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ALGAE-BASED BIOFUELS:

A Review of Challenges and Opportunities for Developing Countries

ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

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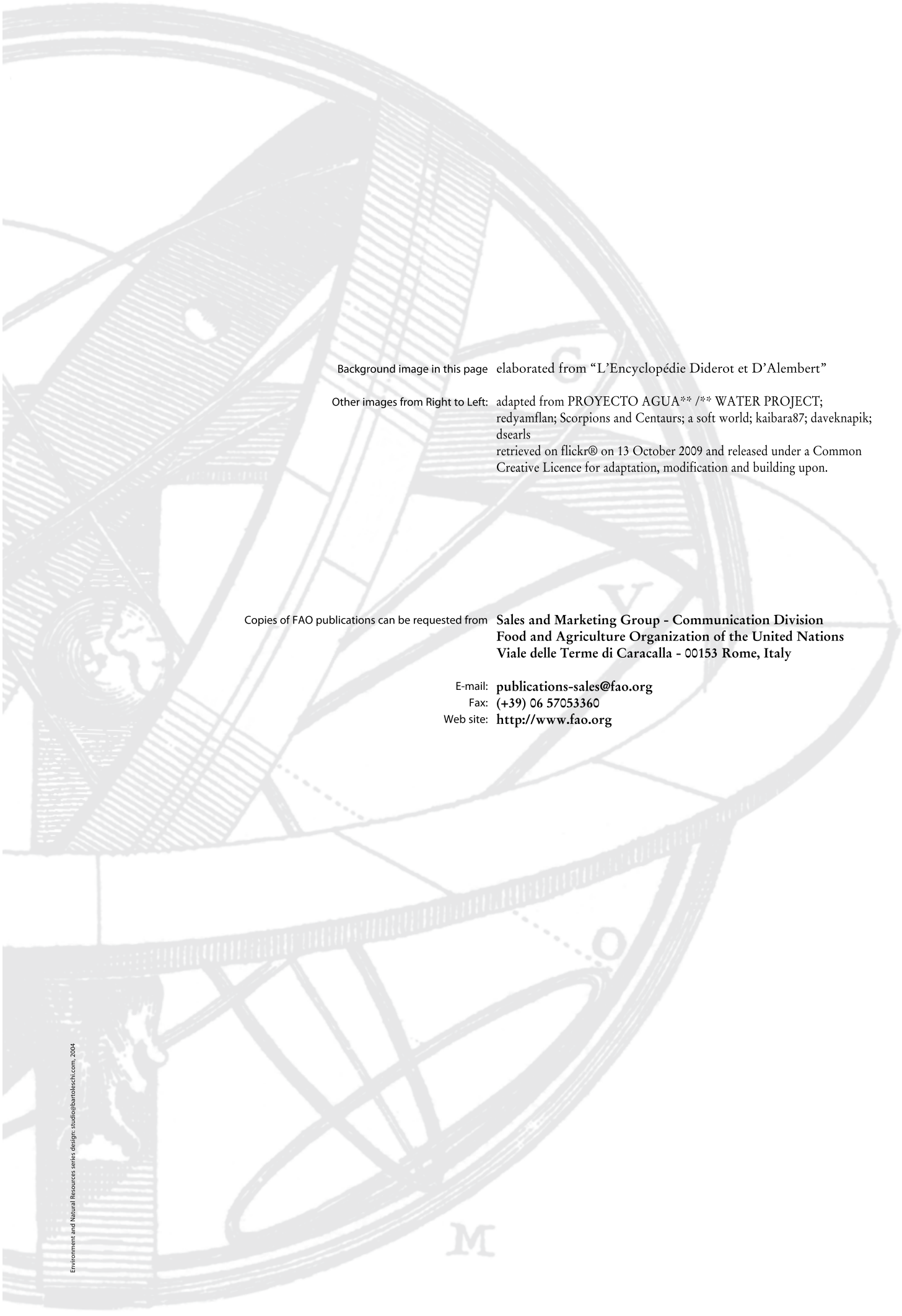

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The lead author of this paper is Sjors van Iersel (Ecofys) with supporting inputs from Liliana Gamba, Andrea Rossi, Sacha Alberici, Bart Dehue, Jasper van de Staaij and Alessandro Flammini.

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Abstract

- A multitude of algae-based biofuel (ABB) pathways are possible and need to be determined on a case- by-case basis.
    - There is a variety of land based cultivation systems, and several different ABBs and other bioenergy carriers can be produced.
    - Land based systems are more developed then sea based systems.
    - Many input sources can be used, like combustion gas, salt water and wastewater. The availability of these influences the exact ABB concept.
    - Climatic conditions, such as annual solar irradiation and temperature, strongly influence ABB design.
    - ABB systems are suitable for many land and water types, with widely varying opportunities and restrictions.
- ABB's economic viability is still in its nascent phase.
    - There are no commercial scale examples producing only bioenergy.
    - Energy and biofuels tend to have a low value.
    - Algae cultivation and processing systems require a high capital input (higher than agriculture).
    - Biomass output is potentially high, but still under development.
    - At least in the short term, and probably in the medium term, higher value co-products are needed for economic viability.
- As with plant based biofuels, ABBs have important sustainability issues, but also several significant sustainability opportunities, often unique to algae.
    - Large amounts of land with a low economic and ecological value can be used.
    - Fresh water usage can be avoided.
    - Even more space in seas and oceans is available for ABB production.
    - Several GHGs can be captured and their emissions reduced.
    - Several waste streams can be treated, while at the same time being used as carbon and/or nutrient and/or water source.

Specific challenges for deployment in developing countries

- ABB production holds future promise for developing countries.
    - A new industry, generating jobs, GDP and energy independence.

- Developing countries are often situated in regions which are geographically interesting for algae cultivation (favourable climatic conditions, cheap labour and underdeveloped land).

- All ABB concepts require significant capital investment.
  - Access to this technology by the poor may be difficult.
  - Foreign investment could lead to revenues leaving the country.
  - Large-scale facilities are more economically viable, but are also more likely to have higher social and ecological impacts.
- Various knowledge levels required:
  - Developing and engineering ABB technology requires a high level of expertise until construction is finished.
  - Innovation for higher productivity also requires some knowledge and/or experience.
  - Operation and maintenance, as well as processing, can be mostly done without specific educational requirements. This group will be the majority of the workforce.
- Knowledge gaps exist for several critical factors:
  - Due to a lack of industrial scale experiments, there is insufficient knowledge to adequately judge the economic viability.
  - Productivity data is often extrapolated from small experiments, and not always presented clearly and consistently.
  - Overall analysis of energy balances, GHG balances and CO_2 abatement potential are lacking.

ABB technical concept considerations

- **Land based systems**
  - Closed systems have a higher capital, technology, technical skill, research and maintenance requirement than open systems, and therefore the latter are generally preferable.
  - Open systems have a high water loss due to evaporation, so a renewable water source that can be replenished is required.
  - Locally occurring algae species should be cultivated.
  - A renewable nutrient source is needed.
  - Co-production of food or feed strongly increases economic viability, allows small scale, near-term implementation, food supply and

experience, and therefore has to be considered a strict requirement in the short term.

- **Sea based systems**
  - Large potential in territorial waters of developing countries.
  - Can be labour intensive. This benefits developing countries in that more jobs are created, while this has a small economic impact due to lower wages.
  - Co-production of food or feed has the potential to increase economic viability and can build on existing experience.
  - Synergy with fish cultivation has high potential.

Algae-based biofuels

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Abstract

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