This century’s greatest technological challenge is the conversion of sunlight into usable energy in a sustainable, environmentally benign and carbon-neutral way on a global scale. For light to chemical energy conversion in a designed photosynthetic system, the splitting of water into its constituent elements is the key energy-storing reaction. As with natural photosynthesis, such a system relies on light absorption, charge separation, and catalysis. Recent efforts are described that focus on different components and system compatibility for the reductive side of the water splitting reaction. The light absorbers include strongly absorbing organic dyes and water-solubilized semiconductor nanoparticles whereas the catalysts are redox-active metal complexes. Both the light absorbers and the hydrogen-forming catalysts are composed mainly of earth abundant elements. The studies provide clues to initial charge transfer steps, the mechanism(s) of H2 generation and sources of system instability.