Cosmological hydrodynamics simulations are an increasingly popular method to study galaxy formation and evolution. We have developed a framework to generate synthetic observations from UV to mm wavelengths for hydrodynamics simulations, in which the effects of interstellar dust are properly taken into account. We have applied this framework to the EAGLE cosmological hydrodynamics simulation, and generated panchromatic SEDs for hundreds of thousands of simulated galaxies. We find that the EAGLE simulation reproduces the dust scaling relations, cosmic SED, IR luminosity functions and dust mass function in the local Universe remarkably well. We also study the cosmic evolution of the panchromatic EAGLE SEDs. The agreement between the simulated IR luminosity functions and the observed ones gradually worsens with increasing lookback time. We discuss the possible origins of this discrepancy, and the implications for the cosmic evolution of dust.