A new pseudocapacitive combination, viz. CoO–MnO₂–MnCo₂O₄ hybrid nanowires (HNWs), is synthesized using a facile single-step hydrothermal process, and its properties are benchmarked with conventional battery-type flower-shaped MnCo₂O₄ obtained by similar processing. The HNWs showed high electrical conductivity and specific capacitance ($C_s$) (1650 F g⁻¹ or 184 mA h g⁻¹ at 1 A g⁻¹) with high capacity retention, whereas MnCo₂O₄ nanoflower electrode showed only one-third conductivity and one-half of its capacitance (872 F g⁻¹ or 96 mA h g⁻¹ at 1 A g⁻¹) when used as a supercapacitor electrode in 6 M KOH electrolyte. The structure–property relationship of the materials is deeply investigated and reported herein. Using the HNWs as a pseudocapacitive electrode and commercial activated carbon as a supercapacitive electrode we achieved battery-like specific energy ($E_s$) and supercapacitor-like specific power ($P_s$) in aqueous alkaline asymmetric supercapacitors (ASCs). The HNWs ASCs have shown high $E_s$ (90 Wh kg⁻¹) (volumetric energy density $E_v ≈ 0.52$ Wh cm⁻³) with $P_s$ up to $~10^4$ W kg⁻¹ (volumetric power density $P_v ≈ 5$ W cm⁻³) in 6 M KOH electrolyte, allowing the device to store an order of magnitude more energy than conventional supercapacitors.