INTEGRATED ENERGY SYSTEM FOR WHOLE HOME OR BUILDING

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Publication Classification

Int. Cl.
F25B 29/00  (2006.01)
F24J 2/04  (2006.01)
F24J 2/46  (2006.01)
F24J 2/42  (2006.01)
H01L 35/30  (2006.01)

U.S. Cl. ......... 165/48.2; 126/640; 126/628; 126/615; 126/714; 136/205

ABSTRACT

An integrated energy system for a home or other building utilizes a heated reservoir for energy storage. The reservoir is mainly heated by one or more solar collectors. The system also includes an environment-coupled piping loop through which a cooling fluid is circulated such that heat is exhausted from the cooling fluid to the environment. The thermal energy from the reservoir and the cooling fluid are then used in an integrated set of systems that provide space heating, space cooling, and electrical generation. Electricity is generated by a thermoelectric generator that exploits the temperature differential between the reservoir and the cooling fluid. The system may include heating and storage for domestic hot water, and may use excess power for hydrogen production. Backup heating and electrical systems may be provided for.
FIG. 2
INTEGRATED ENERGY SYSTEM FOR WHOLE HOME OR BUILDING

[0001] This application claims priority to provisional application 61/060,377, filed Jun. 10, 2008 and titled “Combined Heat and Power and Hydrogen Generation for Whole Home or Building with Ground Heat Exchanger Using Thermoelectric Seebeck Modules,” the entire disclosure of which is hereby incorporated by reference herein for all purposes.

CROSS REFERENCE TO RELATED APPLICATIONS

[0002] This application is related to U.S. patent application Ser. No. ____ (Attorney docket number 027483-000300US), titled “Automatic Configuration of Thermoelectric Generation System to Load Requirements” and to U.S. patent application Ser. No. ____ (Attorney docket number 027483-000500US), titled “Thermoelectric Generator”, both having the same inventor as the present application and filed Jun. 10, 2009. The disclosures of those two applications are hereby incorporated herein in their entirety for all purposes. Provisional U.S. patent application 60/306,274, titled “Combination outdoor portable heating pad and electricity generator” is also hereby incorporated by reference herein for all purposes.

BACKGROUND OF THE INVENTION

[0003] A typical home or other building includes several energy systems. For example, the building maybe connected to the mains power grid and receive electrical power generated at a remote power plant. The building may be supplied with natural gas for space and water heating. Many of these traditional energy systems depend on non-renewable and ever-more-expensive fossil fuels.

[0004] Alternative energy systems have been proposed. However, prior alternative energy systems have evolved piecemeal. Furthermore, many alternative electrical systems rely on photovoltaic cells to generate electricity from sunlight, and store the resulting electrical energy in batteries. While the day-to-day operating cost of a photovoltaic system is low, these systems typically have a high installation cost, and the batteries have a finite life, requiring expensive periodic replacements. Battery systems also are typically oversized, as the life of the batteries is optimized by avoiding discharges of more than 20 percent of the stored energy from the batteries.

BRIEF SUMMARY OF THE INVENTION

[0005] In one embodiment, an integrated energy system for a building comprises at least one reservoir of thermal energy, at least one solar collector that provides heat to the reservoir, and at least one environment-coupled piping loop through which a cooling fluid is circulated such that heat is exhausted from the cooling fluid to the environment. The system further comprises a thermoelectric generator that generates electric power from a temperature differential between the reservoir of thermal energy and the cooling fluid, and at least one hydronic heating unit through which heated fluid is piped, providing space heating to at least one space in the building, the heated fluid deriving its heat from the reservoir of thermal energy. The system may also comprise at least one hydronic cooling loop through which at least some of the cooling fluid is piped, providing space cooling to at least one space in the building. In some embodiments, the system further comprises a backup heater that provides heat to the reservoir of thermal energy, supplementing the solar collector. The backup heater may derive heat from a fossil fuel.

[0006] In some embodiments, the system comprises a tank of hot water designated for domestic hot water use. The system may further comprise a backup domestic water heater that supplies heat to water designated for domestic hot water use when insufficient energy is otherwise available. The backup domestic water heater may comprise at least one on-demand heater. The backup domestic water heater may derive heat from a fossil fuel.

[0007] In some embodiments, the system further comprises a direct-current power grid within the building. In some embodiments, the system includes an inverter that converts direct-current power from the thermoelectric generator to alternating-current power.

