED	EXTRACTS
Mostly for:	**Aquaculture**	**Food & Feed**	**Ceuticals**
	Usually from 5 to 15% d.w	Spray- dried, freeze-dried or sun-dried	Solvents, super-critically or just with mechanical processes

European companies provide all kinds of products !

Adapted from V. Verdelho 2016

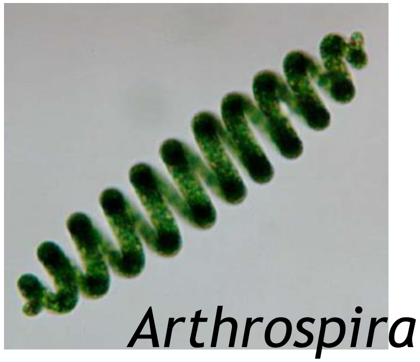
ALGAE FACILITIES EU SITUATION @ 2019

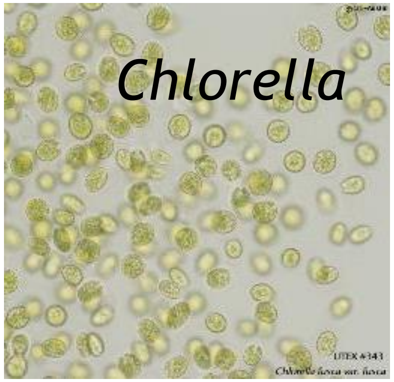


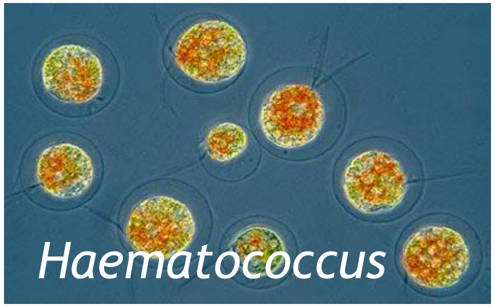
- **#20** PRODUCTION PLANTS > 0.1 HA SURFACE
- ABOUT **30 HA** TOTAL SURFACE
- ESTIMATED PRODUCTION CAPACITY: **500 TON/YEAR**
- ABOUT **#15** SPECIES CULTIVATED

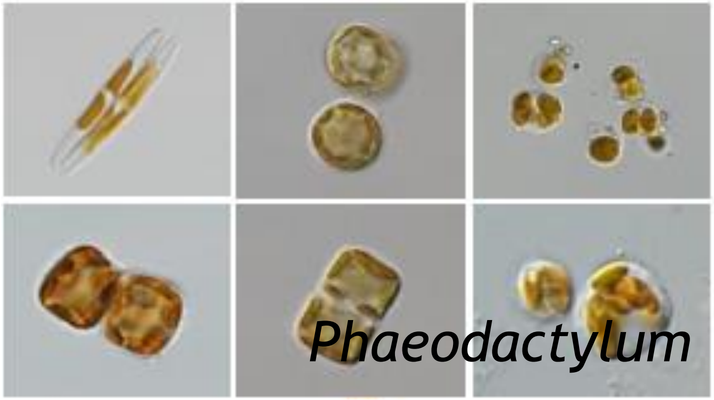
- 100 SMALL SPIRULINA PRODUCERS
- 1 Kg /m^2/year

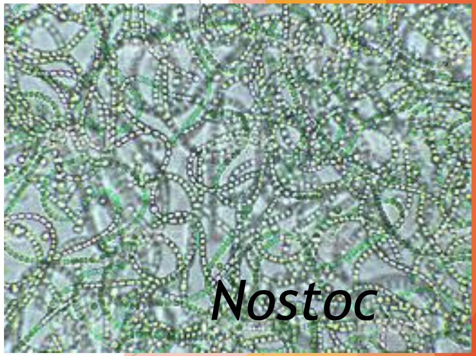
Despite thousands of existing species, world microalgae biomass production with no more than 15 species











WHY?

CHALLENGES:

A. POLICY & REGULATION:

i. Novel Food (Reg. 2283/2015)

ii. EU Fertilizing products (Reg. 1009/2019)

iii. Lack of Standards (CEN TC454)

B. OUTDOOR MICROALGAL CULTURE ARE COMPLEX SYSTEM REQUIRING HIGH CAPEX (> 2.5 M€/ha)

i. Mixing

ii. Temperature

iii. Irradiance

iv. Oxygen build-up

v. Harvesting & drying

vi. Carbon Dioxide

vii. Fertilizers

C. BIOLOGICAL LIMITATIONS:

i. Contamination (grazers, fungi, bacteria, virus & other algae)

D. ENVIROMENTAL LIMITATIONS FOR OUTDOOR CULTURES:

i. Rely on disperse source of energy (solar radiation) → Low Power Density (< 2 kW/m2)

ii. Hourly, daily and monthly variations of PPFD.

