

WHAT IS CLAIMED IS:

1. A panel assembly comprising:
a heat sink; and
at least one module mounted on the heat sink including:
an emitter assembly;
an energy conversion assembly separated from the emitter assembly by a gap; and
a fastener applying a force to maintain the gap.
2. A panel assembly as recited in Claim 1, wherein the panel assembly is thermophotovoltaic, the energy conversion module is a photovoltaic module having a photovoltaic element, the emitter assembly includes an emitter and the photovoltaic assembly includes .
3. A panel assembly as recited in Claim 2, wherein the emitter bolts to the heat sink.
4. A panel assembly as recited in Claim 1, further comprising a force application layer positioned adjacent to the emitter and the fastener is at least one bolt extending through the force application layer to couple to the heat sink.
5. A panel assembly as recited in Claim 2, further comprising a base substrate between the photovoltaic assembly and the heat sink.
6. A panel assembly as recited in Claim 5, wherein the base substrate is fabricated from a material having high thermal conductivity properties.
7. A panel assembly as recited in Claim 5, further comprising a force application layer positioned adjacent to the emitter and the fastener is at least one bolt extending through the force application layer to couple to the base substrate.

8. A panel assembly as recited in Claim 2, further comprising:
a housing having an inner surface defining an interior;
a mounting bracket; and
at least one support bar extending from the mounting bracket and coupling to the heat sink so that the heat sink is cantilevered into the interior to define a space between the at least one thermophotovoltaic module and the inner surface.
9. A panel assembly as recited in Claim 8, wherein the housing is tubular with a closed distal end and an open proximal end.
10. A panel assembly as recited in Claim 9, further comprising a flange surrounding the open proximal end for mounting the housing and wherein the housing is mounted to the mounting bracket.
11. A panel assembly as recited in Claim 8, wherein: the housing maintains a vacuum and, in turn, the gap is evacuated;
the heat sink defines a passageway for receiving a cooling fluid pumped therethrough;
and
the fastener is selected from the group consisting of: at least one bolt; at least one rivet; at least one staple; at least one clamp; at least one bond; and combinations thereof, and
further comprising a pressure relief valve between the housing and a vacuum source.
12. A panel assembly as recited in Claim 2, further comprising:
a housing having an inner surface defining an interior; and
at least one support element between the heat sink and the inner surface so that a space is formed around the heat sink between the at least one thermophotovoltaic module and the inner surface.

13. A panel assembly as recited in Claim 2, further comprising an electrical wire assembly coupled to the heat sink for providing electrical connections to the at least one thermophotovoltaic module.

14. A panel assembly as recited in Claim 2, further comprising:
a first housing having a first inner surface defining a first interior and the heat sink and, thereby, the at least one thermophotovoltaic module extends into the first interior;
a second housing having a second inner surface defining a second interior and the first housing extends into the second interior for protecting the first housing.

15. A panel assembly as recited in Claim 14, wherein the second housing is mounted in a hot environment and further comprising a linear actuator for moving the first housing selectively into the second housing and, thereby, the at least one thermophotovoltaic module to a desired location.

16. A panel assembly as recited in Claim 2, further comprising:
a housing having an inner surface defining an interior and the at least one thermophotovoltaic module is in the interior, wherein the housing is fixed in place in a hot environment; and
a linear actuator for moving the at least one thermophotovoltaic module to a desired location within the housing.

17. A panel assembly comprising:
a housing having an inner surface defining an interior;
a heat sink within the interior; and
at least one module coupled to the heat sink including an element assembly separated from an emitter assembly by a gap,
wherein the at least one module and inner surface define a space therebetween so that the housing absorbs energy and, thereby, radiates energy to the emitter assembly, and the emitter

assembly absorbs energy and, in turn, emits energy across the gap for conversion into electricity by the element assembly.

18. A panel assembly as recited in Claim 17, wherein the heat sink is cantilevered into the housing and the element assembly is a thermophotovoltaic element assembly.

19. A panel assembly as recited in Claim 17, wherein the heat sink is surrounded by at least one thermally insulating element to reduce thermal conduction with the housing.

20. A panel assembly as recited in Claim 17, wherein the emitter assembly applies a force for maintaining the gap.

21. A panel assembly as recited in Claim 17, wherein the module includes: a photovoltaic element; an emitter; and a base substrate between the photovoltaic element and the heat sink, and

further comprising a force application layer positioned adjacent to the emitter assembly and coupled to the base substrate.

22. A panel assembly comprising:
a housing having an inner surface defining an interior;
a heat sink within the interior; and
at least one module coupled to the heat sink,
wherein the interior includes a space between the at least one module and the inner surface so that energy coming into the housing radiates to the at least one module and, in turn, the at least one module absorbs energy to generate electricity.

