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(19) **United States**(12) **Patent Application Publication**
Bloxam(10) **Pub. No.: US 2010/0083950 A1**(43) **Pub. Date: Apr. 8, 2010**(54) **SOLAR ENERGY WATER HEATING SYSTEM****Publication Classification**(76) Inventor: **Michael J. Bloxam**, London (CA)(51) **Int. Cl.**
F24J 2/40 (2006.01)
F24J 2/42 (2006.01)(52) **U.S. Cl.** **126/585; 126/615**(57) **ABSTRACT**Correspondence Address:
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In one aspect, the invention is directed to a solar energy water heating system for heating water in a water storage tank. In one particular embodiment, the system includes a controller, a solar energy collector whose energy contribution to water in the tank is controlled by the controller, and a non-solar heating system that is not controlled by the controller. Water in the tank may be heated by one or both of the non-solar heating system and energy from the solar energy collector. The controller can determine the amount of energy contributed by solar energy to the water in the tank. In another embodiment, the solar energy water heating system incorporates a controller that controls both the operation of the pump and the operation of the non-solar heating system. In another embodiment, a network of solar energy water heating systems is provided.

(21) Appl. No.: **12/567,007**(22) Filed: **Sep. 25, 2009****Related U.S. Application Data**

(60) Provisional application No. 61/100,002, filed on Sep. 25, 2008.

