ARPA-E Novel Approaches to Direct-Solar Fuel Technologies
October 21, 2009
Breakout Session I
Metabolic Engineering/Synthetic Biology

We could discuss what we can/can't engineer, however the big problem is scaleup

Getting from CO_2 to fuel and be competitive with Fischer Tropsch

Direct continuous production of molecules

Metabolic engineering will become relatively simple, the challenge will be cost

Questions of waste and downstream processing must be factored into the calculations

DOE report on comparisons between pyrolysis vs. competitive technologies will soon be available – a Techno-Economic Analysis - always determined in dollars/gallon

Big question – is the evaluation of cost in production to be determined at the point of metabolic engineering or is it a purely engineering question?

What kinds of molecules are infrastructure-compatible? Jet fuel C8-C12 branched, automotive, C10-C12 straight chains

Petroleum refining companies can deal with any type of hydrocarbon that is available. In fact, there is an interest in mixtures of hydrocarbons.

The chemical profile of various fuels is actually a suite of hydrocarbons. Should synthetic biology aim to make many different compounds or focus on just a few?

For jet fuels, as long as ASDM standards are met, they can be used. Infrastructure is changeable.

For automobiles, changing the US infrastructure would be very difficult. (Possible in China).

Let's focus on going from sunlight to biofuels.

Maybe focusing on the perceived **myths** would be useful: Rubisco is a lousy enzyme; photosynthesis is inefficient; photobioreactors will never work; metabolism is wasteful of energy.

1) Rubisco is a lousy enzyme – biology has overcome this issue – C4 biosynthesis (carboxysomes) is highly efficient

2) Photosynthesis is inefficient -

3) metabolism is wasteful of energy

4) photobioreactors will never work – Currently they are not efficient, but they may be produced to be efficient by capturing all light, etc.

Synthetic biology starts by assuming that these are myths, and that synthetic biology can address the issue of making direct solar fuels a more efficient process.

Real biology does not happen in pure cultures. Nature uses multiple organisms to produce and consume biomass.

Efficiency has a different definition depending upon the situation.

Synthetic biology can create efficient pathways – photosynthesis works well.

This morning we heard that if you can get to acetyl-CoA, any pathway is possible.

Are we here to take the minimum number of enzymes to move from CO2 and light to hydrocarbons?

Is there an avenue that should not be pursued?

Metagenomics has produced interesting chemistries, but existing pathways are highly represented.

What about finding functionalities from unknown enzymes in genomes? This is discovery-based science. ARPA-E is interested in transformational applied science.

Gene regulation is a very important aspect of synthetic biology. It has been understudied in photosynthetic organisms and should be addressed. Control systems at the metabolic level, gene regulation, sensory level, and application to photosynthetic organisms, is valuable.

Metabolism with regard to environment is also poorly understood. Engineering organisms to work in an “anthromophorsized process” – process compatibility is important.

Separation from the water phase is a critical issue – this could be secretion or harvesting/extraction.

Fuel needs to be very cheap – high value products may need expensive processing. For example, animal feed could be a useful value added product, but this is not compatible with an excretion model.

Do we know the different pathways to make liquid fuels? Fatty acid biosynthesis, terpenoids – C5-C20 (cyclic, linear, etc), alcohols, ketoacid pathway

Organisms – cyanobacteria vs. algae.

Photobioreactors increase efficiency and can enable CO_2 utilization.

CO_2 concentration – sources of CO_2 are needed for algae growth. Bubble air through acid? Not enough concentration. Growers are still interested in CO_2 concentrating technologies. Overexpress CO_2 transporters.

Photobioreactor myth is based on old technology. Extinguishing the light can make it work. A goal of synthetic biology is to make it as efficient as E. coli in terms of carbon utilization.

Thermal stability of the organism in the bioreactor is still an ongoing issue.

In vitro systems were not covered here.

Secretion systems are an applied research problem.

Tools:

Improved culture platforms for high-throughput growing of organisms.

DNA synthesis, and the omics – flux analysis, directed evolution