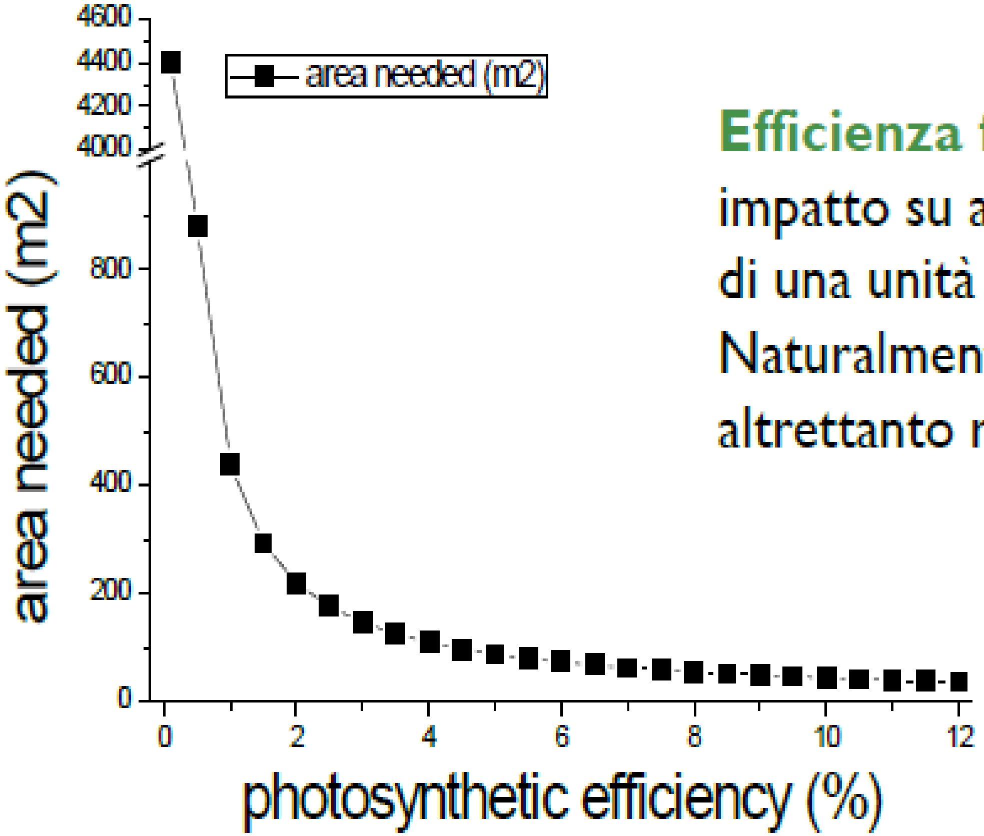
LOW PHOTOSYNTHETIC EFFICIENCY OF OUTDOOR ALGAE CULTURES
<3 %

ALGAE OUTDOOR EFFICIENCIES

- 100% — Total solar radiation at sea Level
- 45 % — Suitable radiation (PAR)
- 27 % — Maximum PE on PAR
- 12 % — Maximum PE on total solar radiation
- 2.5% — Maximum PE under real outdoor conditions
- 1.5% — Actual best average in commercial plants

A PE of 1.5% with an average solar radiation of 20 MJ m^{-2} d^{-1}

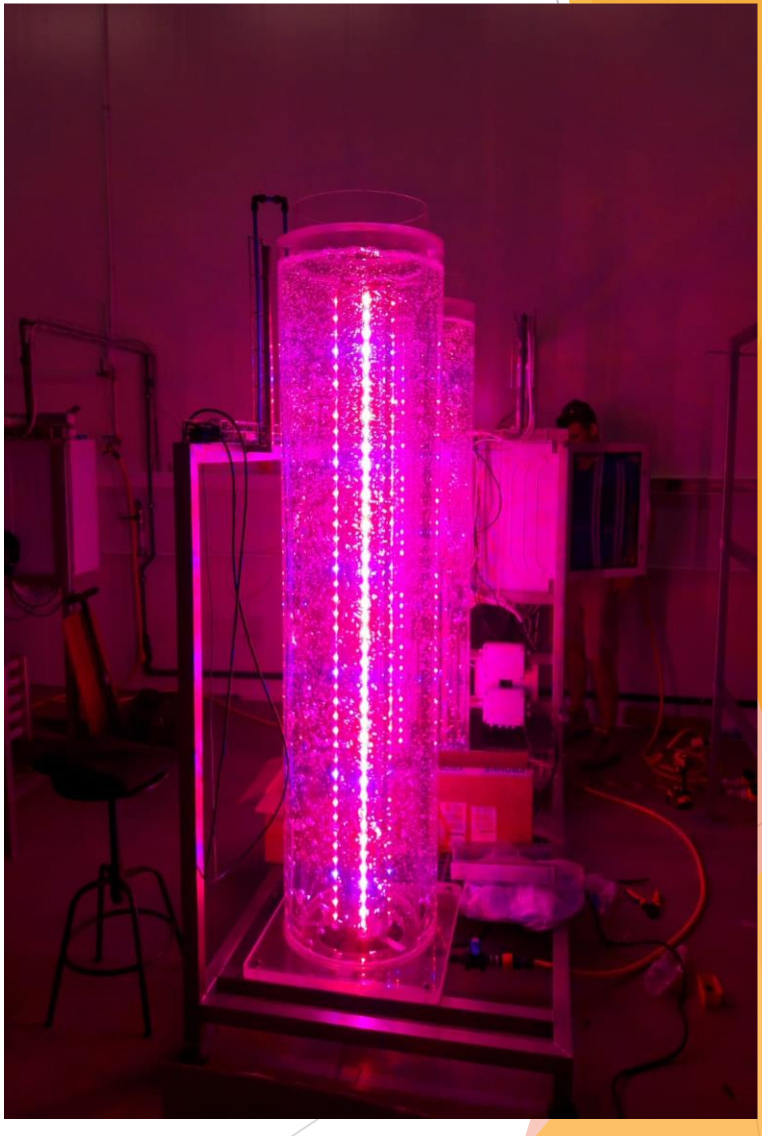
15 g m^{-2} d^{-1} ~ **55 t ha^{-1} $year^{-1}$**



Efficienza fotosintetica ha enorme impatto su area necessaria per la produzione di una unità di biomassa.
Naturalmente questo ha un impatto altrettanto rilevante sui costi di produzione.

