Future for clean energy lies in 'big bang' of evolution

August 25 2008

Amid mounting agreement that future clean, "carbon-neutral", energy will rely on efficient conversion of the sun's light energy into fuels and electric power, attention is focusing on one of the most ancient groups of organism, the cyanobacteria. Dramatic progress has been made over the last decade understanding the fundamental reaction of photosynthesis that evolved in cyanobacteria 3.7 billion years ago, which for the first time used water molecules as a source of electrons to transport energy derived from sunlight, while converting carbon dioxide into oxygen. The light harvesting systems gave the bacteria their blue ("cyano") colour, and paved the way for plants to evolve by "kidnapping" bacteria to provide their photosynthetic engines, and for animals by liberating oxygen for them to breathe, by splitting water molecules. For humans now there is the tantalising possibility of tweaking the photosynthetic reactions of cyanobacteria to produce fuels we want such as hydrogen, alcohols or even hydrocarbons, rather than carbohydrates.

Progress at the research level has been rapid, boosting prospects of harnessing photosynthesis not just for energy but also for manufacturing valuable compounds for the chemical and biotechnology industries. Such research is running on two tracks, one aimed at genetically engineering real plants and cyanobacteria to yield the products we want, and the other to mimic their processes in artificial photosynthetic systems built with human-made components. Both approaches hold great promise and will be pursued in parallel, as was discussed at a recent workshop focusing on the photosynthetic reaction centres of cyanobacteria, organised by the European Science Foundation (ESF).

A key point noted by Eva Mari Aro, the vice-chair of the ESF conference, was that there is now universal agreement over the ability of photosynthesis to provide large amounts of clean energy in future. While the sustainable options currently pursued such as wind and tidal power will meet some requirements, they will not be able to replace fossil fuels as sources of solid energy for driving engines, nor are they likely to be capable on their own of generating enough electricity for the whole planet. Meanwhile the current generation of biofuel producing crops generally convert less than 1% of the solar energy they receive to biomass, which means they would displace too much agricultural land used for food production to be viable on a large scale. There is the potential to develop dedicated systems, whether based on cyanobacteria, plants, or artificial components, capable of much higher efficiencies, reaching 10% efficiency of solar energy conversion. This would enable enough energy and fuel to be produced for a large part of the planet's needs without causing significant loss of space for food production.

As Aro pointed out, photosynthesis evolved by cyanobacteria produced all our fossil fuels in the first place. However the rapid consumption of these fossil fuels since the industrial revolution would if continued return atmospheric carbon dioxide towards the levels at the time cyanobacteria evolved, also heating the planet up to the much higher temperatures that prevailed then. The objective now is to exploit the same reactions so that the remaining fossil fuels can be left in the ground. Among promising contenders discussed at the ESF conference was the idea of an artificial leaf that would simulate not just photosynthesis itself but also the ability of plants to regenerate themselves. This could be important, since the reactions of photosynthesis are destructive, dismantling the protein complexes where they take place, which therefore need regular reconstruction. Under a microscope, chloroplasts, the sub-cellular units where photosynthesis take place, resemble a permanent construction site, and even artificial systems would probably need some form of regenerative capability.

A future aim therefore is to build an artificial leaf-like system comprised of self-assembling nanodevices that are capable of regenerating themselves – just as in real plants or cyanobacteria. "Fundamental breakthroughs in these directions are expected on a time scale of 10 to 20 years and are recognized by the international science community as major milestones on the road to a renewable fuel," said Aro.

Such breakthroughs depend on further progress in understanding the precise structure and mechanisms of photosynthesis, in particular the protein complex known as photosystem II, which breaks down the hydrogen atoms of water into their constituent protons and electrons to carry the energy derived from sunlight onto photosystem I, leading to production of carbohydrates and ultimately also the proteins and fats required by all organisms.

Source: European Science Foundation