

# MARE

## Micro-Algae Renewable Energy

### 2<sup>nd</sup> Gen. Biofuel Production Demonstration Project

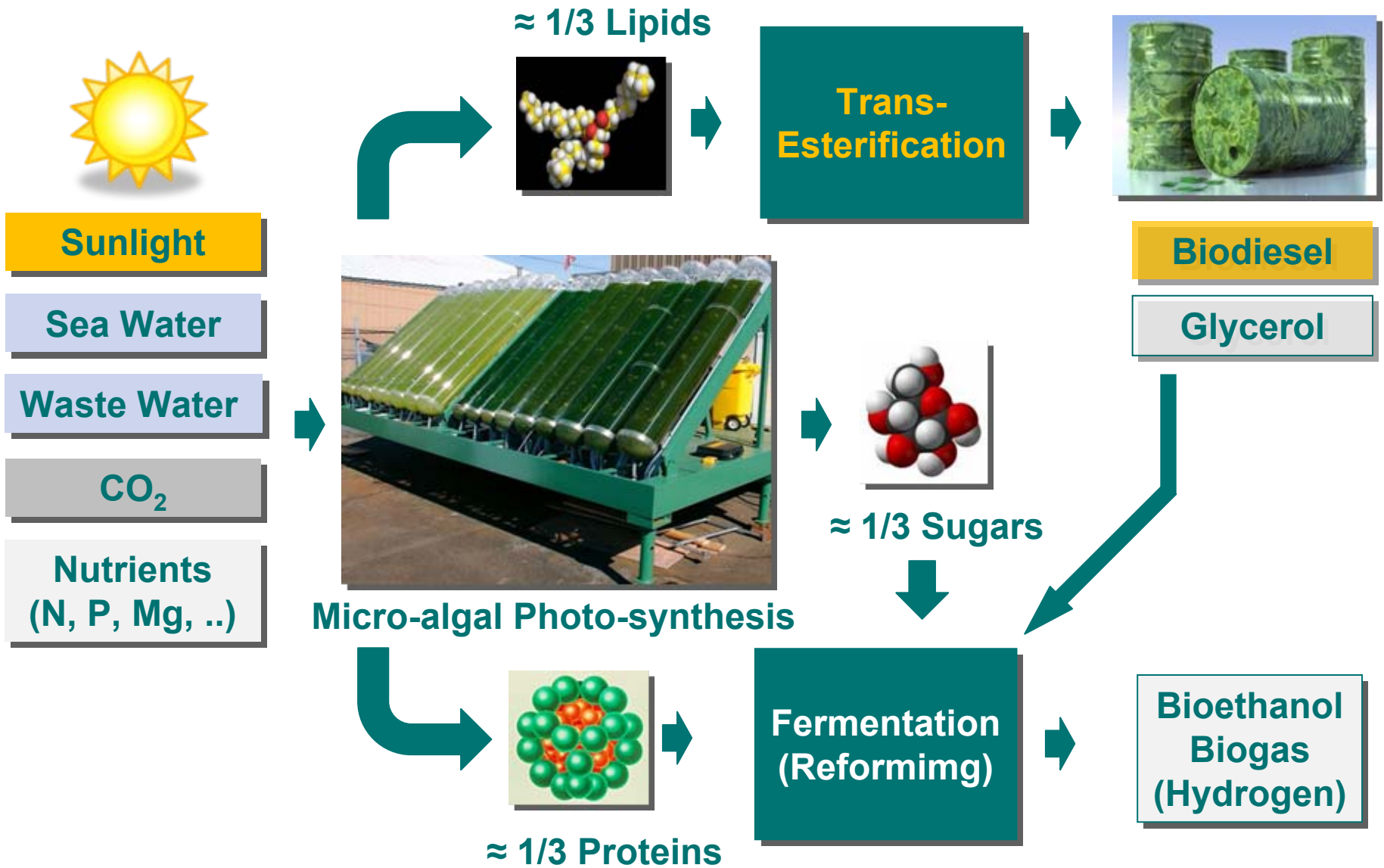
**Giorgio Simbolotti, Technology Advisor - President's Office, Rome**  
**Giulio Izzo, Research Director - Casaccia National Labs**

**ENEA - Italian National Agency for New Technologies, Energy and Environment**  
**Some 2000 Researches and 10 Research Labs in Italy**  
**Nuclear and Renewable Energy, Energy Efficiency, Biotechnology, Material**  
**Science, Environment and Climate – Technical Support to Italian Government**

