What is claimed is:

1. A device for energy generation and wastewater treatment, comprising:

a first modular microbial fuel cell (MFC) device operable to bioelectrochemically process wastewater that includes organic matter in a fluid that concurrently generates electrical energy and digests the organic matter to produce a treated water, the first modular MFC device comprises:

a first housing, and

a first bioelectrochemical reactor encased within the first housing, the first bioelectrochemical reactor including a plurality of anodes arranged between a cathode assembly, wherein the cathode assembly includes two gas-diffusion cathodes separated on two sides of the plurality of anodes and arranged along a flow direction of the fluid through the first bioelectrochemical reactor for the fluid to flow between the two gas-diffusion cathodes, the gas-diffusion cathodes able to allow oxygen to permeate into the fluid within the first bioelectrochemical reactor; and

a second modular MFC device fluidically coupled to the first modular MFC device and operable to bioelectrochemically process the treated water produced by the first modular MFC device to concurrently generate electrical energy and digest organic matter in fluid of the treated water to produce a further treated water, the second modular MFC device comprises:

a second housing, and

a second bioelectrochemical reactor encased within the second housing, the second bioelectrochemical reactor including a plurality of anodes arranged between a cathode assembly, wherein the cathode assembly includes two gas-diffusion cathodes separated on two sides of the plurality of anodes and arranged along a flow direction of the fluid through the second bioelectrochemical reactor for the fluid to flow between the two gas-diffusion cathodes, the gas-diffusion cathodes able to allow oxygen to permeate into the fluid within the second bioelectrochemical reactor.

2. The device of claim 1, wherein one or both of the first modular MFC device and the second modular MFC device has a first dimension in the flow direction that is larger than a second dimension perpendicular to the first dimension.

3. The device of claim 1, wherein one or both of the first housing and the second housing includes an input hole and output hole arranged on opposing sides of the respective housing along the flow direction, and wherein one or both of the first housing and the second housing includes a first opening and a second opening on opposing sides of the respective housing perpendicular to the flow direction that allow for air flow into one or both of the first bioelectrochemical reactor and the second bioelectrochemical reactor, respectively, to provide oxygen to the cathode assembly.

4. The device of claim 1, wherein an anode of the plurality of anodes of one or both of the first bioelectrochemical reactor and the second bioelectrochemical reactor includes carbon fibers that protrude from an interior cylinder.

5. The device of claim 1, wherein one or both of the first modular MFC device and the second modular MFC device includes a double reactor configuration, the double reactor configuration including two bioelectrochemical reactors arranged in series along the flow direction and encased in the respective housing.

6. The device of claim 1, wherein one or both of the first modular MFC device and the second modular MFC device includes a triple reactor configuration, the triple reactor configuration including three bioelectrochemical reactors arranged in series along the flow direction and encased in the housing.

7. The device of claim 1, wherein each of the first modular MFC device and the second modular MFC device bioelectrochemically processes the wastewater:

oxidizing the organic matter in the wastewater fluid by biologically-catalyzed oxidation using biological species within the bioelectrochemical reactor, which causes excretion of protons in solution that diffuse to a cathode of the cathode assembly and an extracellular transfer of electrons released during the oxidation to a conductive surface of an anode of the plurality of anodes, and

electrically transferring the electrons to the cathode through an electrical circuit, which facilitates electrochemical reduction at the cathode by interaction of the protons, the electrons and oxygen to produce hydrogen peroxide and/or new water.

8. The device of claim 1, wherein each of the first modular MFC device and the second

modular MFC device is operable to bioelectrochemically process the wastewater under a flow rate of at least 100 mL/min and/or at least 120 L/day for at least 10 consecutive hours of operation.

9. The device of claim 1, wherein each of the first modular MFC device and the second modular MFC device is operable to generate the electrical energy and produce the treated water with net-zero energy consumption.

10. The device of claim 1, wherein the wastewater includes sewage received from a domestic infrastructure system, agricultural system, or industrial system.

11. A system for energy generation and wastewater treatment, comprising:

a wastewater pretreatment system to pre-treat raw wastewater by removing solid particles and produce a pre-treated wastewater that that is outputted from the wastewater pretreatment system;

one or more modular microbial fuel cell (MFC) devices to bioelectrochemically process the pre-treated wastewater by concurrently generating electrical energy and digesting organic contaminants and particulates in the pre-treated wastewater to yield a treated water, the one or more modular MFC devices comprising a housing and a bioelectrochemical reactor that is encased within the housing, wherein the bioelectrochemical reactor includes a plurality of anodes arranged between a cathode assembly, wherein the cathode assembly includes two cathodes separated on two sides of the plurality of anodes and arranged along a flow direction of fluid through the bioelectrochemical reactor for the fluid to flow between the two cathodes; and

a water collection system to receive the treated water from the one or more modular MFC devices and store the treated water and/or route the treated water from the system.

12. The system of claim 11, wherein the wastewater pretreatment system includes a degritting device to filter solid matter having (i) a size of 1 cm or greater, (ii) a mass of 50 g or greater, or (iii) a size of 1 cm or greater and a mass of 50 g or greater.

13. The system of claim 12, wherein the wastewater pretreatment system includes one or more equalization tanks to receive and collect the degritted wastewater and modulate a steady organic load and flow of the pre-treated wastewater.

14. The system of claim 11, wherein the wastewater pretreatment system includes one or more chemical, physical or biological pre-treatment devices to remove unwanted chemical species including one or more of sulfur species, grease or oil.