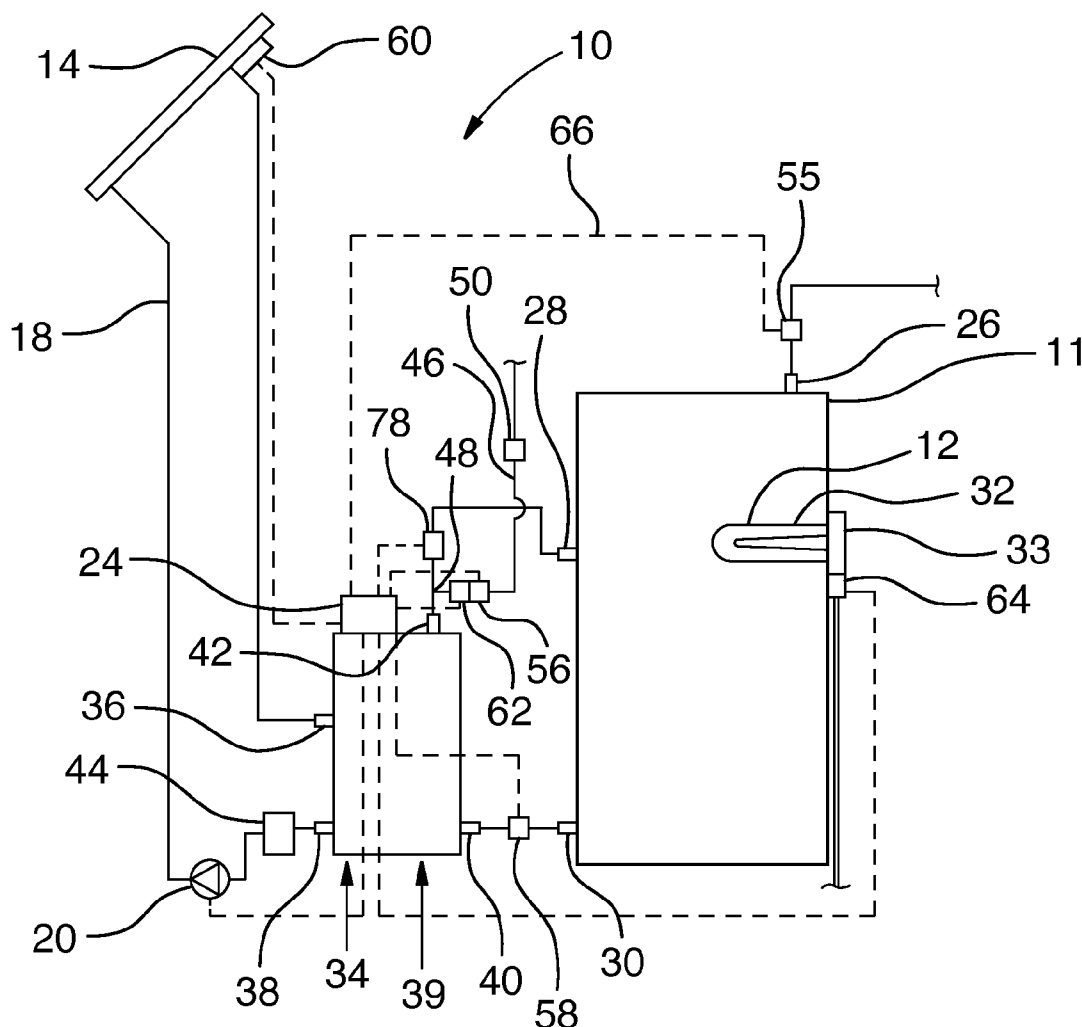


FIG.1

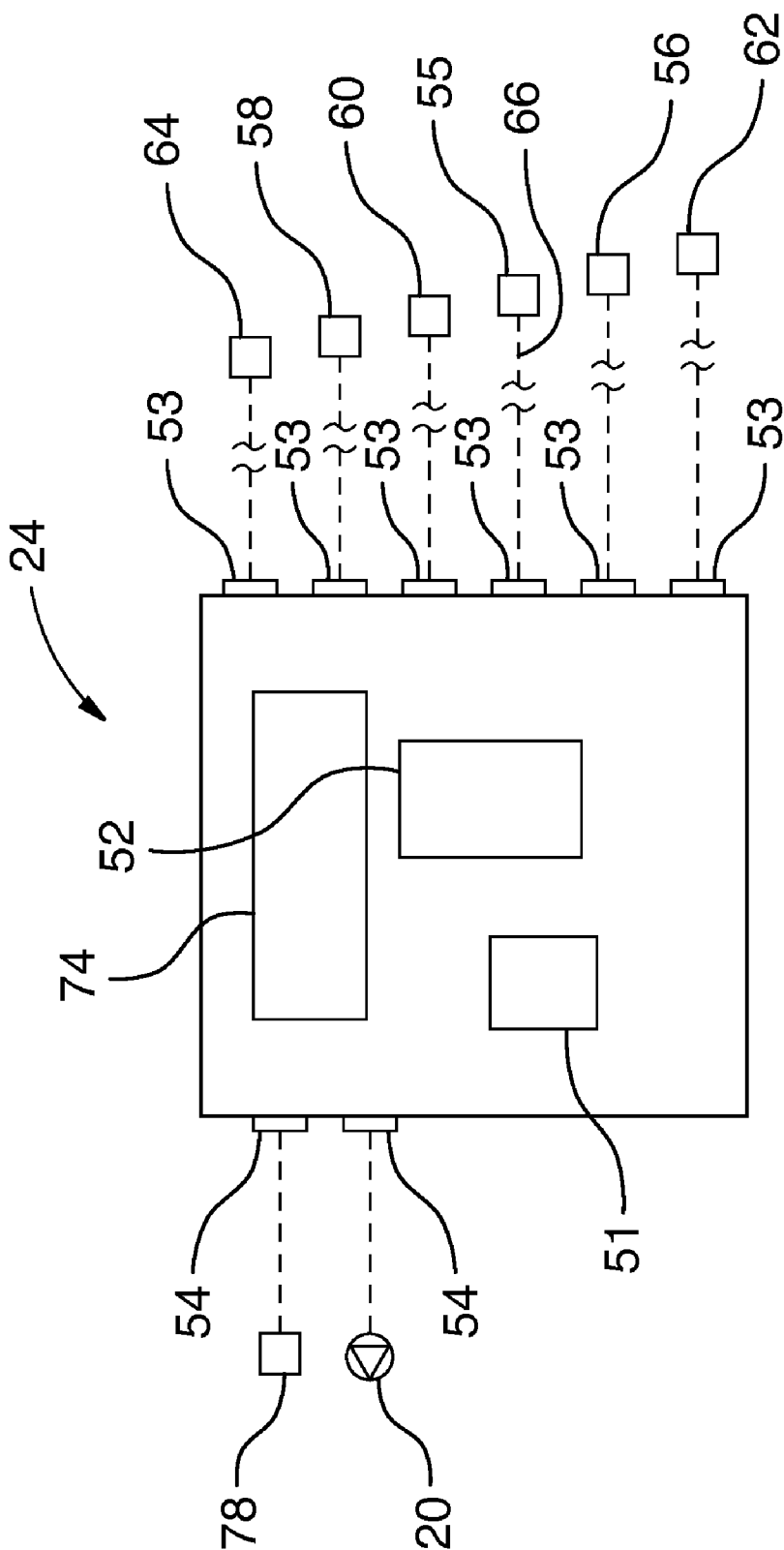


FIG.2

FIG.3

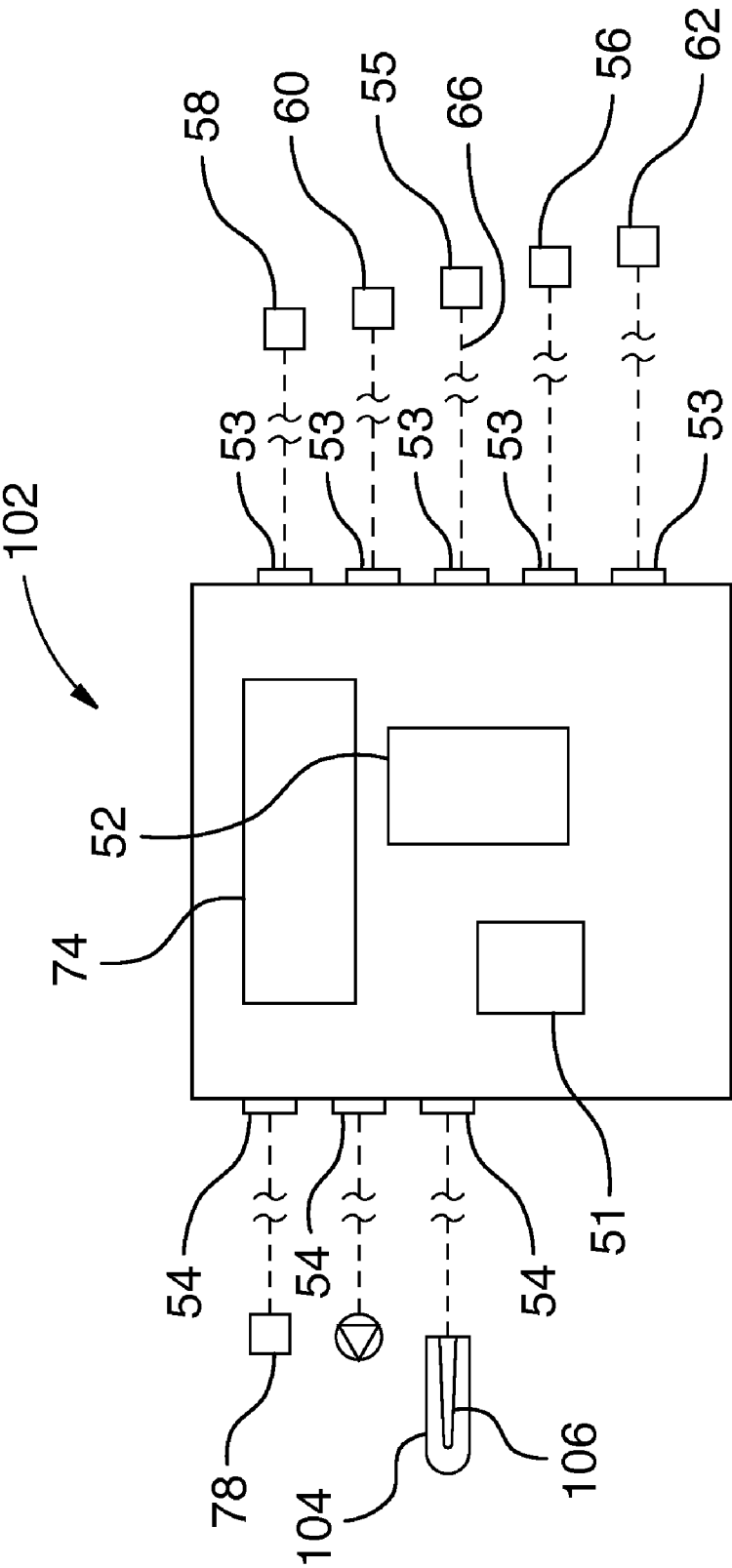


FIG.4

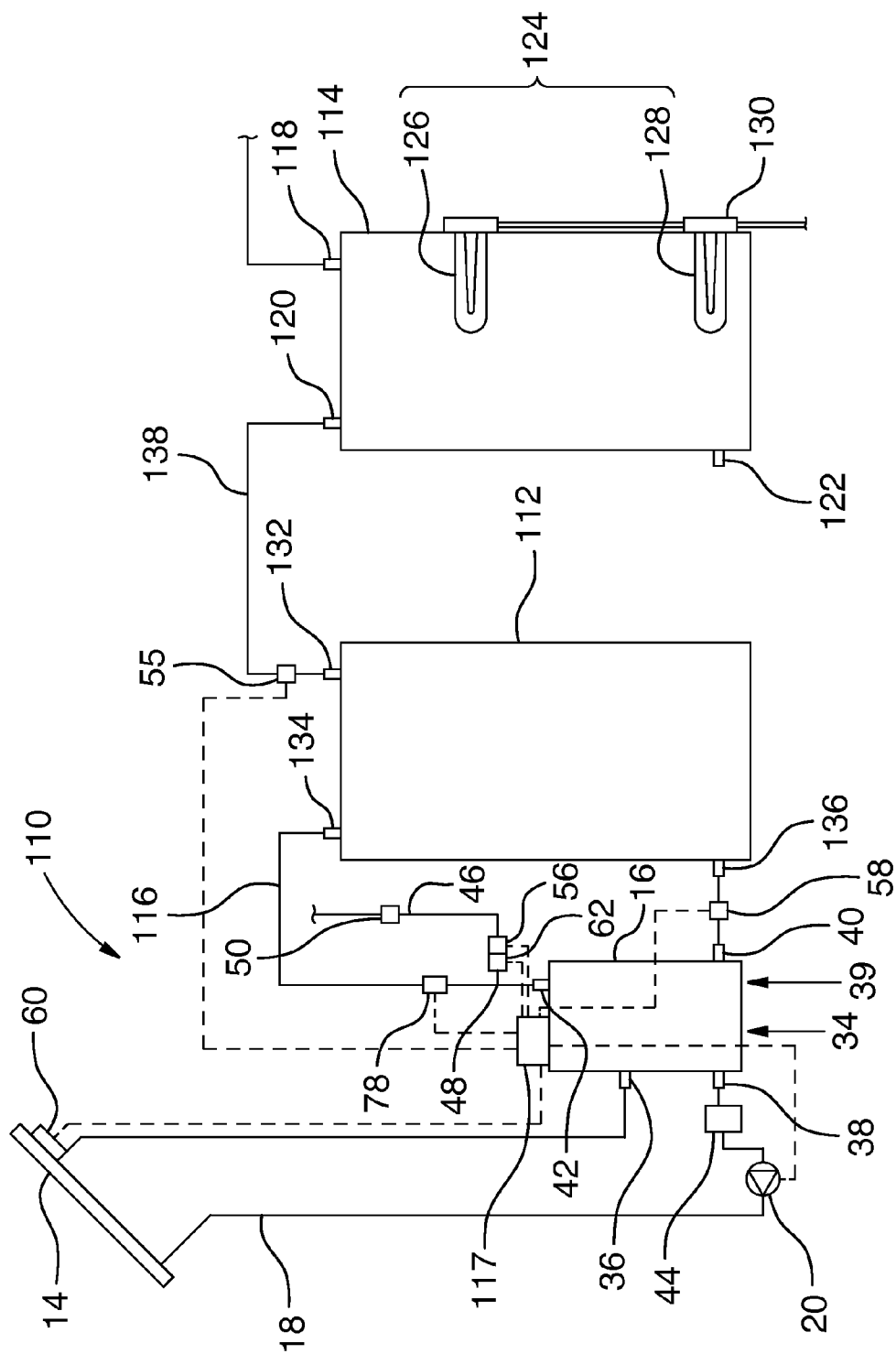


FIG.5