[0008] In some embodiments, the thermoelectric generator comprises a plurality of banks, and the integrated energy system further comprises a thermoelectric generator controller and a matrix switch that, under control of the thermoelectric generator controller, configures the interconnection of the banks.

[0009] In some embodiments, the system further comprises a load controller that at least temporarily prevents the operation of at least one load based in part on the amount of electrical power being consumed by other loads. In some embodiments, the system comprises a backup connection to the mains power grid, the backup connection providing electrical power to the building to supplement the thermoelectric generator.

[0010] In some embodiments, the system includes a hydrogen generator powered by electricity from the thermoelectric generator. The system may also include a backup domestic water heater, wherein the backup domestic water heater derives heat from hydrogen generated by the hydrogen generator.

[0011] In some embodiments, the reservoir of thermal energy comprises a tank of heated water. A medium in the reservoir of thermal energy may be heated directly by the solar collector. The medium in the reservoir of thermal energy may be heated though a heat exchanger carrying a second medium heated by the solar collector.

[0012] In some embodiments, the heated fluid circulated through the at least one hydronic heating unit derives its heat from the reservoir of thermal energy through a heat exchanger. The at least one environment-coupled piping loop may comprise a deep earth-coupled piping loop. The at least one environment-coupled piping loop may comprise a shallow earth-coupled piping loop. The at least one environment-coupled piping loop may comprise an air-coupled piping loop.

[0013] In another embodiment, a method of operating an energy system in a building comprises, heating a reservoir of thermal energy using a solar collector. Heated fluid that derives its heat from the reservoir of thermal energy is circulated through a hydronic heating loop, providing space heating to at least one space in the building. A cooling fluid is circulated through an environment-coupled piping loop such that heat is exhausted from the cooling fluid to the environment, and electrical power is generated a thermoelectric generator subjected to a temperature differential between reservoir and the cooling fluid.
In some embodiments, the method further comprises circulating at least some of the cooling fluid through a hydronic cooling loop, providing space cooling to at least one space in the building. The method may comprise generating hydrogen using electrical energy generated by the thermoelectric generator. In some embodiments, the method comprises storing, separately from the reservoir of thermal energy, water designated for domestic hot water use. In some embodiments, the method further comprises heating the water designated for domestic hot water use with heat from the reservoir of thermal energy. In some embodiments, the method comprises dynamically configuring, using a thermoelectric generator controller, interconnections of thermoelectric modules within the thermoelectric generator. In some embodiments, the method comprises temporarily preventing the operation of at least one electrical load based in part on the amount of electrical power being consumed by other loads. In some embodiments, circulating the cooling fluid through and environment-coupled piping loop comprises circulating the cooling fluid through and earth-coupled piping loop.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**FIG. 1** shows an integrated energy system for a building in accordance with a first embodiment.

**FIG. 2** shows a portion of the system of **FIG. 1** in greater detail, in accordance with another embodiment.

**DETAILED DESCRIPTION OF THE INVENTION**

An integrated energy system for a home or other building utilizes a heated reservoir for energy storage. The reservoir is mainly heated by one or more solar collectors. The system also includes at least one environment-coupled piping loop through which a cooling fluid is circulated such that heat is exhausted from the cooling fluid to the environment. The thermal energy from the reservoir and the cooling fluid are then used in an integrated set of systems that provide space heating, space cooling, and electrical generation. Electricity is generated by a thermoelectric generator that exploits the temperature differential between the reservoir and the cooling fluid. The system may include heating and storage for domestic hot water, and may use excess power for hydrogen production. Backup heating and electrical systems may be provided for.

The ensuing description provides preferred exemplary embodiment(s) only, and is not intended to limit the scope, applicability or configuration of the disclosure. Rather, the ensuing description of the preferred exemplary embodiment(s) will provide those skilled in the art with an enabling description for implementing a preferred exemplary embodiment. It being understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope as set forth in the appended claims.

Specific details are given in the following description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits may be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine readable medium. A processor(s) may perform the necessary tasks.

Prior alternative energy systems have evolved piecemeal. For example, in a typical “solar” home, electricity generation is provided by photovoltaics with battery storage, while domestic hot water is provided by direct solar heating of water. Space heating may be enhanced by passive solar design techniques, with supplemental backup provided by burning natural gas, propane, wood, or another fuel. Space cooling may or may not be provided. This piecemeal approach to building energy management is complex and involves many different technologies. Electricity generation by photovoltaics requires different solar collectors than those used for water heating, and requires expensive batteries that require periodic replacement. The batteries are typically oversized, in order to maximize their useful life by avoiding deep discharges.