15. The system of claim 11, wherein the modular MFC device has a first dimension in the flow direction of fluid through the modular MFC device that is larger than a second dimension perpendicular to the first dimension, wherein the housing includes an input hole and output hole arranged on opposing sides of the housing along the flow direction, and wherein the housing includes a first opening and a second opening on opposing sides of the housing perpendicular to the flow direction that allow for air flow into the bioelectrochemical reactor to provide oxygen to the cathode assembly.

16. The system of claim 11, wherein an anode of the plurality of anodes includes carbon fibers that protrude from an interior cylinder.

17. The system of claim 11, wherein the two cathodes of the cathode assembly include two gas-diffusion cathodes able to allow oxygen to permeate into the fluid within the bioelectrochemical reactor.

18. The system of claim 11, wherein the one or more modular MFC devices include an array of a plurality of the modular MFC devices arranged in a hydraulic series, wherein a first modular MFC device receives the pre-treated wastewater from the wastewater pretreatment system and bioelectrochemically processes the pre-treated wastewater to output a first treated water that is received at a second modular MFC device of the array, which bioelectrochemically processes the first treated water to output a second treated water that is received at the water collection system or received at a next modular MFC device of the array.

19. The system of claim 18, wherein the array of the plurality of the modular MFC devices are arranged in the hydraulic series in multiple vertical planes between one or more groups of modular MFC devices of the array.

20. The system of claim 11, wherein the one or more modular MFC devices include a

double reactor configuration, the double reactor configuration including two of the bioelectrochemical reactors encased in the housing of the one or more modular MFC devices.

21. The system of claim 11, wherein the one or more modular MFC devices include a triple reactor configuration, the triple reactor configuration including three of the bioelectrochemical reactors encased in the housing of the one or more modular MFC devices.

22. The system of claim 11, wherein the pre-treated wastewater is gravity-fed through a feeder box to at least one of the one or more modular MFC devices.

23. The system of claim 11, wherein the modular MFC devices are operable to clean the pre-treated wastewater and yield the treated water under a flow rate of at least 100 mL/min and/or at least 120 L/day for at least 10 consecutive hours of operation.

24. The system of claim 11, wherein the one or more modular MFC device is operable to generate the electrical energy and produce the treated water with net-zero energy consumption.

25. A method for energy generation and wastewater treatment, comprising:

pretreating, at a wastewater pretreatment system, a raw wastewater by removing at least some of solid particles from a wastewater fluid outputted from the wastewater pretreatment system that produces a pre-treated wastewater;

processing, at one or more modular microbial fuel cell (MFC) devices, the pre-treated wastewater by a bioelectrochemical conversion process that generates electrical energy and concurrently cleans the pre-treated wastewater to produce treated water by digesting matter in the wastewater fluid, wherein the one or more modular MFC devices includes a housing and a bioelectrochemical reactor that is encased within the housing, wherein the bioelectrochemical reactor includes a plurality of anodes arranged between a cathode assembly, wherein the cathode assembly includes two cathodes separated on two sides of the plurality of anodes and arranged along a flow direction of fluid through the bioelectrochemical reactor for the fluid to flow between the two cathodes;

extracting the generated electrical energy for storage or transfer to an external electrical device; and

outputting, at a water collection system, the treated water from the one or more modular MFC devices for storing or routing the treated water.

26. The method of claim 25, wherein the bioelectrochemical conversion process includes:

oxidizing organic matter in the wastewater fluid by biologically-catalyzed oxidation using biological species within a bioelectrochemical reactor comprising a plurality of anodes spatially arranged between at least two cathodes, which causes excretion of protons in solution that diffuse to a cathode in the bioelectrochemical reactor and an extracellular transfer of electrons released during the oxidation to a conductive surface of an anode in the bioelectrochemical reactor, and

electrically transferring the electrons to the cathode through an electrical circuit, which facilitates electrochemical reduction at the cathode by interaction of the protons, the electrons and oxygen to produce hydrogen peroxide and/or new water.

27. The method of claim 25, wherein the pretreating the raw wastewater includes at least one of:

removing the at least some of the solid particles having one or both of a large size of 1 cm or greater and a large mass of 50 g or greater; or

removing chemical species including one or more of sulfur species, grease or oil from the wastewater fluid.

28. The method of claim 25, wherein the one or more modular MFC devices includes an array of a plurality of the modular MFC devices arranged in a hydraulic series, wherein a first modular MFC device receives the pre-treated wastewater and bioelectrochemically processes the pre-treated wastewater to output a first treated water that is received at a second modular MFC device of the array, which bioelectrochemically processes the first treated water to output a second treated water outputted from the array or received at a next modular MFC device of the array.

29. A device for energy generation and wastewater treatment, comprising:

a modular microbial fuel cell (MFC) device operable to bioelectrochemically process wastewater that includes organic matter in a fluid that concurrently generates electrical energy and digests the organic matter to yield a treated water, the modular MFC device comprises:

a housing, and

a bioelectrochemical reactor encased within the housing, the bioelectrochemical reactor including a plurality of anodes arranged between a cathode assembly, wherein the cathode assembly includes two cathodes separated on two sides of the plurality of anodes and arranged along a flow direction of the fluid through the bioelectrochemical reactor for the fluid to flow between the two cathodes.

30. The device of claim 29, wherein the two cathodes of the cathode assembly include two gas-diffusion cathodes able to allow oxygen to permeate into the fluid within the bioelectrochemical reactor.