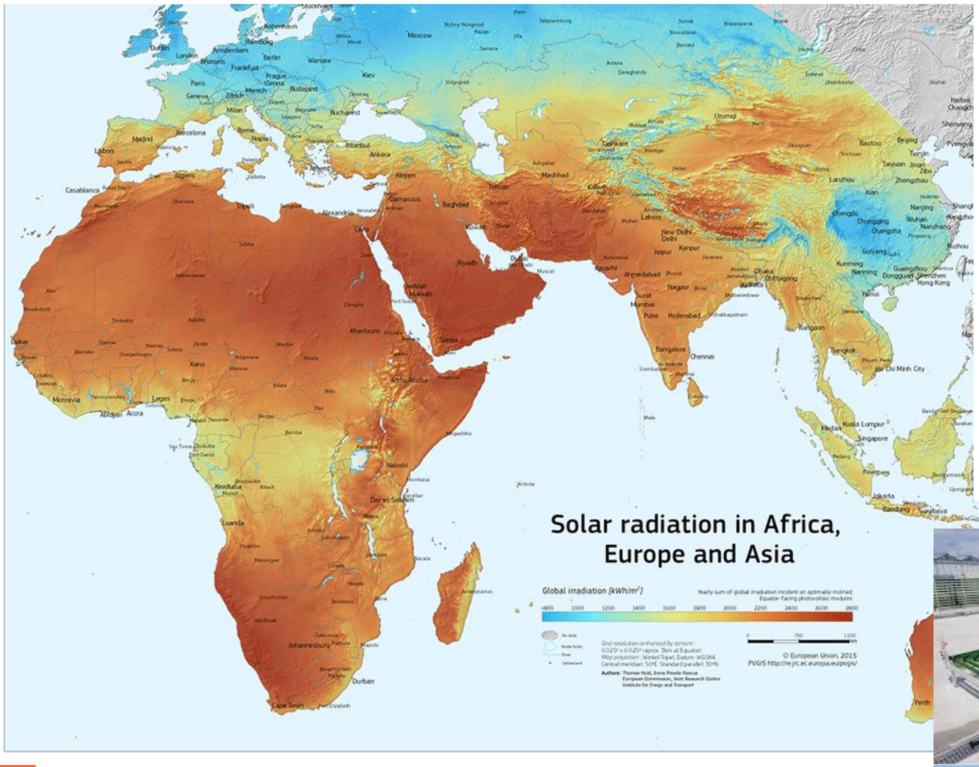
From F. Bezzo 2017

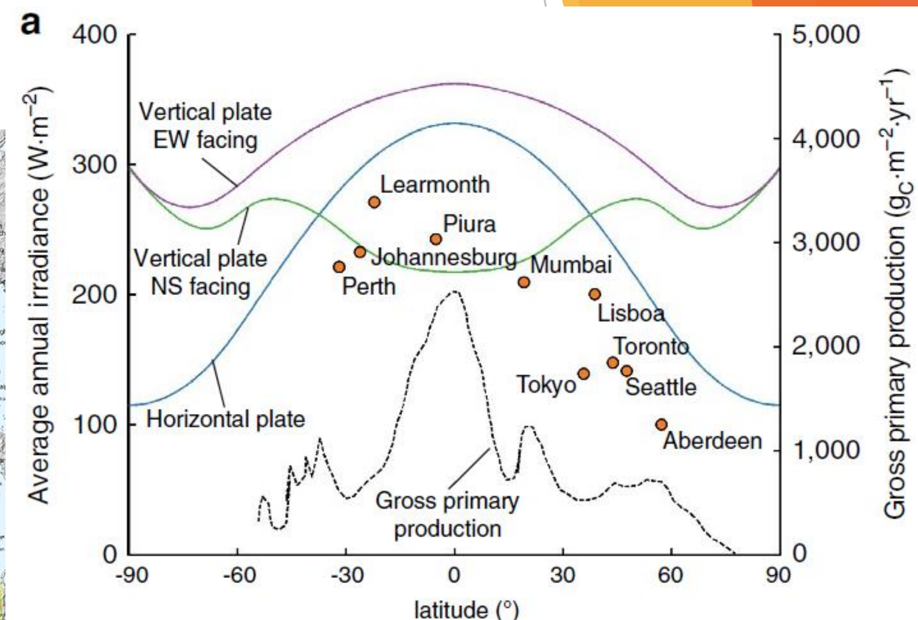
CAN ARTIFICIAL LIGHT CAN SOLVE THE PROBLEM ?