Embodiments of the present invention exploit efficiencies made possible by integrating the various energy systems in a building. A single solar collector (or collector array) heats a reservoir of thermal energy. The reservoir of thermal energy may be a simple tank of heated water that stores thermal energy by virtue of the elevated temperature of the water. In other embodiments, the reservoir of thermal energy may comprise another medium, for example a eutectic or phase change medium such as Glauber’s salt that stores energy primarily in the change of the salt between solid and liquid phases.

The reservoir of thermal energy is used for multiple purposes in the system. The thermal energy may be used directly for space and domestic water heating. Electricity generation is provided by a thermoelectric generator, using the elevated temperature of the reservoir as the “hot” side of a temperature differential exploited by the thermoelectric generator. The other “cold” side of the temperature differential is provided by a cooling fluid, preferably water, circulated through an environment-coupled piping loop that cools the fluid via its thermal contact with the earth or atmosphere. The cooling fluid may also be used for hydronic space cooling.

The advantages of such a system will be apparent to one of skill in the art. Energy storage is provided by a single reservoir, which may be as simple as a tank of water. No harsh or dangerous chemicals are needed for energy storage, and no expensive battery replacement is ever needed. Space heating, domestic water heating, and electrical generation are powered by a single solar collector or array of collectors. Space cooling comes as a by-product of electrical generation. Such a system is simpler, less expensive, and more flexible than the traditional piecemeal approach to alternative energy systems.

**FIG. 1** shows an integrated energy system 100 for a building 109 in accordance with a first embodiment. In example system 100, a solar collector 101 heats fluid in a tube 103, using energy from the sun 104. In this example, solar collector 101 is a concentrating type solar collector, for example a parabolic trough that concentrates solar radiation on tube 103 and tracks the motion of the sun under control of a motor 102. One of skill in the art will recognize that other kinds of solar collectors may be used, including flat panel collectors or heat pipe collectors. One collector or an array of...
collectors may be used, depending on the design capacity of the system. At present, many square meters of collector area may be needed to provide sufficient electrical generation capacity in system 100, but it is anticipated that future improvements in the efficiency of thermoelectric materials will reduce the required collector area dramatically.

The fluid in tube 103 is heated and is circulated by a pump (not shown), carrying thermal energy to a reservoir of thermal energy 105. The working fluid in tube 103 may be water, a natural or synthetic oil, or another kind of fluid. Reservoir 105 contains a storage medium. The medium may simply be water. If water from reservoir 105 is also circulated through tube 103, then the water is heated directly by solar collector 101. Alternatively, the medium in reservoir 105 may be heated indirectly, for example, through a heat exchanger. For example, if the working fluid in tube 103 is an oil and the storage medium in reservoir 105 is water, the water may take heat from the oil through a heat exchanger. If the storage medium in reservoir 105 is water, it is estimated that a 1000 gallon reservoir will be sufficient for a typical residential application. Preferably, the pump circulating the fluid in tube 103 operates only as necessary to maintain the temperature of reservoir 105. For example, the pump may be turned off at night when no effective fluid heating is available from solar collector 101.

The storage medium in reservoir 105 may be another kind of medium. In some embodiments, the medium in reservoir 105 may be a phase-change medium such as Glauber’s salt, which efficiently stores thermal energy by virtue of a phase change from solid to liquid. Other media, including other phase change media, may be used.

Reservoir 105 provides simple, reliable, maintenance-free energy storage for the system. The storage medium need not be changed or serviced, as would be the case with batteries.

Thermal energy from reservoir 105 may be used directly or indirectly for various heating needs in the building. For example, if the medium in reservoir 105 is water, water could be drawn from reservoir 105 for domestic hot water use. In that case, reservoir 105 would be replenished with additional supply water as needed to replace that drawn off for use. For the purposes if this disclosure, “domestic hot water” is heated water used for washing, bathing, cooking, or other processing or the like, whether system 100 is installed in a home, business, or industrial setting. Domestic water is typically dispensed to a sanitary sewer after use. “Supply water” is water from an external water supply, such as a municipal water utility, a local well, or other source.