# Objective, Framework, Potential

- Demonstrate technical-economic feasibility of 2<sup>nd</sup> gen. biodiesel production from micro-algae in Italy, and at different latitudes in Developing Countries
  - Mitigate oil use and CO<sub>2</sub> emissions
- 
- Traditional technology is not convenient in Italy (climate, land cost, biodiesel output price)
  - 30 t/ha\*y (420 bbl/ha) at \$100/bbl are not enough
  - New approaches for more productivity & by-products
- 
- Up to 20% of national CO<sub>2</sub> emissions reduction target
  - Up to 80% of national biodiesel production target using some 4% of unused arable land

# Micro-algae Biotechnology



# Micro-algae Cultivation Systems



## Raceway Ponds

20cm-deep, outdoor open pools,  
with slowly moving water

**No so much land in Italy !**



## Photo Bio-Reactors

In/outdoor plastic containers  
with natural/artificial lighting

# Major Technical Hurdles

- 1. Algae selection and bioreactor design**
- 2. Optimal lighting (complement natural light with artificial light)**
- 3. Harvesting and oil production process**
- 4. Scaling-up to industrial plants**

# 1. Micro-algae & Bioreactor Design

Technical Objective	Solution
<p>Optimal algal species for :</p> <ul style="list-style-type: none"> <li>■ Fast growth</li> <li>■ High content of lipids (50%)</li> <li>■ Resistance to a/biotic stress</li> <li>■ Large cell size</li> <li>■ Quick sedimentation</li> </ul>	<p>Balance competing requirements Nannochloropsis, Diatomea Marina (in seawater)</p> <p>Continue Research<sup>1</sup></p>
<p>Vertical bioreactors Bioreactor material lifetime &gt; 20y</p>	<p>Green wall reactors Polymeric PTEFs mat.</p>

1. Over the past decades, advances in conventional agriculture cultivations have enabled 8-10X yield increases (wheat)

## 2. Optimal Lighting

Technical Objective	Solutions
Adapt to daily, seasonal and regional solar radiation <sup>1</sup> and climate to stimulate growth	Complement natural light with artificial light, with varying spectrum and energy <sup>2</sup>
Ensure uniform light and avoid photo-inhibition in summer light	Light reflecting and dilution elements in new <i>cascade</i> bioreactors
Energy Saving	Highly efficient light (LED)

- 1. Optimal lighting may result in 2-3X production increase (1-10 Khz pulsed light tests with potentially 6X increase ?)**
- 2. Patented Solar Simulator (M2M Engineering) to simulate and test conditions in different regions and seasons**



# 3. Harvesting, Oil Production

Technical Objective	Solutions
Continuous production and harvesting cycle while avoiding contamination	Select algal species with quick flocculation-sedimentation and larger size to reduce preconcentration cost <sup>1</sup>
Low cost oil extraction from liquid biomass with: <ul style="list-style-type: none"> <li>■ high lipid extraction rate</li> <li>■ fuel-grade quality output</li> </ul>	Dry/wet 18-40 kHz ultrasonic cavitation, centrifugal separation, proper algae species (low acidity) and solvents, direct trans-metilation to reduce cost