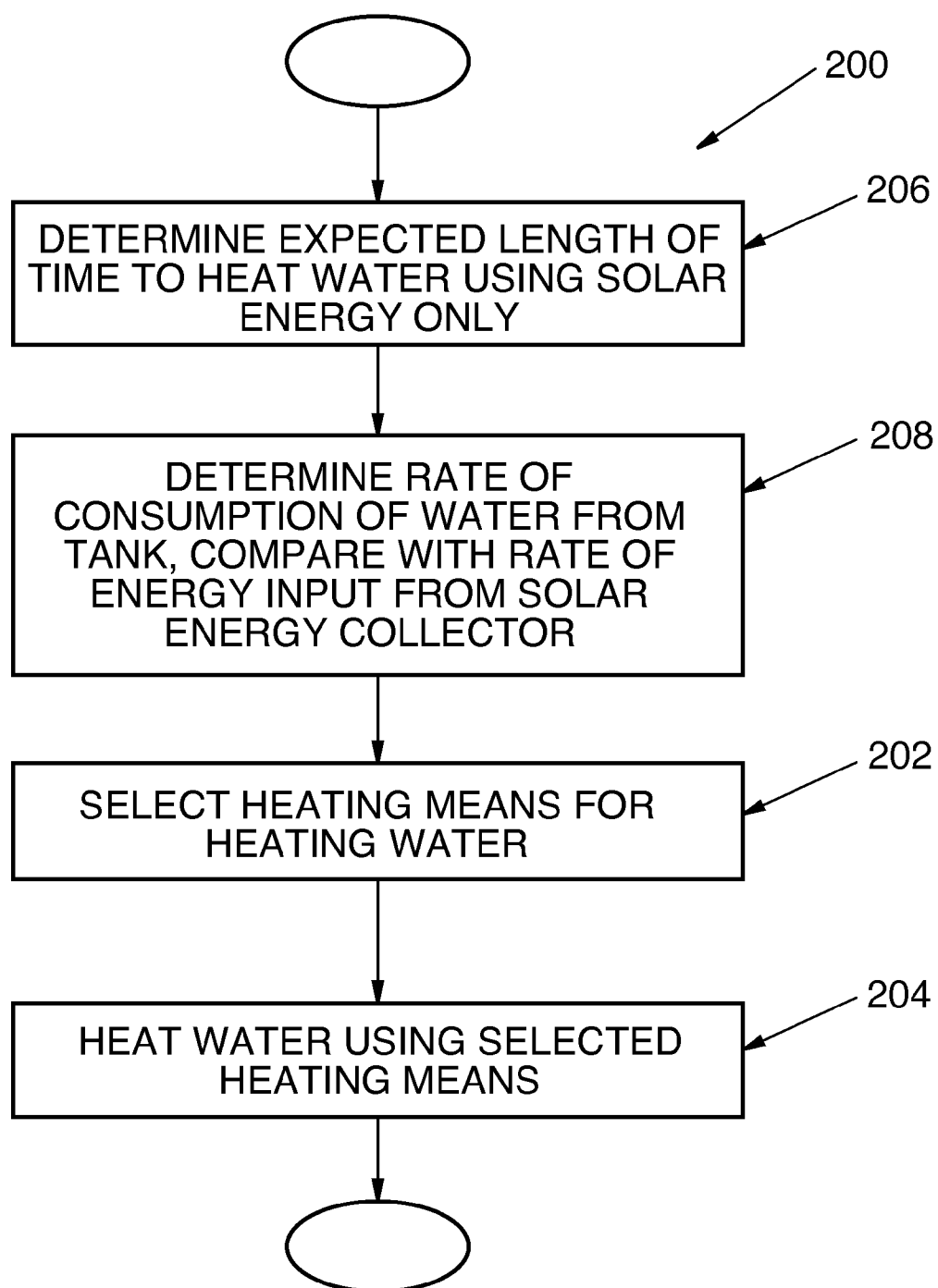


FIG.6

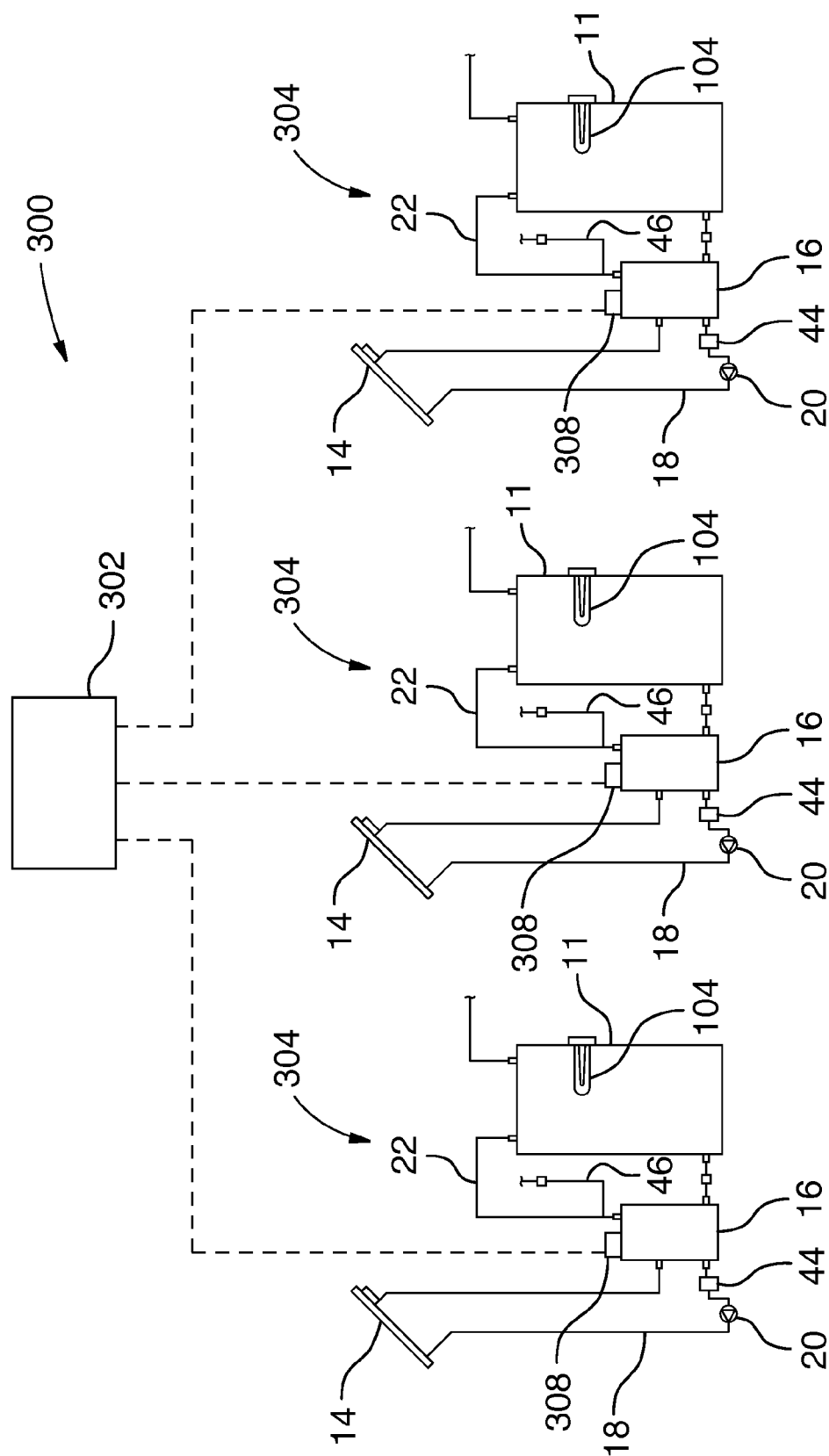


FIG. 7

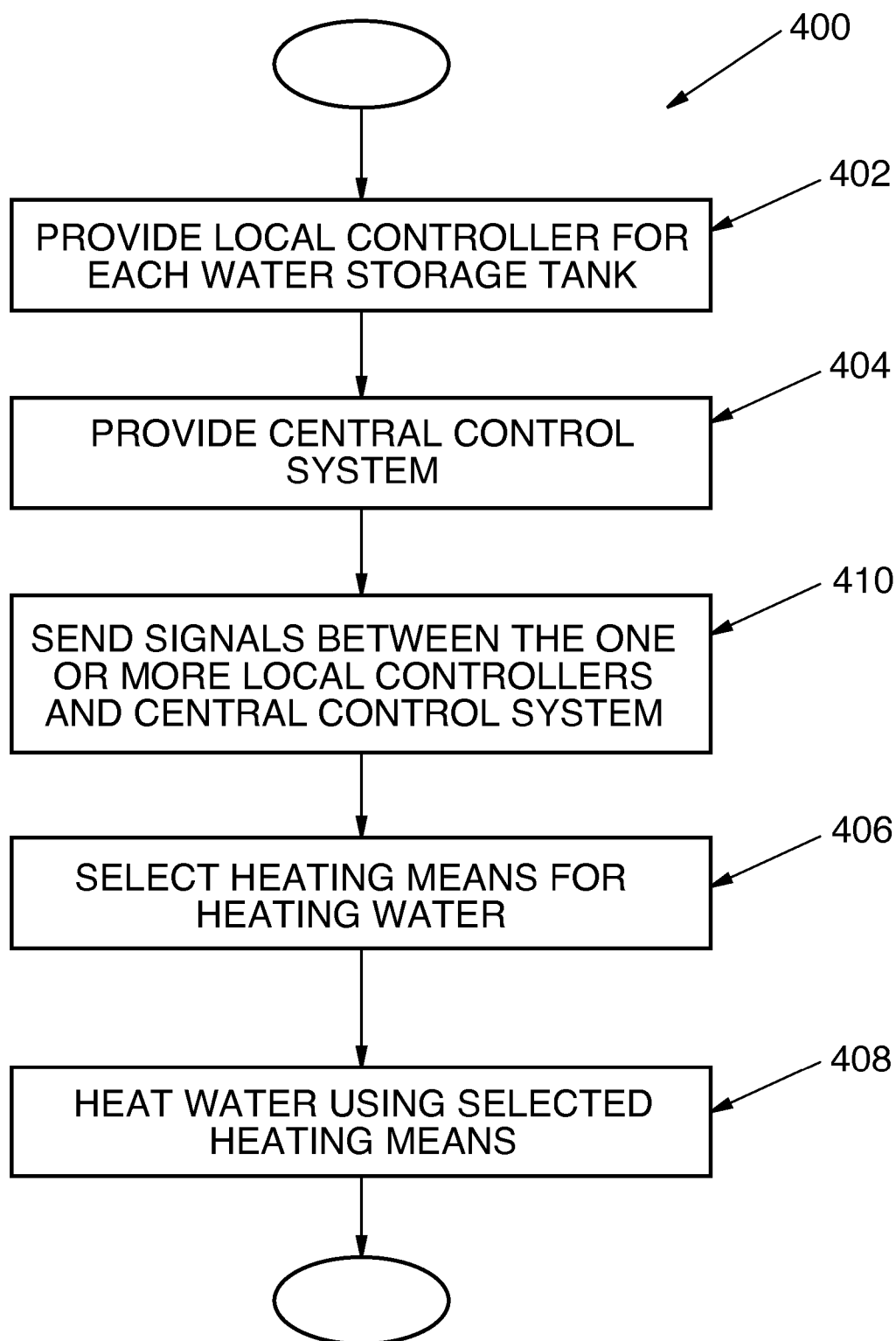


FIG.8

SOLAR ENERGY WATER HEATING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. patent application 61/100,002, filed Sep. 25, 2008, which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a solar energy water heating system, network and method, particularly to a solar energy water heating system that heats water using a combination of solar energy and a non-solar heating system, and more particularly to a solar energy water heating system that heats water using a combination of solar energy and an electric heating system.

