Background Information
- Algae ranges anything from microscopic cyanobacteria to giant kelp. Algae are rich in fats, carbohydrates, and proteins.  
- Algae convert light energy into starch and lipids (Fig. 2).
- Lipid Granules  
  Photosynthetic Membranes  
  Nucleoid (DNA)  
  Cell wall  

**Figure 2. Algae cell diagram showing lipid locations.**

- Algae has gained huge interest because of high biomass yield and environmental benefits such as removing carbon from the air and nitrogen from wastewater.  
- The idea to use algae for fuel, food, and feed goes back about half a century.
- The use of algae started in the 1950’s for the production of methane and hydrogen gas.
- The Department of Energy (DOE) funded the Aquatic Species Program with $25 million dollars for 20 years with a specific goal of producing oil from microalgae.
- It was terminated in 1995 because of financial crisis and cheap oil, however was reinstated a few years later because of demand for clean fuels.

**Table 1. Oil yields, biofuels productivity from various biomass sources.**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Oil Yield (l/ha/yr)</th>
<th>Biofuel productivity (kg/ha/yr)</th>
<th>Land use (m²/year/kg biodiesel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>172</td>
<td>152</td>
<td>66</td>
</tr>
<tr>
<td>Soybean</td>
<td>446</td>
<td>562</td>
<td>18</td>
</tr>
<tr>
<td>Sunflower</td>
<td>952</td>
<td>946</td>
<td>11</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>1,190</td>
<td>862</td>
<td>NA</td>
</tr>
<tr>
<td>Jatropha</td>
<td>1,892</td>
<td>656</td>
<td>15</td>
</tr>
<tr>
<td>Oil palm</td>
<td>5,950</td>
<td>4,747</td>
<td>2</td>
</tr>
<tr>
<td>Microalgal</td>
<td>58,700</td>
<td>51,927</td>
<td>0.2</td>
</tr>
<tr>
<td>Microalgal (30% oil by wt.)</td>
<td>136,900</td>
<td>121,104</td>
<td>0.1</td>
</tr>
</tbody>
</table>

- Table 1 shows the more efficient use of resources by algae compared to crops traditionally used for biofuel production.
- Algae grows much faster and can triple their biomass every day.  
- Algae provides many co-products such as livestock feed and glycerol.

**Constraints**
- Selecting and testing genetically improved strains that are highly concentrated, have high oil content, and can be broken down for oil extraction.
- To create a highly concentrated crop they will need adequate CO₂ resources.
- Finding a reliable water supply is critical to the success of biofuel production.
- Solar radiation is very important factor in algae growth and it is limited in the US.
- High cost to extract from water and separate oils.
- Most methods require significant energy and cost

**Opportunities**

**Potential Solutions**
- The cultivation system should be designed so that solar radiation reaches all algae cells efficiently (higher surface area, Fig. 3).
- The cost efficiency of algae can be improved by implementing lower energy appliances and developing new technologies for algae processing.
- Biological limitation of algae feedstock can be overcome with genetic engineering that could allow faster growth of algal biomass and/or higher lipid yields.

**References**