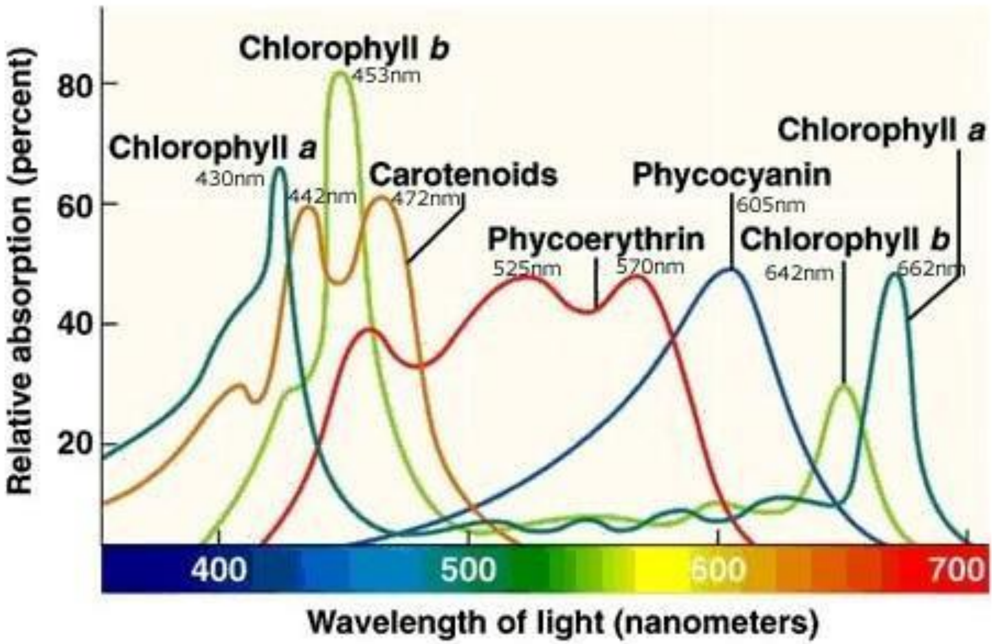
ADVANTAGES

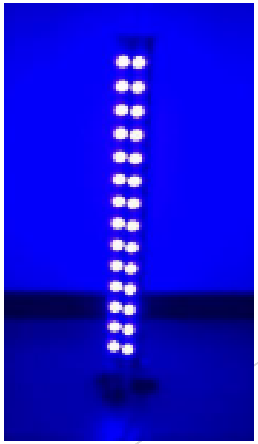
1. Independent from weather, location and reactor design

