Given the tremendous cost of an exascale HPC system, its architecture must match the requirements of the applications it is supposed to run as precisely as possible. Conversely, applications must be designed such that building an appropriate system becomes feasible, motivating the idea of co-design. In this process, a fundamental aspect of the application requirements are the rates at which the demands for different resources grow as a code is scaled to a larger machine. However, if the anticipated scale exceeds the size of available platforms this demand can no longer be measured. This is clearly the case when designing an exascale system. Moreover, creating analytical models to predict these requirements is often too laborious—especially when the number and complexity of target applications is high. In this paper, we show how automated performance modeling can be used to quickly predict application requirements for varying scales and problem sizes.