Preferably, especially where a medium other than water is used in reservoir 105, domestic hot water may be heated from reservoir 105 by use of a heat exchanger, and optionally may be stored in a separate tank 106. Separate storage with independent temperature control may be advantageous because domestic water should be stored within a narrow temperature range for safety and utility reasons. The medium in reservoir 105 may undergo large temperature fluctuations during operation of system 100, and may reach temperatures that would be unsafe for domestic hot water use.

A similar arrangement may be used for water used for space heating. Water from reservoir 105 may be circulated to a hydronic heating loop 107 that may include baseboard, subfloor, valence or other piping and fixtures that provide heat to spaces in the building primarily through convection, radiation, or both. Alternatively, the fluid circulated through hydronic heating loop 107 may derive its heat from reservoir 105 through a heat exchanger. Optionally, a separate storage tank 108 may be provided for the water or other fluid used for hydronic heating, enabling separate temperature control. In some embodiments, the fluid used for hydronic heating may be a fluid other than pure water, for example a water and antifreeze mix.

Optionally, backup heating may be provided to one or more of the heated reservoirs in the system, including any one, any combination, or all of reservoir 105 and any additional storage tanks such as tanks 106 and 107. Backup heating may be in the form of a boiler or other kind of heater that burns fossil fuel, or may be another kind of heater. Backup heating may be required during extended periods without adequate sun to maintain a sufficient temperature of reservoir 105, or during times when temporary guests increase the energy demands of building 109.

If backup heating is supplied to reservoir 105, then a single backup heater may be sufficient. Alternatively, separate backup heating units may be provided for domestic hot water tank 106 and space heating storage tank 108, if they are present. In yet another alternative, backup heating for domestic hot water may be an “on demand” type heater that heats water only as it is used, rather than maintaining a tank of hot water at a specified temperature. An on-demand heater may be placed at a central location and heat water for domestic hot water use throughout the building, or multiple on-demand heaters may be placed at the various points of use of hot water, such as one in each bathroom and kitchen.

In another aspect of system 100, water or another fluid is circulated by a pump (not shown) through an environment-coupled piping loop such as deep earth-coupled piping loop 110. Deep earth-coupled piping loop 110 cools this “cooling fluid” by virtue of its thermal contact with the earth. Heat is exhausted from the cooling fluid to the earth, thereby maintaining the cooling fluid at a relatively cold temperature. At sufficient depths, usually about five feet (1.6 m) or more below the surface, the earth maintains a relatively constant temperature, for example about 54-57°F (12-14°C) in many parts of the United States. Alternatively or additionally, other environment-coupled piping loops such as shallow earth-coupled piping loop 122 or air-coupled piping loop 123 may be used as described in more detail below. Optionally, a storage tank 111 for some of the cooling fluid is provided. The cooling fluid may also be used for multiple purposes. In one use, some of the cooling fluid is circulated as needed through a hydronic cooling loop 112 that may include baseboard, subfloor, valence or other piping and fixtures that remove heat from spaces in the building primarily through convection, radiation, or both. It is estimated that 1000 feet of tubing coiled in a trench 100 feet long can provide one ton (12,000 BTU/hr, or 3.516 kW) of cooling capacity. Vertical cooling wells can be used to save space, but at a slightly higher installation cost. Preferably, the pump circulating the cooling fluid operates only as needed to maintain a relatively cold temperature in the fluid supplied to hydronic cooling loop 112, and for electricity generation as described below. Typically, fluid will be circulated through only one of hydronic cooling loop 112 and hydronic heating loop 107 at any one time.

Generation of electricity is provided by a thermoelectric generator 113. A thermoelectric generator generates electrical power from a difference in temperature using the thermoelectric effect exhibited by many materials. A typical
thermoelectric generator comprises many thermoelectric elements arranged in thermoelectric couples. Each thermoelectric element may be a conductive or semiconductive element, for example pieces of n-type and p-type semiconductor material. The elements are connected electrically in series and thermally in parallel in a thermoelectric module. The module produces a direct current (DC) voltage that is a function of the properties of the materials used, the temperature differential, the absolute temperature at which the generator is operated, the size of the module, and other factors. More information about thermoelectric generators is found in the related applications previously incorporated herein by reference. A thermoelectric generator may have a life span of 200,000 hours, making it suitable for long-term use without expensive replacement.

