In this study a CO$_2$ mass transfer model was developed for carbonic anhydrase-enhanced MDEA solutions based on a mechanistic kinetic enzyme model. Four different enzyme models were compared in their ability to predict the liquid side mass transfer coefficient at temperatures in the range 298 to 328 K, solvent concentrations in the range 15 to 50 wt%, CO$_2$ partial pressures up to 50 kPa, solvent loading between 0 and 0.5 mole CO$_2$ per mole MDEA and enzyme concentrations up to 8.5 g/L. The reversible Michaelis Menten model (MR) and the simplified model with product inhibition by the bicarbonate ion (SP) were able to predict the mass transfer with an absolute average relative deviation of less than 15%. The MR model could account for every influence (solvent concentration, temperature, solvent loading, CO$_2$ partial pressure) of the different process conditions on the mass transfer, whereas the SP model is limited to applications with low CO$_2$ partial pressure such as CCS from coal burning power plants. Two other models that were also investigated are not suitable for implementation into an absorber column simulation, as they cannot describe the influence of changing solvent loading on the mass transfer.