Biofuels are a promising alternative to fossil fuels due to their ability to lower greenhouse gas emissions, provide sustainable supplies of energy and create cleaner environments. *Camelina sativa* has features that make it an ideal energy crop such as its short growing season and ability to grow on marginal lands with little water and nutrient provision. Its seeds contain a high amount of oil (up to 40%), and the remaining protein rich meal can be used for livestock feed. This study is focused on increasing the carbon fixation capabilities in *Camelina sativa* in order to enhance its oil and biomass production. A novel synthetic carbon fixation pathway, called the SynCycle, has been generated in order to overcome the CO_2-uptake and assimilation limitations of the conventional Calvin-Benson cycle. The SynCycle, which is the shortest, energetically feasible reverse TCA cycle known, is composed of five microbially derived enzymes, which will lower the energy cost by 30% compared to the conventional Calvin-Benson cycle. The product of the SynCycle, glyoxylate, will serve as an intermediate in an engineered photorespiration bypass that feeds into the Calvin-Benson cycle. Candidate enzymes for the SynCycle were identified and kinetic properties of the SynCycle enzymes, singly and in combination, were determined using a variety of spectrophotometric, LC-MS, and NMR techniques. Functional production of individual SynCycle enzymes *in planta* was evaluated using a transient tobacco expression system. The cycle was also recently transformed into *Camelina sativa*, and a cultivar is being established for evaluation of biomass and seed oil production.