In system 100, the temperature differential between reservoir 105 and the cooling fluid circulating through an environment-coupled piping loop is exploited to generate electricity. Fluid drawn from or heated by reservoir 105 may be circulated to a “hot” side of thermoelectric generator 113, while cooling fluid is circulated to a “cold” side of thermoelectric generator 113. In some embodiments, for residential use, thermoelectric generator 113 produces about 1 kW when subjected to a temperature differential of 110° F. (61° C.). This amount of power is sufficient to supply most of the electrical needs of a conservatively-managed household. The system may be scaled up as needed by adding additional capacity to reservoir 105 and additional thermoelectric modules to thermoelectric generator 113.

While deep earth-coupled piping loop 110 is one example of an environment-coupled piping loop that may be used to cool the cooling fluid, the system may be further optimized by the use of other kinds of environment-coupled loops as well. For example, a shallow earth-coupled loop 122 may be provided. Shallow earth-coupled piping loop 122 may be placed, for example, within about 1.5 feet (0.5 m) of the ground surface. During the winter, soil temperatures near the surface may be significantly colder than the relatively constant temperature maintained several feet below surface. In some places, the ground may even freeze to a depth of several inches during the winter. The temperature differential experienced by thermoelectric generator 113, and therefore also the amount of power generated by thermoelectric generator 113, may be increased if the cooling fluid is circulated through shallow earth-coupled piping loop 122 rather than deep earth-coupled piping loop 110 during times when the surface temperature is colder. Similarly, alternatively or additionally, an air-coupled piping loop 123 may be provided. During times of extreme cold weather, air-coupled piping loop 123 exposed to the atmosphere may experience temperatures even colder than shallow earth-coupled piping loop 122, and may therefore cool the cooling fluid to an even colder temperature so that the amount of power generated by thermoelectric generator 113 may be even further increased by circulating the cooling fluid through air-coupled piping loop 123.

When any of the environment-coupled piping loops is expected to experience below-freezing temperatures, the cooling fluid circulated through that loop is preferably not pure water, but may be water mixed with anti-freeze, or another kind of fluid. It is not necessary that all of the environment-coupled piping loops be present or carry the same cooling fluid, as long as the cooling fluids can efficiently remove heat from thermoelectric generator 113. Typically, the cooling fluid would be circulated through only one environment-coupled piping loop at a time. In one scenario, a system controller selects which environment-coupled piping loop to utilize at any particular time based on the temperatures experienced by each of them.

Because a thermoelectric generator produces DC, system 100 may include as many appliances and other electrical devices as possible that can operate on DC power. For example, lighting 114 may be based on light emitting diodes (LEDs) for very efficient light production from DC power. Many other appliances are available that operate on DC power, and it is anticipated that the number of available DC-powered appliances will grow in the future. For those loads that can utilize DC power, system 100 preferably includes a DC power bus throughout building 109.

In the interim, some loads may still best utilize alternating current (AC) power, for example refrigerator 115. System 100 may therefore include one or more inverters 116, which convert the DC output of thermoelectric generator 113 to AC power. In some embodiments, multiple small inverters may be used in place of a single large-capacity inverter, so that in the event of an inverter failure, a reduced-capacity system can still be operated until the failed inverter is repaired or replaced.

Backup may also be provided for the electrical portion of system 100, in the form of a connection 117 to the mains grid, for example a public utility. Alternatively, a local gasoline-powered or other generator may be connected at connection 116 for emergency use or during times of increased electrical use, for example when hosting guests.

As is apparent from the above discussion, system 100 provides many useful advantages, including the use of energy stored in reservoir 105 for multiple purposes, including both heating and electrical generation. Because energy is stored in reservoir 105, heating, cooling, and electrical generation can continue even at night or during inclement weather when little or no solar radiation is available.

FIG. 1 shows also shows other optional features of system 100, in accordance with other embodiments. Thermoelectric generator 113 may power a hydrogen generator 118 that generates hydrogen, for example from supply water by means of electrolysis or another process, when power is available from thermoelectric generator 113. In one mode of operation, power may be diverted to the hydrogen generator overnight when electrical demands of building 109 are otherwise low. Hydrogen from hydrogen generator 118 could be supplied to a hydrogen powered vehicle 119, or could be stored for other uses, for example to heat domestic hot water when backup heating is needed. Hydrogen generator 118 and associated storage would thus provide additional energy storage utilized during times when reservoir 105 is at its thermal capacity and surplus power is available from thermoelectric generator 113.

