CLAIMS

What is claimed is:

1. A conditioning system comprising:

a liquid-to-air energy exchanger (LAEE) having a plurality of energy exchange (EX) circuits, the LAEE comprising:

a single liquid panel having a plurality of liquid circuits through each of which a liquid is configured to flow, each of the plurality of liquid circuits having a plurality of closed liquid channels through each of which a liquid is configured to flow without mixing with the liquid flowing through other of the plurality of closed liquid channels, and each of the liquid circuits corresponding to each of the plurality of EX circuits;

an air channel adjacent the liquid panel and through which air is configured to flow from an inlet of the LAEE to an outlet of the LAEE, the air channel extending adjacent all of the plurality of liquid circuits; and

a plurality of membranes connected to the liquid panel, at least one of the plurality of membranes corresponding to each of the plurality of liquid circuits, and each one of the plurality of membranes disposed between the respective liquid circuit and the air channel, and

wherein each of the plurality of EX circuits is configured to exchange at least one of latent and sensible energy between a liquid flowing through the respective liquid circuit and the air.

2. The conditioning system of claim 1, wherein:

the plurality of liquid circuits comprises:

a first liquid circuit through which a first liquid is configured to flow; and

a second liquid circuit through which a second liquid is configured to flow, the second liquid circuit arranged downstream of the first liquid circuit in a direction of air flow through the LAEE;

the plurality of membranes comprises:

a first membrane connected to the liquid panel between the first liquid circuit and the air channel and forming a barrier between the first liquid and the air; and

a second membrane connected to the liquid panel between the second liquid circuit and the air channel and forming a barrier between the second liquid and the air; and

the plurality of EX circuits comprises:

a first EX circuit configured to exchange at least one of latent and sensible energy between the first liquid and the air through the first membrane; and

a second EX circuit configured to exchange at least one of latent and sensible energy between the second liquid and the air through the second membrane.

3. The conditioning system of claim 2, wherein:

the first liquid comprises a liquid desiccant and the second liquid comprises water;

each of the first and second membranes comprise a semi-permeable membrane permeable to gases and vapor and impermeable to liquids and solids;

the first EX circuit is configured to circulate the liquid desiccant to absorb water from the air flowing through the first EX circuit, a moisture content of the air exiting the first EX circuit being lower than a moisture content of the air entering the first EX circuit; and

the second EX circuit is configured to evaporatively cool at least one of the water and the air, a temperature of the at least one of the water and the air exiting the second EX circuit being lower than a temperature of the at least one of the water and the air entering the second EX circuit.

4. The conditioning system of claim 3, wherein:

the LAEE defines a process plenum and the air is process air;

the second EX circuit is configured to evaporatively cool the process air entering the second EX circuit and deliver the conditioned process air to an enclosed space, a temperature of the conditioned process air exiting the second EX circuit being lower than a temperature of the process air entering the second EX circuit.

5. The conditioning system of claim 4, wherein the process air entering the LAEE is at least partially return air from the enclosed space.

6. The conditioning system of claim 4, further comprising a first liquid transport circuit connected to a liquid outlet of the first EX circuit and configured to transport the liquid desiccant from the first EX circuit to a regenerator, the regenerator configured to increase a concentration of the liquid desiccant by removing water from the liquid desiccant, the regenerator fluidically connected to the first EX circuit to transport the concentrated liquid desiccant back to the first EX circuit.

7. The conditioning system of claim 6, further comprising a second liquid transport circuit connected to a liquid outlet of the regenerator and configured to transport at least a portion of the water removed from the liquid desiccant to a liquid inlet of the second EX circuit.

8. The conditioning system of claim 6, wherein the regenerator is a thermally driven regenerator.

9. The conditioning system of claim 3, further comprising:

a liquid transport circuit connected to a liquid outlet of the second EX circuit and configured to transport the water to a heat load in an enclosed space, wherein the second EX circuit is configured to evaporatively cool the water, a temperature of the water exiting the second EX circuit via the liquid outlet being lower than a temperature of the water entering the second EX circuit via a liquid inlet.

10. The conditioning system of claim 9, wherein the air is scavenger air and further comprising:

a process plenum configured to direct process air from the enclosed space through a process air inlet and return conditioned process air to the enclosed space through a process air outlet; and

a liquid-to-air heat exchanger (LAHX) arranged inside the process plenum, the LAHX comprising a liquid inlet connected to and configured to receive the water from the liquid transport circuit, the LAHX configured to directly and sensibly cool the process air using the water flowing through the LAHX, a temperature of the conditioned process air exiting the LAHX being lower than a temperature of the air entering the LAHX,

wherein the conditioned process air exiting the process plenum at the process air outlet is returned to the enclosed space.