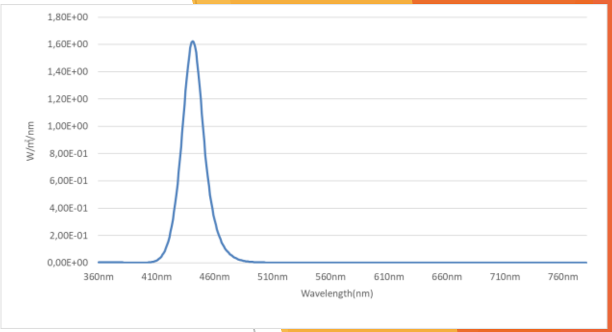


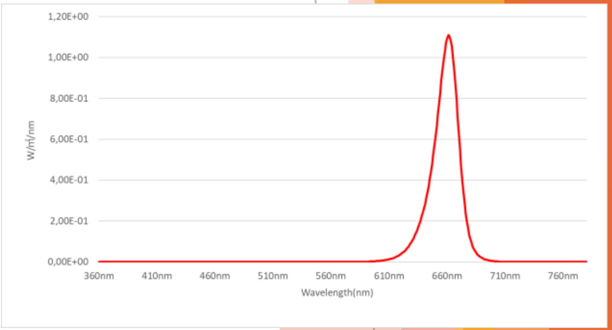


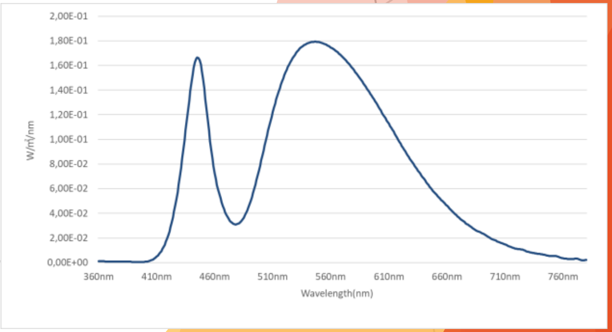
2. Optimized spectra



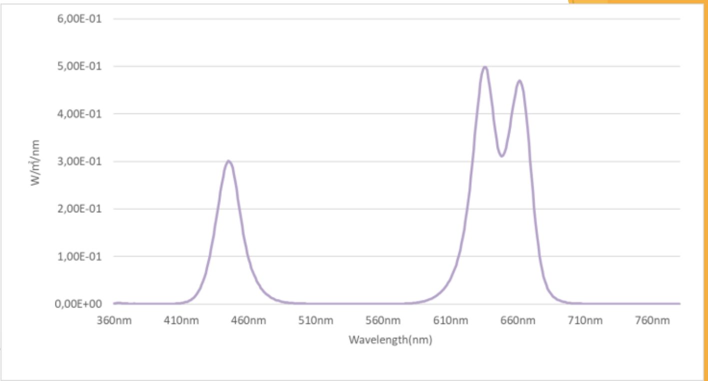


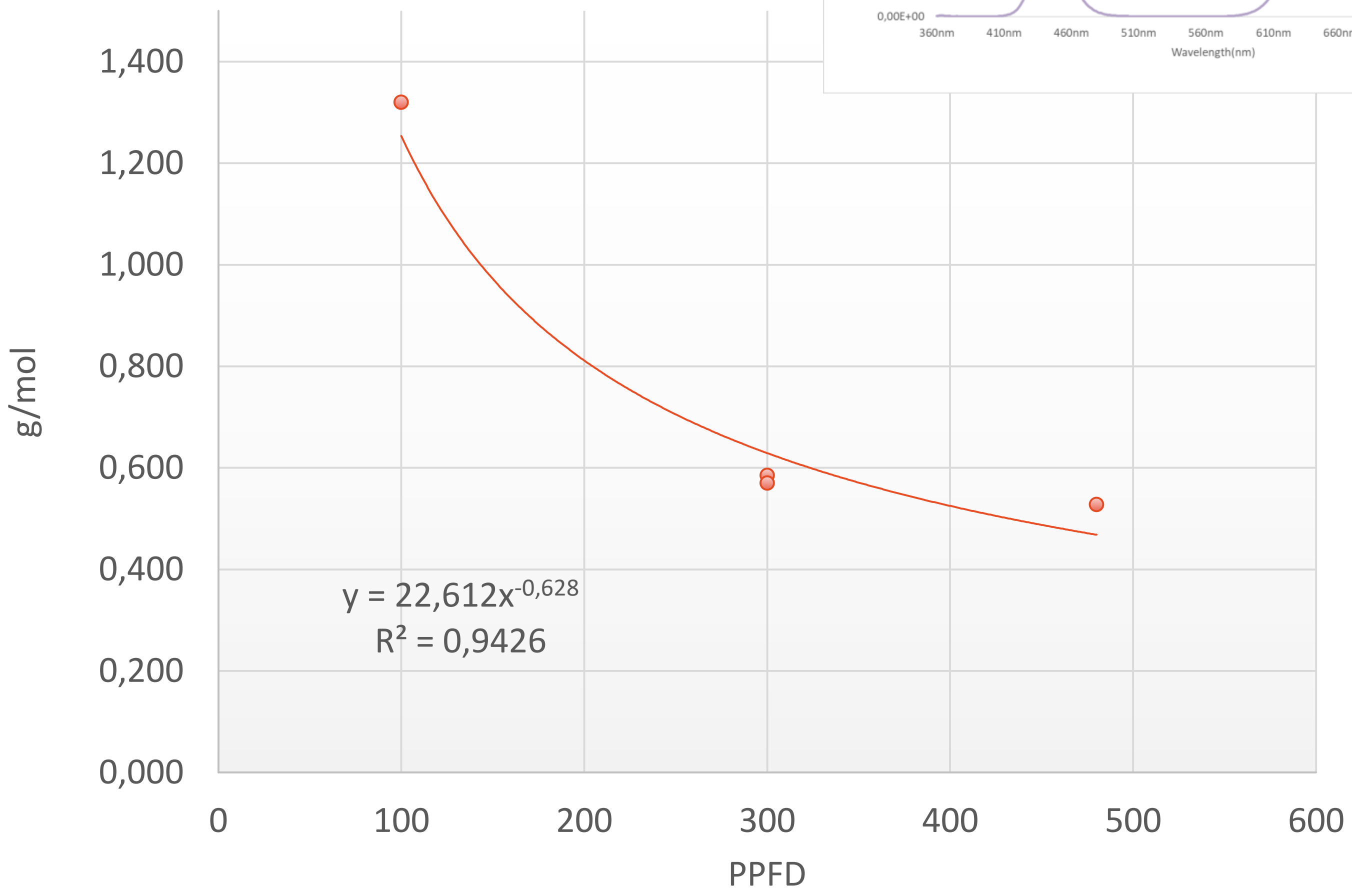






2. Optimized PPFD





PE of *A.platensis* F&M-C252 cultivated in 120 L F&M-AC reactors with purple spectra

4. Possibility to adjust biomass composition

ARTICLE