**1. Dilution (1t dry biomass in 2000t water) and cell size (5-20µm)**



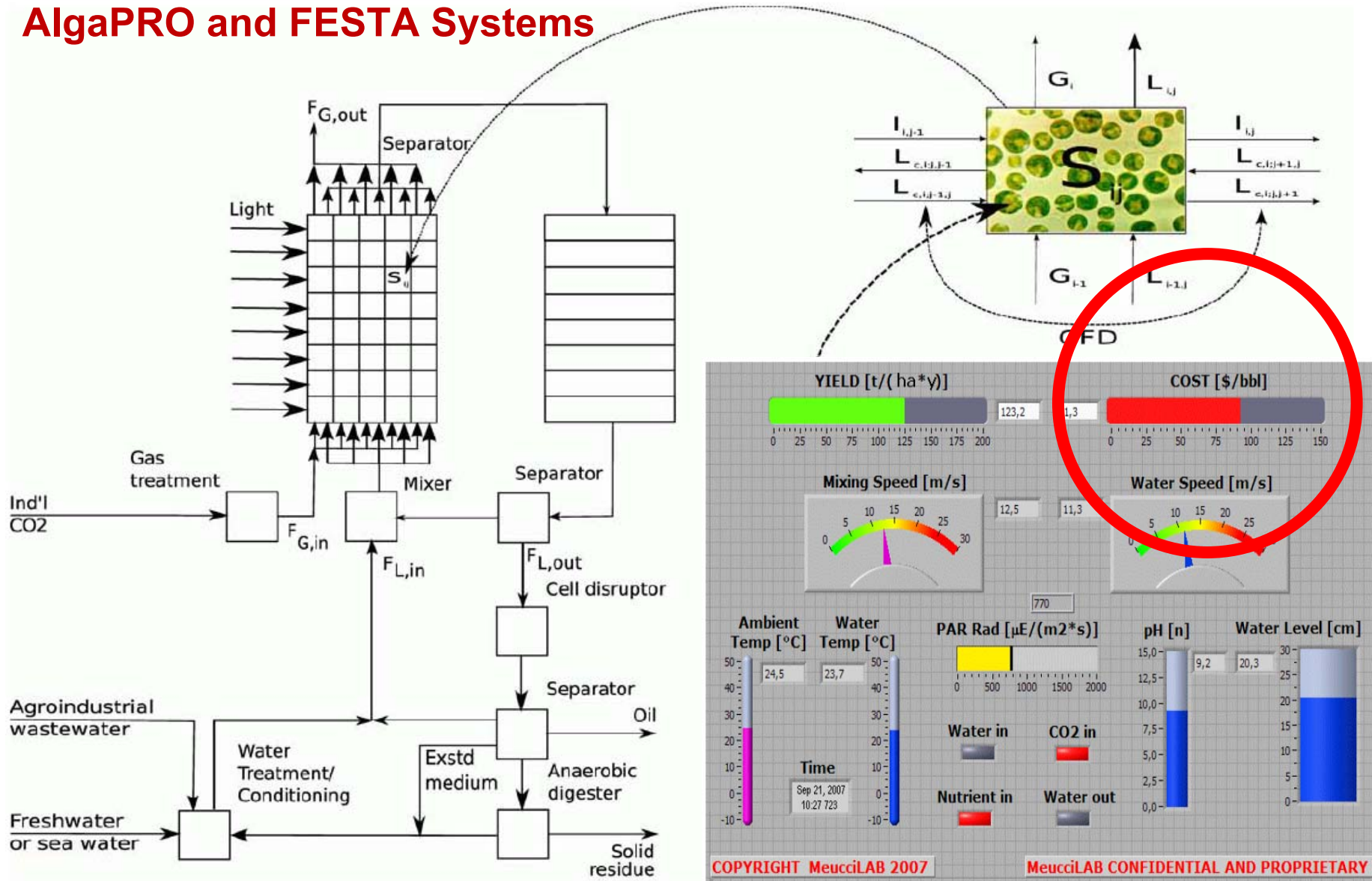
# 4. Scaling-up to Industrial Size

Technical Objective	Solutions
Scaling-up to industrial size with lab quality and yield performance	Technology learning, economy of scale
Process monitoring and control  (complex, living systems with non-linear behavior require continuous quality and cost control)	Control of key parameters by computer-assisted systems  Patented plant simulators based on diagnostics and statistic-forecasting models, with self-learning features <sup>1</sup> .

1. **AlgaPRO for large size plant and FESTA (Functional and Economical Simulator–Technologies Arbitrator) for smaller demonstration plants**

# Monitoring Process and Costs

## AlgaPRO and FESTA Systems



# Three bioreactors for 3 regions

## Mediterranean Basin

	Light	Location	Water	Cost	Yield t/ha-y
North	Nat/Artif.	indoor	Water	High	> 200
Central	Natural	outdoor	Sea water	Medium	> 150
South	Natural	outdoor	Sea water	Low	> 100

