The energy and exergy characteristics of 3D-pinned heat sink (HS) designs have been computationally compared as the second part of a three-part investigation. Different pin profiles, such as circular, square, triangular, strip and elliptic pins, and without pin HS are conducted with three different types of nanofluids—Al_2O_3-water, SiO_2-water, and CuO-water for laminar forced convection. The concentrations of nanofluids vary from 0 to 5 vol% with different Reynolds numbers ranging between 100 and 1000. The finite volume method employing the SIMPLE algorithm for a computational solution is applied to solve the Navier–Stokes and energy equations. Four criterions studies are explained—energy efficiency, exergy loss, and exergy efficiency of HSs with pressure drop. The results showed that the highest energy and exergy efficiencies are nearly 76% and 57%, respectively, for elliptic-pinned HSs using pure water, while about 82% and 62% using 5 vol% of SiO_2-water nanofluids. Besides, the elliptic-pinned HSs have a favorable reduction in the exergy loss, nearly 17% using 5 vol% of SiO_2-water nanofluids. Subsequently, the elliptic-pinned HS is recommended to apply with pure water considering the development in pressure drop required. However, the elliptic-pinned HSs could be employed with 5 vol% of SiO_2-water nanofluids regardless of the development in pressure drop required for thermal energy dissipation applications with more exergy efficiency and reduction of exergy loss.