As advancements in nuclear reactor technology move the world towards producing safer and greener energy, they also come with new nuclear proliferation risks. Antineutrino detection has been proposed as a novel method that can contribute to safeguarding nuclear reactors from special nuclear material diversions. Accurate prediction of the antineutrino emission from nuclear reactors is needed to maximize the sensitivity of this method to material diversion. Estimates of the antineutrino source term can be obtained from simulations of nuclear reactors, but simulations differ significantly in their level of detail and computational cost. We have been examining four different levels of complexity in nuclear reactor simulations in order to determine how these levels of complexity impact the estimate of the antineutrino source term and to determine the acceptable level of complexity that meets the needs of nuclear safeguards. Four models of the same light water reactor were studied: a 2D model that simulates each assembly independently, a full 2D model, a 3D model, and a 3D model with thermal-hydraulic feedback. These simulations are used to calculate the time-dependent antineutrino source term over the cycle such that it is compared across different models and with the available data from experiments. Preliminary results show up to ~3% difference among the fission reaction rates of selected nuclides in certain models. These differences are measurable with the current generation of antineutrino detectors, which motivates a careful selection of the reactor simulation methodology if this method for reactor safeguards is to be considered for adoption in practice.