23. A panel assembly as recited in Claim 22, wherein the housing is opaque and fully absorbing of surrounding heat and, upon heating, the housing then radiates infra-red energy to the at least one module.

24. A panel assembly as recited in Claim 22, wherein the housing is translucent so that some energy is absorbed to heat the housing and some energy is transferred therethrough.

25. A panel assembly as recited in Claim 22, wherein the housing is transparent so that surrounding energy is transferred therethrough to the at least one thermophotovoltaic module.

26. A panel assembly as recited in Claim 22, wherein the housing includes one or more windows that vary a level of transparency in different regions thereof.

27. A panel assembly as recited in Claim 22, wherein the at least one module includes: an emitter assembly; a photovoltaic assembly separated from the emitter assembly by a gap; and a fastener applying a force to maintain the gap,

further comprising a base substrate between the photovoltaic assembly and the heat sink, wherein the heat sink is cantilevered into the interior to define a space between the at least one module and the inner surface, and

wherein the housing maintains a vacuum.

28. A panel assembly as recited in Claim 22, wherein the heat sink defines at least one cooling bay adjacent to the at least one module and the at least one cooling bay is coupled to a cooling fluid source.

29. A panel assembly as recited in Claim 28, wherein the at least one cooling bay includes fins that facilitate the heat exchange.

30. A panel assembly as recited in Claim 28, wherein the at least one cooling bay is a plurality of cooling bays, each cooling bay having an inlet, wherein the inlets vary according to position on the heat sink to address local variation in cooling requirements.

31. A thermophotovoltaic assembly comprising:
a photovoltaic element with an effective spectrum for converting first photons in the effective spectrum into electricity; and
an emitter assembly separated from the photovoltaic assembly by a gap, wherein the emitter assembly allows the first photons in the effective spectrum to pass therethrough.
32. A thermophotovoltaic panel assembly as recited in Claim 31, wherein the emitter assembly is at least partially transparent for visual observation of the gap, wherein the emitter assembly is fabricated from a material selected from the group consisting of magnesium fluoride, quartz, silica, sapphire, quartz with a first coating, silica with a second coating, and sapphire with a third coating.
33. A thermophotovoltaic panel assembly as recited in Claim 31, wherein the emitter assembly is fabricated from a thermally insulating material.
34. A thermophotovoltaic panel assembly as recited in Claim 31, wherein the emitter assembly radiates photons in the effective spectrum when heated.
35. A thermophotovoltaic panel assembly as recited in Claim 31, wherein the emitter assembly includes a plurality of spacers formed on the emitter for maintaining the gap.
36. A thermophotovoltaic panel assembly as recited in Claim 31, wherein the emitter assembly defines a thermal isolation trench around each spacer.
37. A thermophotovoltaic panel assembly as recited in Claim 31, further comprising a backside reflector coating on the photovoltaic element for reflecting second photons outside the effective spectrum back onto the emitter for absorption.

38. A thermophotovoltaic panel assembly as recited in Claim 31, further comprising at least one layer on a side of the emitter.

39. A thermophotovoltaic panel assembly as recited in Claim 38, wherein the at least one layer is for index of refraction matching.

40. A thermophotovoltaic panel assembly comprising:
a heat sink; and
at least one thermophotovoltaic module mounted on the heat sink including:
a photovoltaic assembly having a photovoltaic element with an effective spectrum for converting first photons in the effective spectrum into electricity; and
an emitter assembly separated from the photovoltaic assembly by a gap, wherein the emitter assembly allows the first photons in the effective spectrum to pass therethrough.

41. A thermophotovoltaic panel assembly as recited in Claim 40,
wherein the heat sink defines at least one cooling bay adjacent to the at least one thermophotovoltaic module, the at least one cooling bay is coupled to a cooling fluid source by an inlet manifold, and each cooling bay defines an inlet, and
further comprising a sleeve inserted in the inlet manifold to vary flow through each cooling bay according to a position on the heat sink to address local variation in cooling requirements.

42. A thermophotovoltaic panel assembly as recited in Claim 40, further comprising a hermetic seal on the thermophotovoltaic module.

43. A thermophotovoltaic panel assembly as recited in Claim 42, wherein the hermetic seal maintains a vacuum so that only an interior of the thermophotovoltaic module is under vacuum.

44. A thermophotovoltaic panel assembly as recited in Claim 42, wherein the hermetic seal includes walls that sustain a force to maintain a gap between the emitter assembly and the photovoltaic element.

