According to one aspect of this disclosure, there is provided an integrated multi-layer energy apparatus comprises: a transparent or semi-transparent substrate; a solar-cell layer coupled to the substrate, the solar-cell layer comprising a plurality of solar cells for receiving light through the substrate and converting energy of the received light to a first electrical energy; an energy-storage layer coupled to the solar-cell layer, the energy-storage layer comprising one or more energy-storage units for storing a second electrical energy; and a converter layer, in a single layer, comprising a solar-input converter electrically connected to the solar-cell layer, a battery-input converter electrically connected to the energy-storage layer, and an output converter configured to receive the first electrical energy and the second electrical energy and convert the first electrical energy and the second electrical energy into a third electrical energy; wherein the solar-input converter, the battery-input converter, and the output converter are coupled to a ferrite core comprising a first ferrite loop, a second ferrite loop, and a third ferrite loop, each of the first and second ferrite loops sharing a portion of the third ferrite loop; and wherein the solar-input converter comprises coils winding around the first ferrite loop, the battery-input converter comprises coils winding around the second ferrite loop, and the output converter comprises coils winding around the third ferrite loop.

In some embodiments, the substrate comprises a layer of glass or a flexible, transparent or semi-transparent material.

In some embodiments, the substrate comprises at least one of polyethylene terephthalate (PET) and poly(ether sulfones) (PES).

In some embodiments, the solar-cell layer is printed or deposited to the substrate.

In some embodiments, the energy-storage layer is printed or deposited to the solar-cell layer.

In some embodiments, the solar-cell layer comprises: an anode sublayer coupled to the substrate; a sublayer of zinc oxide (ZnO) coupled to the anode sublayer; a sublayer of poly(ethylenimine) and poly(ethylenimine) ethoxylated (PEIE) coupled to the sublayer of ZnO; a sublayer of organic solar cells coupled to the sublayer of PEIE; a sublayer of Molybdenum trioxide (MoO_3) coupled to the sublayer of solar cells; and a cathode sublayer coupled to the sublayer of MoO_3.

In some embodiments, the sublayer of organic solar cells comprises polymer solar cells.

In some embodiments, the sublayer of solar cells comprises a sublayer of bulk heterojunctions (BHJs).

In some embodiments, the energy-storage layer comprises at least one of one or more battery cells and one or more semiconductor capacitors.

In some embodiments, each of the one or more battery cells comprises: a first current-collector sublayer; an anode sublayer coupled to the first current-collector sublayer; a solid-state electrolyte sublayer coupled to the anode sublayer; a cathode sublayer coupled to the solid-state electrolyte sublayer; and a second current-collector sublayer coupled to the cathode sublayer.

In some embodiments, the solid-state electrolyte sublayer comprises LiBrF4 with Al2O3 and a first semi-interpenetrating polymer network (semi-IPN) skeleton material.

In some embodiments, the solid-state electrolyte sublayer is made of 1 Molar (mol per liter) LiBrF4 in Sebaconitrile (SBN) and a first semi-IPN skeleton material at a ratio of 85/15 weight-by-weight (w/w), mixed with about 300 Molar Al2O3 at a ratio of 60/40 w/w.

In some embodiments, the anode sublayer comprises activated Li4Ti5O12 (LTO) with a first carbon material and a second semi-IPN skeleton material.

In some embodiments, the cathode sublayer comprises activated LiCoO2 (LCO) with a second carbon material and a third semi-IPN skeleton material.

In some embodiments, the first and/or the second carbon comprises at least one of single-walled carbon nanotubes (SWCNT) and carbon powder.

In some embodiments, the activated LTO is SWCNT-coated LTO.

In some embodiments, the activated LCO is SWCNT-coated LCO.

In some embodiments, the semi-IPN skeleton material comprises an ultraviolet (UV) curable polymer.

In some embodiments, the UV-curable polymer comprises ethoxylated trimethylolpropane triacrylate (ETPTA) incorporating 1.0 weight percent (wt%) 2-hydroxy-2-methylpropiophenone (HMPP) and poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP) with HFP of six mole percent (mol%) and ETPTA/PVdF-HFP at a ratio of 75/25 weight-by-weight (w/w).