BACKGROUND OF THE INVENTION

[0003] In homes, other residential buildings, commercial buildings and industrial buildings, a hot water tank is typically provided so that hot water is readily available for use by a user for a variety of purposes. A heating system that may be powered by electricity, natural gas, oil, propane or by some other means is provided for heating water in the tank. The heating system, however, can be expensive to operate due to the cost of electricity or fuel. Some systems have been proposed that incorporate solar energy collectors for the purposes of heating water in the hot water tank. Such systems, however, may include a non-solar heating system, such as an electric heating system, but may lack control over the non-solar heating system, and may also lack the ability to determine the savings achieved by the use of the solar energy collector.

[0004] It would be advantageous to provide a solar energy water heating system that overcomes one or more of the problems described above.

SUMMARY OF THE INVENTION

[0005] In one aspect, the invention is directed to a solar energy water heating system for heating water in a water storage tank. In one particular embodiment, the system includes a controller, a solar energy collector whose energy contribution to water in the tank is controlled by the controller, and a non-solar heating system that is not controlled by the controller. Water in the tank may be heated by one or both of the non-solar heating system and energy from the solar energy collector. The controller can determine the amount of energy contributed by solar energy to the water in the tank. In another embodiment, the solar energy water heating system incorporates a controller that controls both the operation of the pump and the operation of the non-solar heating system. In another embodiment, a network of solar energy water heating systems is provided.

[0006] In a first embodiment, the invention is directed to a solar energy water heating system comprising a water storage tank, a non-solar heating system configured to heat water in the water storage tank, a thermostat positioned to sense the temperature indicative of the temperature of water in the water storage tank, a solar energy collector, a heat exchanger, a first fluid circuit between the solar energy collector and the heat exchanger, a pump configured to pump fluid through the first fluid circuit, a second fluid circuit between the water storage tank and the heat exchanger, and a controller. The second fluid circuit is fluidically connectable to a water source. The heat exchanger is configured to transfer heat from

fluid in the first fluid circuit to water in the second fluid circuit. The thermostat is operatively connected to the non-solar heating system. The controller is configured to control the operation of the pump. The controller is further configured to receive non-solar heating system state signals indicative of whether the non-solar heating system is on and is configured to determine the amount of energy transferred from the solar energy collector to water in the water storage tank based at least in part on the non-solar heating system state signals.

[0007] In a second embodiment, the invention is directed to a solar energy water heating system comprising a water storage tank, a non-solar heating system configured to heat water in the water storage tank, a solar energy collector, a heat exchanger, a first fluid circuit between the solar energy collector and the heat exchanger, a pump configured to pump fluid through the first fluid circuit, a second fluid circuit between the water storage tank and the heat exchanger, a storage tank water temperature sensor, and a controller. The second fluid circuit is fluidically connectable to a water source. The heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit. The controller is configured to receive signals from the storage tank water temperature sensor indicative of the temperature of water in the water storage tank. The controller is configured to prevent operation of the pump if the signals from the storage tank water temperature sensor indicate the temperature of water in the water storage tank exceeds a predetermined high storage tank water temperature.

[0008] In a third embodiment, the invention is directed to a solar energy water heating system comprising a water storage tank, a solar energy collector, a heat exchanger, a first fluid circuit between the solar energy collector and the heat exchanger, a pump configured to pump fluid through the first fluid circuit, a second fluid circuit between the water storage tank and the heat exchanger, a solar energy collector temperature sensor positioned to sense temperature indicative of the temperature of the solar energy collector, a source water temperature sensor positioned to sense temperature indicative of the temperature of water from the water source and a controller. The second fluid circuit is fluidically connectable to a water source. The heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit. The controller is configured to receive solar energy collector temperature sensor signals from the solar energy collector temperature sensor and source water temperature sensor signals from the source water temperature sensor. The controller is further configured to prevent operation of the pump if either the solar energy collector temperature sensor signals indicate a solar energy collector temperature that is below a predetermined low solar energy collector temperature or if the source water temperature sensor signals indicate a source water temperature that is below a predetermined low source water temperature.

[0009] In a fourth embodiment, the invention is directed to a solar energy water heating system comprising a water storage tank, a non-solar heating system configured to heat water from the water storage tank, a solar energy collector, a heat exchanger, a first fluid circuit between the solar energy collector and the heat exchanger, a pump configured to pump fluid through the first fluid circuit, a second fluid circuit between the water storage tank and the heat exchanger, and a controller configured to control the operation of the pump and the non-solar heating system. The heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit. The second fluid circuit is fluidically connectable to a water source.

[0010] In a fifth embodiment, the invention is directed to a solar energy water heating system for operation with a first water storage tank and a non-solar heating system configured to heat water from the first water storage tank. The system comprises a second water storage tank having a second water storage tank consumption outlet that is fluidically connectable to an inlet on the first water storage tank, a solar energy collector, a heat exchanger, a first fluid circuit between the solar energy collector and the heat exchanger, a pump configured to pump fluid through the first fluid circuit, a second fluid circuit between the second water storage tank and the heat exchanger, and a controller configured to control the operation of the pump and the non-solar heating system. The heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit. The second fluid circuit is fluidically connectable to a water source.

[0011] In a sixth embodiment, the invention is directed to a method of heating water in a water storage tank, comprising: a) selecting at least one heating means from a group of heating means including a non-solar heating system and a solar energy collector; and b) heating water in the water storage tank using the selected heating means based at least in part on the temperature of water in the water storage tank.

[0012] In a seventh embodiment, the invention is directed to a network of solar energy water heating systems, comprising a central control system, and a plurality of solar energy water heating systems. Each system includes a water storage tank, a non-solar heating system configured to heat water from the water storage tank, a solar energy collector, a heat exchanger, a first fluid circuit between the solar energy collector and the heat exchanger, a pump configured to pump fluid through the first fluid circuit, a second fluid circuit between the water storage tank and the heat exchanger, and a local controller configured to control the operation of the pump and the non-solar heating system. The heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit. The second fluid circuit is fluidically connectable to a water source. The central control system is configured to control the operation of the local controllers.