## Production Potential in Italy

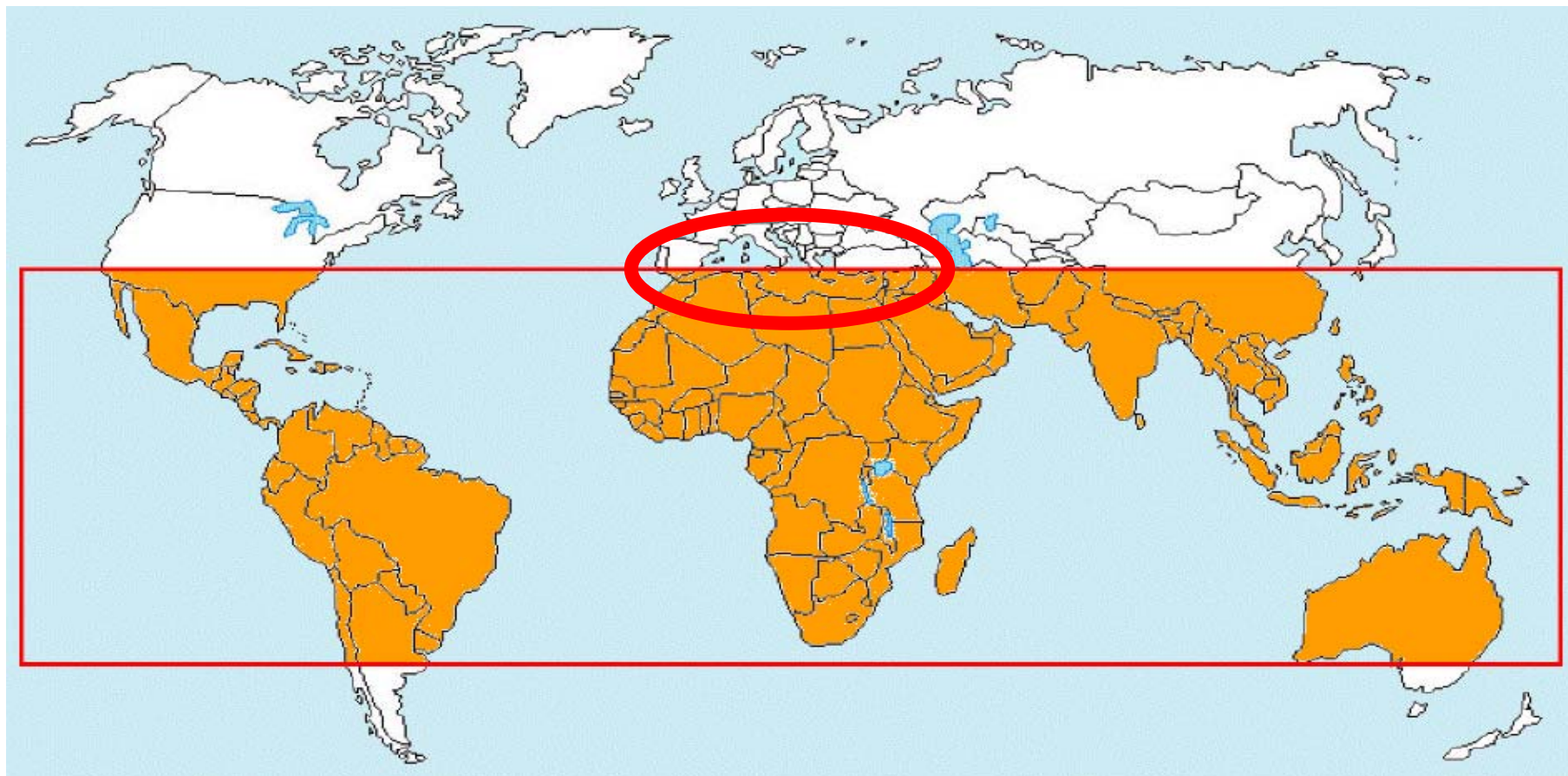
**100 t/ha-y x 400kha (2-3% unused arable) = 40 Mt biom/y =**

**= { 40 Mt/y CO<sub>2</sub> fixation = 20% av. quota (2008-2012)  
20 Mt/y biodiesel = 80% national biodiesel target**

**... plus ethanol or biogas from fermentation ...**

# Optimal Conditions for Micro-Algae

- Nearly constant 50% night/day solar radiation
- Average temp. of  $18^{\circ}\text{C} \pm 7^{\circ}\text{C}$  excursion



# Addressing WB Questions 1

Question	Answer
<p>What are <b>motivations and benefits</b> of the new technology over conventional options?</p>	<ul style="list-style-type: none"> <li>■ Reduce oil import &amp; CO<sub>2</sub> emissions</li> <li>■ No competition with food production and arable land use</li> <li>■ Accessibility: No high-tech needed, Easy transfer to Developing Countries</li> </ul>
<p>What are the <b>biggest barriers</b> to getting the new technology into deployment?</p>	<ul style="list-style-type: none"> <li>■ Cost vs. conventional fuel (target &lt;\$80-100/bbl)</li> <li>■ Current oil market does not help</li> <li>■ Incentives, ETS in transport, and technology learning to reduce cost and increase productivity</li> </ul>



# Addressing WB Questions 2

Question	Answer
<p>Who are the <b>major players</b> in the project, their role and interest?</p>	<ul style="list-style-type: none"> <li>■ <b>Concept, R&amp;D, scaling-up:</b> ENEA, CNR, Universities of Rome, Florence, Napoli, Padua</li> <li>■ <b>Industrialization &amp; commercializ.:</b> Iacorossi SpA, Marseglia Goup, Renova, Enernova, M2M Engineering, MeucciLab</li> </ul>
<p>What <b>World Bank services</b> could assist a sooner technology deployment?</p>	<p><b>Key role in:</b></p> <ul style="list-style-type: none"> <li>■ Foster cooperation;</li> <li>■ Disseminate information;</li> <li>■ Finance demo projects;</li> <li>■ <b>Bridge to Developing Countries;</b></li> <li>■ <b>Network with energy international bodies to select priority techs;</b></li> </ul>

# Many Thanks



Outdoor cultivation of *Nannochloropsis* in green-wall reactors (TUSCANY, ITALY)



Influence of nitrogen and phosphorus starvation)

[giorgio.simbolotti@enea.it](mailto:giorgio.simbolotti@enea.it)  
[giulio.izzo@enea.it](mailto:giulio.izzo@enea.it)