BIOTECHNOLOGY BIOENGINEERING

Growth, Photosynthetic Efficiency, and Biochemical Composition of *Tetraselmis suecica* F&M-M33 Grown With LEDs of Different Colors

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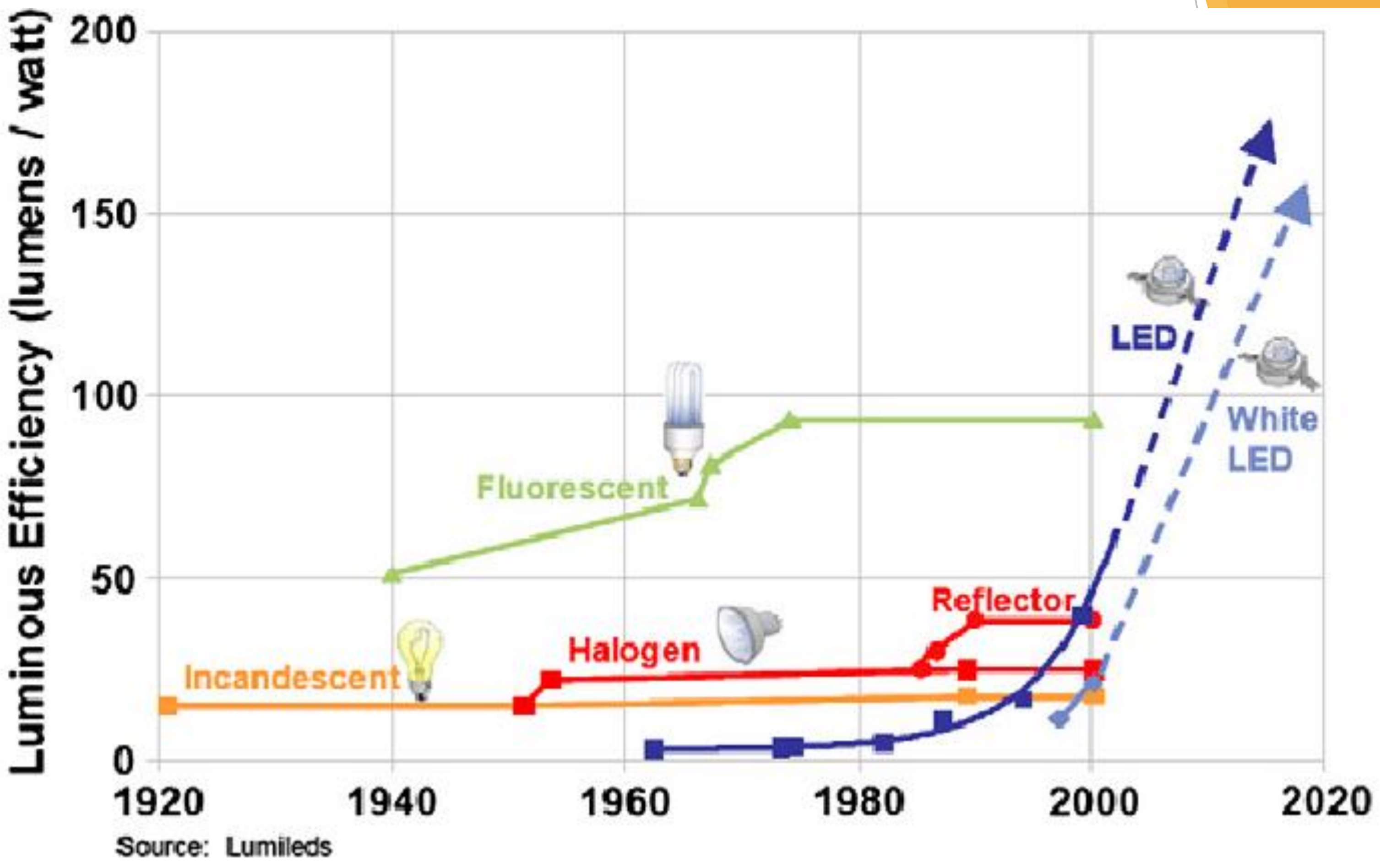
Table III. Fatty acid composition (% of total fatty acids) and total fatty acids content of *Tetraselmis suecica* F&M-M33 grown with different light colors.