11. The conditioning system of claim 10, wherein the process air entering the LAHX is at least partially return air from the enclosed space.

12. The conditioning system of claim 10, wherein the liquid transport circuit is a second liquid transport circuit, and further comprising a first liquid transport circuit connected to a liquid outlet of the first EX circuit and configured to transport the liquid desiccant from the first EX circuit to a regenerator, the regenerator configured to increase a concentration of the liquid desiccant by removing water from the liquid desiccant, the regenerator fluidically connected to the first EX circuit to transport the concentrated liquid desiccant back to the first EX circuit.

13. The conditioning system of claim 12, further comprising a third liquid transport circuit connected to a liquid outlet of the regenerator and configured to transport at least a portion of the water removed from the liquid desiccant to a liquid inlet of the second EX circuit.

14. The conditioning system of claim 12, wherein the regenerator is a thermally driven regenerator.

15. The conditioning system of claim 2, wherein:

the first membrane comprises an impermeable membrane;

the second membrane comprises a semi-permeable membrane permeable to gases and vapor and impermeable to liquids and solids;

the first EX circuit is configured to directly and sensibly cool the air using the first liquid, a temperature of the air exiting the first EX circuit being lower than a temperature of the air entering the first EX circuit; and

the second EX circuit is configured to evaporatively cool at least one of the second liquid and the air, a temperature of the at least one of the second liquid and the air exiting the second EX circuit being lower than a temperature of the at least one of the second liquid and the air entering the second EX circuit.

16. The conditioning system of claim 15, wherein:

the LAEE defines a process plenum and the air is process air;

the second EX circuit is configured to evaporatively cool the process air entering the second EX circuit and deliver the conditioned process air to an enclosed space, a temperature of the conditioned process air exiting the second EX circuit being lower than a temperature of the process air entering the second EX circuit.

17. The conditioning system of claim 16, wherein the process air entering the LAEE is at least partially return air from the enclosed space.

18. The conditioning system of claim 15, further comprising:

a liquid transport circuit connected to a liquid outlet of the second EX circuit and configured to transport the water to a heat load in an enclosed space, wherein the second EX circuit is configured to evaporatively cool the water, a temperature of the water exiting the second EX circuit via the liquid outlet being lower than a temperature of the water entering the second EX circuit via a liquid inlet.

19. The conditioning system of claim 18, wherein the air is scavenger air and further comprising:

a process plenum configured to direct process air from the enclosed space through a process air inlet and return conditioned process air to the enclosed space through a process air outlet; and

a liquid-to-air heat exchanger (LAHX) arranged inside the process plenum, the LAHX comprising a liquid inlet connected to and configured to receive the water from the liquid transport circuit, the LAHX configured to directly and sensibly cool the process air using the water flowing through the LAHX, a temperature of the conditioned process air exiting the LAHX being lower than a temperature of the air entering the LAHX,

wherein the conditioned process air exiting the process plenum at the process air outlet is returned to the enclosed space.

20. The conditioning system of claim 19, wherein the process air entering the LAHX is at least partially return air from the enclosed space.

21. A method comprising:

arranging a liquid-to-air energy exchanger (LAEE) having a plurality of energy exchange (EX) circuits within or in proximity to an enclosed space, the LAEE comprising:

a single liquid panel having a plurality of liquid circuits through each of which a liquid is configured to flow, each of the liquid circuits corresponding to each of the plurality of EX circuits;

an air channel adjacent the liquid panel and through which air is configured to flow from an inlet of the LAEE to an outlet of the LAEE, the air channel extending adjacent all of the plurality of liquid circuits; and

a plurality of membranes connected to the liquid panel, each of the plurality of membranes corresponding to each of the plurality of liquid circuits and disposed between the respective liquid circuit and the air channel;

directing air through the air channel from the inlet of the LAEE to the outlet of the LAEE;

directing one or more liquids through each of the plurality of liquid circuits of the single liquid panel; and

in each of the plurality of EX circuits, exchanging at least one of latent and sensible energy between a liquid flowing through the respective liquid circuit and the air flowing through the air channel through the respective membrane.