45. A thermophotovoltaic panel assembly comprising:
a photovoltaic element with an effective spectrum for converting first photons in the effective spectrum into electricity; and
an emitter assembly separated from the photovoltaic assembly by a gap, wherein the emitter assembly includes:
a substrate having a first planar surface and a second surface opposing the first surface, the second surface being separated from the photovoltaic element by a gap; and
a thin layer of optically opaque or high index material deposited on the second surface for absorbing second photons emitted from a hot radiative heat source in order to heat the emitter assembly so that the emitter assembly radiates the first photons to the photovoltaic element for absorption thereby, wherein the second photons are outside the effective spectrum.

46. A thermophotovoltaic panel assembly as recited in Claim 45, wherein the thin layer is carbon.

47. A thermophotovoltaic panel assembly as recited in Claim 45, wherein the substrate forms a plurality of spacers to set the gap.

48. A thermophotovoltaic panel assembly as recited in Claim 45, wherein the second photons are different from the first photons and the emitter assembly allows the first photons in the effective spectrum to pass therethrough.

49. A thermophotovoltaic panel assembly as recited in Claim 45, wherein the substrate is the group consisting of silica, fused silica, quartz, and fused quartz.

50. A thermophotovoltaic panel assembly as recited in Claim 45, further comprising a back-side reflector layer on the photovoltaic element.

51. A thermophotovoltaic panel assembly as recited in Claim 50, wherein the back-side reflector layer is gold.

52. A method of manufacturing an emitter for a thermophotovoltaic panel assembly with a photovoltaic element, the method comprising the steps of:

providing an optically transparent substrate having a first surface and a second surface opposing the first surface;

forming a plurality of spacers on the second surface for separating the emitter from the photovoltaic element by a gap; and

depositing a thin layer of optically opaque material on the second surface for absorbing first photons emitted from a hot radiative heat source in order to heat the emitter so that the emitter can radiate second photons to the photovoltaic element for absorption thereby.

53. A thermophotovoltaic panel assembly as recited in Claim 4, further comprising:

a base substrate between the photovoltaic assembly and the heat sink, the base substrate defining a plurality of recesses, each recess having a mounting assembly therein, each mounting assembly including a nut and a spring; and

a force application layer positioned adjacent to the emitter, and the fastener is a plurality of bolts, each bolt for coupling to a nut in the recess.

54. A thermophotovoltaic panel assembly as recited in Claim 53, wherein the recesses include: an outer portion sized and configured to retain the nut in a set orientation; and an inner portion that is relatively more radially narrow so that when assembled, the spring is retained in the inner portion by the nut, and the plurality of bolts passes through the spring and threadably couples to the nut so that the spring provides a compressive force.

55. A thermophotovoltaic panel assembly as recited in Claim 53, wherein a shape of the force application layer is somewhat square, and the plurality of bolts is 8 bolts arranged in opposing pairs in corners of the shape.

56. A portable diagnostic tool for evaluating production of power from waste heat environments comprising:
an energy conversion assembly;
a mounting system coupled to the energy conversion assembly for selectively inserting the thermophotovoltaic panel assembly into the waste heat environment; and
a control unit coupled to the mounting system and the thermophotovoltaic panel assembly for controlling operation of the thermophotovoltaic panel assembly

57. A portable diagnostic tool as recited in Claim 56, wherein the mounting system includes a base structure, locking swivel casters on the base structure for moving the portable diagnostic tool, an alarm unit, a cooling system, a vacuum system, and a rail system for selectively moving the thermophotovoltaic panel assembly along an axis.

58. A portable diagnostic tool as recited in Claim 57, wherein at least one of the cooling unit and the vacuum unit are placed to act as a counter-balance during deployment of the thermophotovoltaic panel assembly.

59. A portable diagnostic tool as recited in Claim 56, wherein the control unit includes video recording and monitoring equipment, connectors for coupling to utilities, a UPS backup unit, a data acquisition module, and a remote access control unit.

60. A portable diagnostic tool as recited in Claim 59, wherein the control unit is operable to automatically retract the thermophotovoltaic panel assembly from the waste heat environment when a predetermined condition is met.

61. A portable diagnostic tool as recited in Claim 60, wherein the control unit controls a speed of insertion and a speed of extraction.

62. A portable diagnostic tool as recited in Claim 56, wherein the energy conversion assembly includes a thermophotovoltaic panel assembly having:

- a heat sink;

- at least one thermophotovoltaic module mounted on the heat sink including:

- an emitter assembly;

- a photovoltaic assembly separated from the emitter assembly by a gap; and

- a fastener applying a force to maintain the gap; and

- a housing having an inner surface defining an interior;

- a mounting bracket; and

- at least one support bar extending from the mounting bracket and coupling to the heat sink so that the heat sink is cantilevered into the interior to define a space between the at least one thermophotovoltaic module and the inner surface.