	White	Red	Blue	Green
C14:0	0.49 ± 0.13	nd	nd	nd
C16:0	16.39 ± 1.09	20.71 ± 0.19[a]	21.88 ± 0.18[a]	21.19 ± 0.54[a]
C16:1 n9	5.31 ± 0.12	3.87 ± 0.07	6.32 ± 0.07	6.82 ± 0.17
C16:2 n6	0.87 ± 0.06	nd	nd	nd
C16:3 n3	3.93 ± 0.15[a]	4.03 ± 0.12[a]	4.68 ± 0.43[a]	2.94 ± 0.07
C18:1 n9	16.13 ± 0.56[a]	14.06 ± 1.72[a]	26.78 ± 0.14	25.40 ± 0.65
C18:1 n7	4.45 ± 0.04[a]	3.18 ± 0.24	4.05 ± 0.08[a]	5.34 ± 0.14
C16:4	12.68 ± 0.37[a]	12.44 ± 1.31[a]	7.17 ± 0.22	9.85 ± 1.03
C18:2 n6	7.57 ± 0.11	5.89 ± 0.36	8.78 ± 0.73	5.33 ± 0.14
C18:3 n3	20.07 ± 0.02	15.66 ± 1.98[a,b]	14.75 ± 0.21[a]	13.52 ± 0.35[b]
C18:4 n3	6.40 ± 0.23[a]	11.19 ± 1.34	2.99 ± 0.38	6.18 ± 0.16[a]
C20:4 n6	1.48 ± 0.05	1.88 ± 0.33	nd	nd
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total saturated	16.88 ± 0.22	20.71 ± 0.19[a]	21.88 ± 0.41[a]	21.19 ± 0.54[a]
Total monounsaturated	25.89 ± 0.57	21.11 ± 1.90	37.15 ± 0.76[a]	37.56 ± 0.96[a]
Total polyunsaturated	57.23 ± 0.39[a]	58.17 ± 2.08[a]	40.97 ± 0.62[b]	42.10 ± 0.48[b]
Total fatty acids (% dry biomass)	5.69 ± 0.21	4.74 ± 0.25	7.41 ± 0.42[a]	6.65 ± 0.50[a]

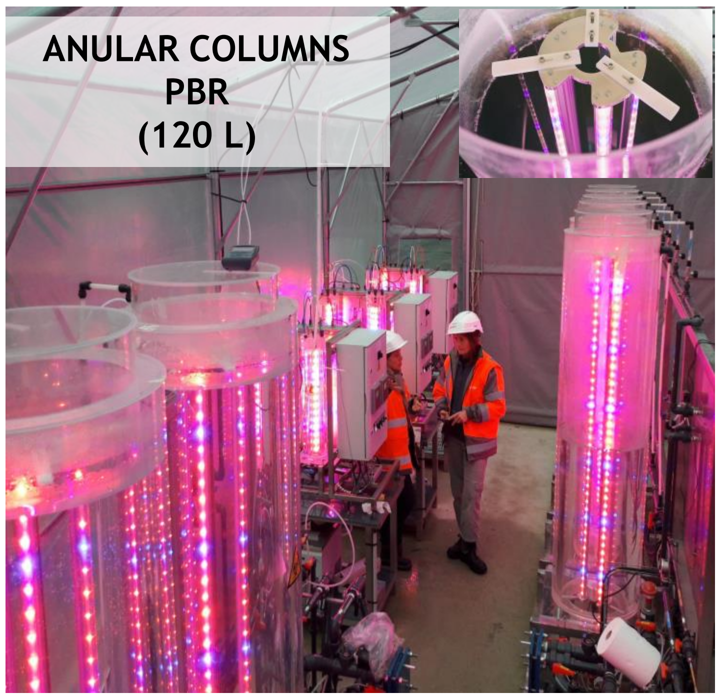
5. Technology improvements

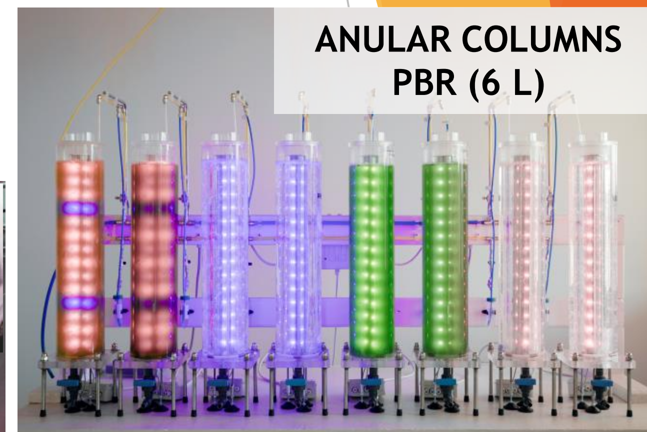


In 1996, LED luminous efficacy was about 5 lm/W. Today we are approaching to 200 lm/W