[0013] In an eighth embodiment, the invention is directed to a method of heating water from a plurality of water storage tanks, comprising:

- a) providing a local controller in association with each water storage tank wherein the local controller is operatively connected to a non-solar heating system for the associated water storage tank and a solar energy collector system for the associated water storage tank;
- b) providing a central control system that is in communication with the local controllers;
- c) selecting for each water storage tank at least one heating means from a group of heating means including a non-solar heating system and a solar energy collector;
- d) heating water in each water storage tank using the selected heating means; and
- e) sending signals from one of the group consisting of the central control system and at least one local controller to the other of the group consisting of the central control system and at least one local controller, wherein the signals relate to the operation of the at least one local controller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention will now be described by way of example only with reference to the attached drawings, in which:

[0015] FIG. 1 is a schematic illustration of a single-tank solar energy water heating system in accordance with an embodiment of the present invention;

[0016] FIG. 2 is a schematic illustration of a controller used with the solar energy water heating system shown in FIG. 1;

[0017] FIG. 3 is a schematic illustration of another single-tank solar energy water heating system in accordance with another embodiment of the present invention

[0018] FIG. 4 is a schematic illustration of a controller used with the solar energy water heating system shown in FIG. 3;

[0019] FIG. 5 is a schematic illustration of a dual-tank solar energy water heating system in accordance with another embodiment of the present invention;

[0020] FIG. 6 is a flow diagram illustrating a method of heating water in a water storage tank;

[0021] FIG. 7 is a schematic illustration of a network of solar energy water heating systems in accordance with another embodiment of the present invention; and

[0022] FIG. 8 is a flow diagram illustrating a method of heating water in a plurality of water storage tanks.

DETAILED DESCRIPTION OF THE INVENTION

[0023] Reference is made to FIG. 1, which shows a solar energy water heating system 10 in accordance with an embodiment of the present invention. The solar energy water heating system 10 is used to heat water in a water storage tank 11 using a combination of solar energy and using a non-solar heating system 12. Using the solar energy water heating system 10 to heat the water in the water storage tank 11 can reduce the energy costs associated with heating the water relative to some prior art systems that utilizes a non-solar heating system only.

[0024] The solar energy water heating system 10 may reside in a home, a multi-unit residential building, a commercial building, an industrial building or any other structure where hot water is used.

[0025] The solar energy water heating system 10 includes the water storage tank 11, the non-solar heating system 12, a solar energy collector 14, a heat exchanger 16, a first fluid circuit 18 between the solar energy collector 14 and the heat exchanger 16, a pump 20 configured to pump fluid through the first fluid circuit 18, a second fluid circuit 22 between the water storage tank 11 and the heat exchanger 16, and a controller 24.

[0026] The water storage tank 11 includes a first storage tank port 26, which may be a consumption outlet through which hot water is drawn for use by a user. The water storage tank 11 includes a second storage tank port 30 and a third storage tank port 32, which connect the water storage tank 11 to the second fluid circuit 22. The second storage tank port 30 may be positioned approximately $\frac{2}{3}$ of the way up the water storage tank 11. The third storage tank port 32 may be positioned proximate the bottom of the water storage tank 11.

[0027] The non-solar heating system 12 may be any suitable type of heating system, such as, for example, an electric heating system. Alternatively, the non-solar heating system 12 may operate using oil, natural gas, propane or some other means. The non-solar heating system 12 may include a single heating element 32 which may be positioned approximately $\frac{2}{3}$ of the way up the water storage tank 11, preferably slightly above the height of the second storage tank port 30. The positioning of the heating element 32 is discussed further below.

[0028] In the embodiment shown in FIG. 1, a thermostat 33 is operatively connected to the non-solar heating element 12 and controls the operation of the heating element 12 based on the temperature of water in the water storage tank 11.

[0029] The solar energy collector 14 may be any suitable type of solar energy collector. The solar energy collector 14 may be positioned on the roof of the structure, or in some other suitable position, such as on a wall that is oriented for exposure to the sun.

[0030] The heat exchanger 16 may be any suitable type of heat exchanger, such as a brazed plate heat exchanger. The heat exchanger 16 includes a primary side 34, having a primary side inlet 36 and a primary side outlet 38, and a secondary side 39 having a secondary side inlet 40 and a secondary side outlet 42.

[0031] A heat transfer fluid is pumped by the pump 20 through the first fluid circuit 18. More particularly, the heat transfer fluid is pumped by the pump 20 from an expansion tank 44 to the solar energy collector 14 for heating thereby, after which the heat transfer fluid flows through the primary side 34 of the heat exchanger 16 and back to the expansion tank 44. The heat transfer fluid may be any suitable type of fluid, such as a solution of propylene glycol and water to resist freezing during exposure to cold weather. The solution may comprise about 50 wt % propylene glycol and about 50 wt % water, or may have some other ratio or composition altogether.

[0032] Water may flow by any suitable means through the second fluid circuit 22, such as by means of a temperature differential that may be present across the second side 39 of the heat exchanger 16. As a result of the positioning of the heating element 32, the second storage tank port 30, and the third storage tank port 30, a temperature gradient can be introduced in the water in the water storage tank 11 where the coldest water is at the bottom of the tank 11, and hotter water is in the top portion of the tank 11.

[0033] Thus, circulation of water through the second fluid circuit 22 may be induced passively (ie. without inducing water flow using a pump). The water may flow from the water storage tank 11 through the third storage tank port 30 into the second fluid circuit 22, upwards through the secondary side 39 of the heat exchanger 16 and then upwards to the second storage tank port 30 where the water reenters the water storage tank 11. The heating element 32 may heat water in the top portion of the tank 11 to be hotter than the water entering the water storage tank 11 through the second storage tank port 30.