Because thermoelectric generator 113 has a finite power output capability, it may be helpful to manage the power demand of building 109. In some embodiments, a load controller 120 may be provided that manages the operation of certain appliances. Load controller 120, may be, for example, a computerized device that monitors the operation of various appliances and other loads, and controls the availability of power to them. The effect may be time-shifting of certain loads in deference to other loads so that power is made available where needed, but the overall operation of the appliances is still satisfactory. In one simple example of the operation of
load controller 120, refrigerator 115 may be prevented from operating when microwave oven 121 is in operation. A microwave oven is an appliance that the user typically wants to use immediately for a short time. A refrigerator operates intermittently, and persons in the household often are not even aware of whether the refrigerator is running. A short delay in the operation of a refrigerator has negligible effect on its performance. Delaying the operation of the refrigerator 115 until microwave 121 is finished prevents both from contributing to the electrical demand at the same time, with little or no perceived effect on the operation of either appliance. Potentially, this arrangement reduces the peak electrical demand of building 109. Many other appliance timing, delay, or interlock strategies may be envisioned. For example, the operation of a clothes dryer may be prevented while an electric range is in operation, or the intensity of lighting may be reduced to free up electrical capacity for the operation of a hair dryer. Many other examples are possible. In other embodiments, certain appliances may be constrained to operate only during certain times of the day. For example, a clothes dryer may be allowed to operate only between 10:00 AM and 3:00 PM, when maximum solar radiation is typically available.

FIG. 2 shows a portion of system 100 in greater detail, in accordance with another embodiment. As thermal energy is drawn from reservoir 105, whether for heating or electricity generation, the temperature differential across thermoelectric generator 113 decreases, and consequently the voltage produced by thermoelectric generator 113 also decreases. Certain loads may have specific voltage ranges in which they must operate. For example, inverter 116 may require that its input voltage be within a certain range, or DC appliances may operate most effectively when supplied with power within a specified voltage range, e.g. near 36 or 48 volts. In the embodiment of FIG. 2, thermoelectric generator 113 comprises multiple banks 201 of thermoelectric elements. Each bank produces a portion of the electrical power available from thermoelectric generator 113, and outputs its power on one of sets of leads 209. A matrix switch 206 dynamically configures the interconnections of the banks to maintain certain power characteristics at main output leads 210. For example, when the full temperature differential is available, matrix switch may configure the banks in parallel, but when the temperature differential is reduced such that each bank produces only a fraction of the voltage it produces at full power, matrix switch 206 may connect the banks in series so that the output voltage is maintained within the required levels. Matrix switch 206 may also interconnect the banks in various series and parallel combinations as needed.

A monitor 202 senses the character of the power being produced at main output leads 210, and sends a signal 203 to a controller 204, which then signals 205 matrix switch 206 to change its interconnection. Monitor 202 may measure the voltage produced at leads 210 using sensing connections 207, may measure the current being supplied using a current probe 208, or may measure some other characteristic upon which to make a decision about the interconnection of the banks.

In this way, nearly all of the energy stored in reservoir 105 may be extracted for electricity generation. (Although the amount of available power may decline as the temperature of reservoir 105 declines.) By comparison, batteries may be restricted to supplying only 20% of their stored energy. More detail about the operation of matrix switch 206 may be found in the applications previously incorporated herein by reference.

The invention has now been described in detail for the purposes of clarity and understanding. However, it will be appreciated that certain changes and modifications may be practiced within the scope of the appended claims.

What is claimed is:

1. An integrated energy system for a building, the system comprising:
   at least one reservoir of thermal energy;
   at least one solar collector that provides heat to the reservoir;
   at least one environment-coupled piping loop through which a cooling fluid is circulated such that heat is exhausted from the cooling fluid to the environment;
   a thermoelectric generator that generates electric power from a temperature differential between the reservoir of thermal energy and the cooling fluid; and
   at least one hydronic heating unit through which heated fluid is piped, providing space heating to at least one space in the building, the heated fluid deriving its heat from the reservoir of thermal energy.

2. The integrated energy system for a building of claim 1, further comprising at least one hydronic cooling loop through which at least some of the cooling fluid is piped, providing space cooling to at least one space in the building.

3. The integrated energy system for a building of claim 1, further comprising:
   a backup heater that provides heat to the reservoir of thermal energy, supplementing the solar collector.