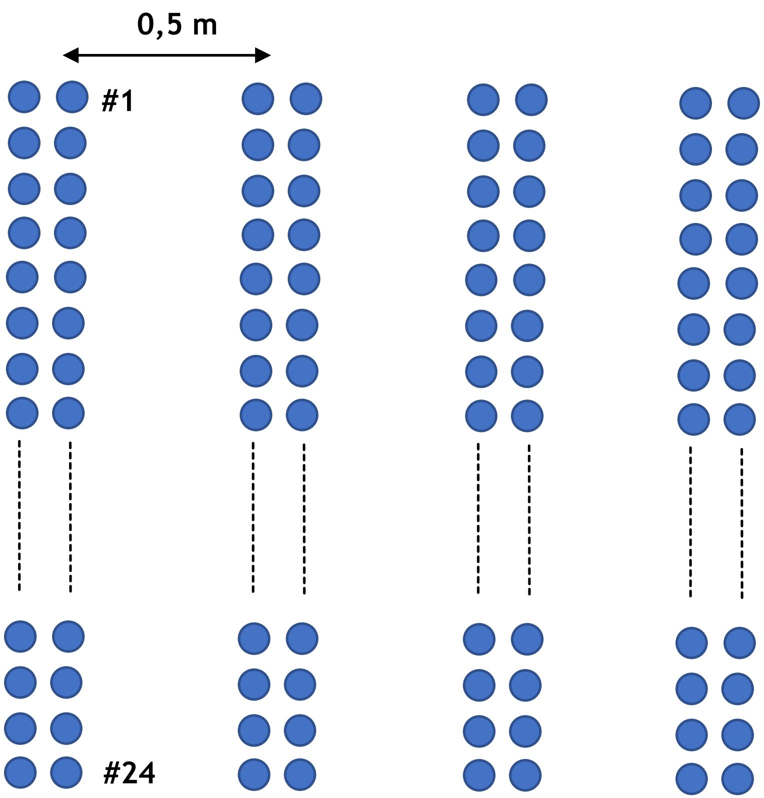
F&M / C-LED RESEARCH COLLABORATION

MAIN GOAL: to develop the best LED for Algae cultivation





LEDs to solve algae limitations…



In an equivalent space of about 600 m^2 in a warehouse

0,6 g biomass/mol. photons with Spirulina @ 300 PPFD

55 Ton./dry biomass yr.

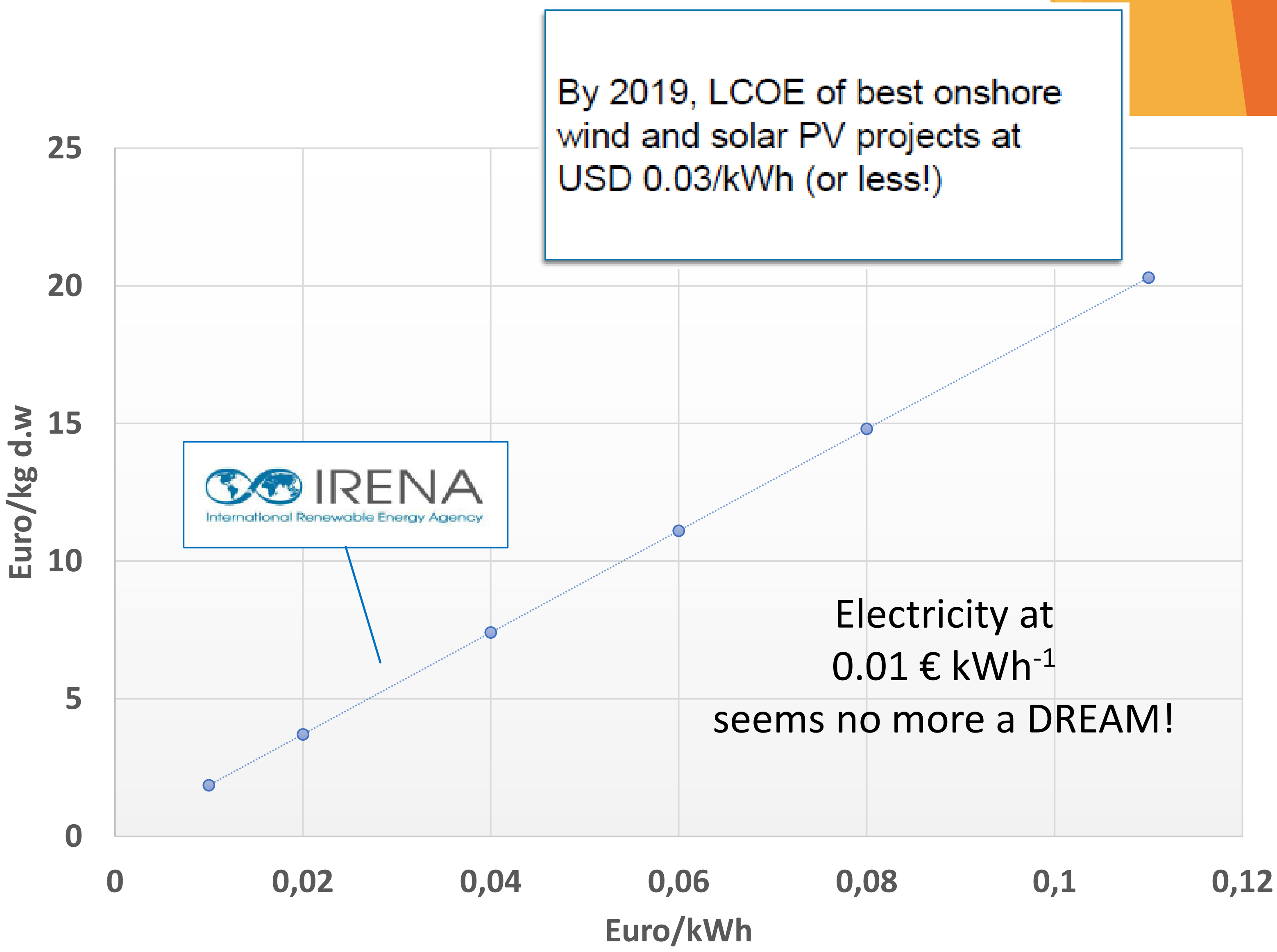
5.8 % PE

WHAT ABOUT THE PRODUCTION COST ?

2019

0.1 €/kWh

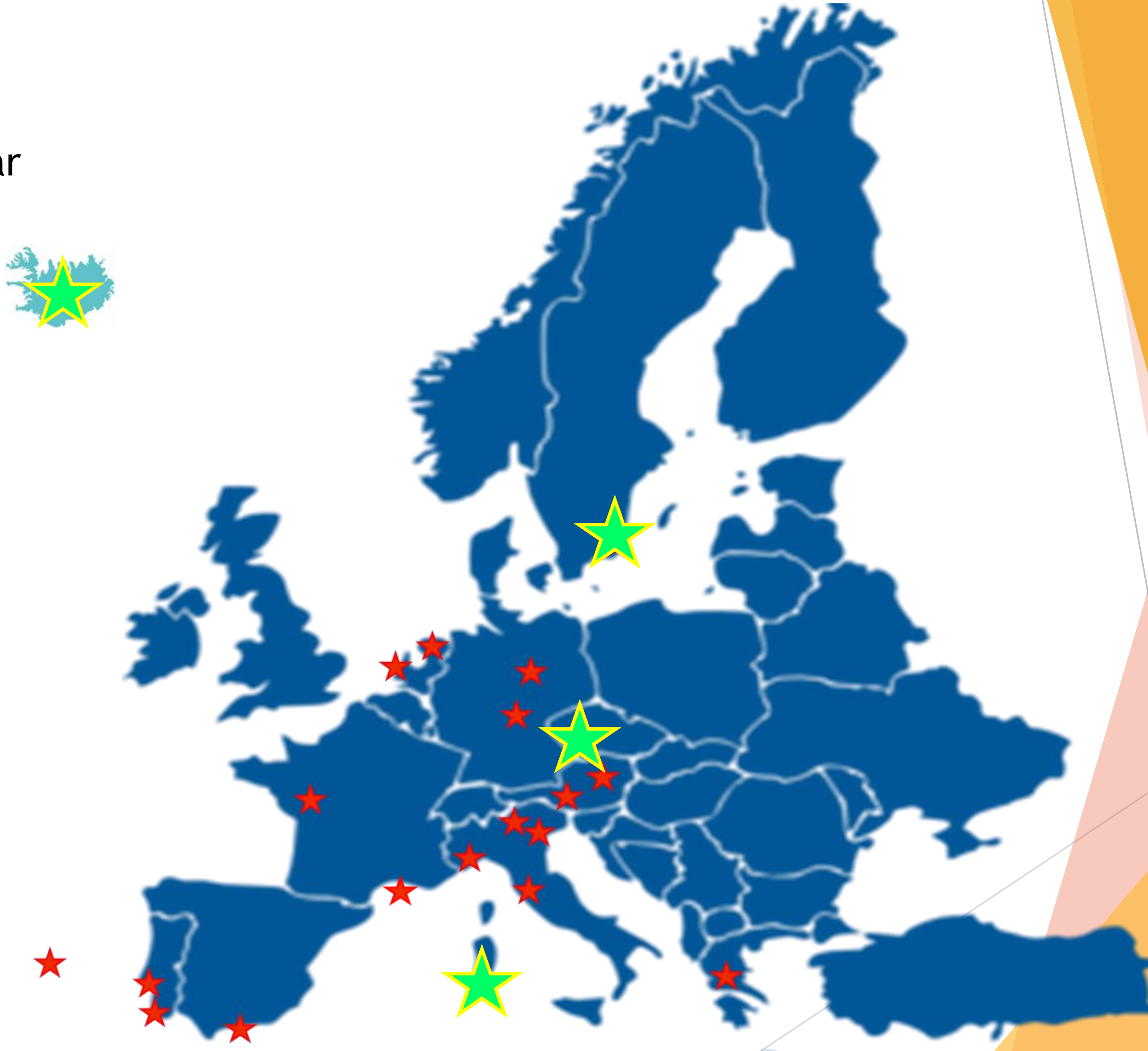
18 €/kg


By 2019, LCOE of best onshore wind and solar PV projects at USD 0.03/kWh (or less!)
IRENA
International Renewable Energy Agency
Electricity at
0.01 € kWh-1
seems no more a DREAM!
25
20
15
10
5
0
Euro/kg d.w
0
0,02
0,04
0,06
0,08
0,1
0,12
Euro/kWh

INDOOR ALGAE FACILITIES WITH LED

LED

Solar



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