4. The integrated energy system for a building of claim 3, wherein the backup heater derives heat from a fossil fuel.

5. The integrated energy system for a building of claim 1, further comprising a tank of hot water designated for domestic hot water use.

6. The integrated energy system for a building of claim 1, further comprising a backup domestic water heater that supplies heat to hot water designated for domestic hot water use when insufficient energy is otherwise available.

7. The integrated energy system for a building of claim 6, wherein the backup domestic water heater comprises at least one on-demand heater.

8. The integrated energy system for a building of claim 6, wherein the backup domestic water heater derives heat from a fossil fuel.

9. The integrated energy system for a building of claim 1, further comprising a direct-current power grid within the building.

10. The integrated energy system for a building of claim 1, further comprising an inverter that converts direct-current power from the thermoelectric generator to alternating-current power.

11. The integrated energy system for a building of claim 1, wherein the thermoelectric generator comprises a plurality of banks, the integrated energy system further comprising:
   a thermoelectric generator controller; and
   a matrix switch that, under control of the thermoelectric generator controller, configures the interconnection of the banks.

12. The integrated energy system for a building of claim 1, further comprising a load controller that at least temporarily prevents the operation of at least one load based in part on the amount of electrical power being consumed by other loads.
13. The integrated energy system for a building of claim 1, further comprising a load controller that constrains at least one appliance to operate only during certain predetermined time intervals.

14. The integrated energy system for a building of claim 1, further comprising a backup connection to the mains power grid, the backup connection providing electrical power to the building to supplement the thermoelectric generator.

15. The integrated energy system for a building of claim 1, further comprising a hydrogen generator powered by electricity from the thermoelectric generator.

16. The integrated energy system for a building of claim 15, further comprising a backup domestic water heater, and wherein the backup domestic water heater derives heat from hydrogen generated by the hydrogen generator.

17. The integrated energy system for a building of claim 1, wherein the reservoir of thermal energy comprises a tank of heated water.

18. The integrated energy system for a building of claim 1, wherein a medium in the reservoir of thermal energy is heated directly by the solar collector.

19. The integrated energy system for a building of claim 1, wherein a medium in the reservoir of thermal energy is heated though a heat exchanger carrying a second medium heated by the solar collector.

20. The integrated energy system for a building of claim 1, wherein the heated fluid circulated through the at least one hydronic heating unit derives its heat from the reservoir of thermal energy through a heat exchanger.

21. The integrated energy system for a building of claim 1, wherein the at least one environment-coupled piping loop comprises a deep earth-coupled piping loop.

22. The integrated energy system for a building of claim 1, wherein the at least one environment-coupled piping loop comprises a shallow earth-coupled piping loop.

23. The integrated energy system for a building of claim 1, wherein the at least one environment-coupled piping loop comprises an air-coupled piping loop.

24. A method of operating an energy system in a building, the method comprising:
   - heating a reservoir of thermal energy using a solar collector,
   - circulating heated fluid through a hydronic heating loop, providing space heating to at least one space in the building, the heated fluid deriving its heat from the reservoir of thermal energy;
   - circulating a cooling fluid through an environment-coupled piping loop such that heat is exhausted from the cooling fluid to the environment; and
   - generating electrical power in a thermoelectric generator subjected to a temperature differential between reservoir and the cooling fluid.

25. The method of operating an energy system in a building of claim 24, further comprising:
   - circulating at least some of the cooling fluid through a hydronic cooling loop, providing space cooling to at least one space in the building.

26. The method of operating an energy system in a building of claim 24, further comprising:
   - generating hydrogen using electrical energy generated by the thermoelectric generator.

27. The method of operating an energy system in a building of claim 24, further comprising:
   - storing, separately from the reservoir of thermal energy, water designated for domestic hot water use.

28. The method of operating an energy system in a building of claim 27, further comprising heating the water designated for domestic hot water use with heat from the reservoir of thermal energy.

29. The method of operating an energy system in a building of claim 24, further comprising dynamically configuring, using a thermoelectric generator controller, interconnections of thermoelectric modules within the thermoelectric generator.

30. The method of operating an energy system in a building of claim 24, further comprising temporarily preventing the operation of at least one electrical load based in part on the amount of electrical power being consumed by other loads.

31. The method of operating an energy system of claim 24, wherein circulating the cooling fluid through an environment-coupled piping loop comprises circulating the cooling fluid through an earth-coupled piping loop.

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