[0034] A source water conduit 46 may be connected to a source water inlet 48 into the second fluid circuit 22, which may be positioned between the heat exchanger 16 and the second storage tank port 30. The source water conduit 46 may be connected to any suitable water source (not shown) such as a city water connection or a well. A source water flow control valve 50 may be provided on the source water conduit 46 to control the introduction of source water into the second fluid circuit 22 as needed based on the consumption of water from the water storage tank 11 through the consumption outlet 26. The operation of the source water flow control valve 50 may be controlled by any suitable means, such as by a storage tank water level sensor (not shown). Alternatively it is possible for the controller 24 to control the operation of the source water flow control valve 50.

[0035] The heat exchanger 16 is configured to transfer heat from the heat transfer fluid in the first fluid circuit 18 to water in the second fluid circuit 22.

[0036] The controller 24 controls the operation of the solar energy water heating system 10. Referring to FIG. 2, the controller 24 may include a processor 51, a memory 52, one or more inputs 53 for receiving signals from one or more sensors, and one or more outputs 54 through which the controller 24 sends output signals (eg. to control a system component). The one or more sensors that may be connected to the

inputs 53 may include, for example, a storage tank water exit temperature sensor 55 (FIG. 2), a source water temperature sensor 56, a heat exchanger secondary inlet water temperature sensor 58, a solar energy collector temperature sensor 60, a source water flow meter 62, and a non-solar heating element state sensor 64. The temperature sensors 55, 56, 58 and 60 may be any suitable types of temperature sensor, such as, for example, thermistors.

[0037] The storage tank water exit temperature sensor 55 is positioned at a suitable position to sense temperature and to send to the controller 24 storage tank water temperature sensor signals that are indicative of the temperature of hot water leaving the water storage tank 11. The storage tank water temperature sensor signals may be sent to the controller 24 any suitable way, such as along an electrical conduit 66 or, for example, via a wireless connection.

[0038] The storage tank water exit temperature sensor 55 is positioned at a suitable position to sense temperature and to send to the controller 24 storage tank water temperature sensor signals that are indicative of the temperature of the hottest water in the water storage tank 11 and indicative of the temperature of the water leaving the water storage tank 11. Thus the storage tank water temperature sensor signals from the storage tank water exit temperature sensor 55 may be referred to as hot storage tank water temperature sensor signals, or storage tank exit water temperature sensor signals. These signals may be sent to the controller 24 any suitable way, such as along an electrical conduit 66 or, for example, via a wireless connection.

[0039] The source water temperature sensor 56 and source water flow meter 62 are positioned at a suitable position to sense temperature and flow respectively and to send to the controller 24 source water temperature sensor signals and source water flow rate signals respectively that are indicative of the temperature and flow rate of any source water entering the second fluid circuit 22. The source water temperature sensor signals and source water flow rate signals may be communicated to the controller 24 by any suitable means, such as along electrical conduits 68 and 70 or, for example, wirelessly.

[0040] The non-solar heating element state sensor 64 is positioned at a suitable position to sense whether the non-solar heating element 12 is on or off and is configured to send to the controller 24 non-solar heating element state sensor signals that are indicative of the state of the non-solar heating element 10. The structure of the non-solar heating element state sensor 64 may depend on the structure of the heating element 32. For example, if the heating element 32 is electric, then the non-solar heating element state sensor 64 may be configured to determine if there is current flow in the electrical conduit connecting the heating element 32 to an electrical power source.

[0041] The controller 24 may be configured to operate in one or more ways. For example, the controller 24 may be configured to determine the amount of energy transferred over a given time period from the solar energy collector 14 to water in the water storage tank 11. This may be determined by any suitable method. For example, it may be determined using energy input including: the temperature history of water in the water storage tank 11 over the time period, the volume of water in the water storage tank 11, the flow history and temperature history of any water introduced to the second fluid circuit 22 from the water source, the amount of time the non-solar heating system was on over the given time period, and the power (eg. the wattage) of the non-solar heating system 12.

[0042] The difference between the current temperature of the water in the water storage tank 11 and the temperature at the beginning of the time period can be used to determine the total energy change in the water in the tank 11. These two temperatures can be obtained by any suitable means, eg. using the storage tank water exit temperature sensor 55.

[0043] The flow history and temperature history of the water introduced into the second fluid circuit 22 from the water source (not shown) combined with the temperature history of the water in the water storage tank 11 may be used to determine the amount of energy lost from the water in the water storage tank 11 as a result of water consumption from the tank 11 and replenishment from the water source (not shown).

[0044] The amount of time the non-solar heating system 12 was on over the given time period and the power (eg. the wattage) of the non-solar heating system 12 can be used to determine the amount of energy introduced by it into the water in the water storage tank 11.

[0045] The total energy change of the water in the water storage tank 11, the amount of energy lost as a result of water consumption and replenishment from the water source, and the amount of energy introduced by the non-solar heating system 12 into the water in the tank 11 can be used to determine the amount of energy introduced into the water from the tank 11 by the solar energy collector 14, which may be referred to as Esolar. It will be understood that the above is but an exemplary way of determining the value of Esolar using the aforementioned sensor data. It is possible for the controller 24 to determine the value of Esolar using the aforementioned energy input information without specifically calculating the individual energy contributions made by the source water and non-solar heating element but instead to perform a single large calculation. It is alternatively possible, for example, for the controller 24 to determine the value of Esolar without calculation at all, but instead to use the values from the sensors as input values for a lookup table, or by some other method that is different than using lookup tables or calculations. As yet another alternative, the controller 24 may use a combination of methods, such as using both lookup tables and calculations, to determine the value of Esolar.

[0046] As an example of a different but related approach to determining the value of Esolar, the controller 24 may compare the expected storage tank water exit temperature with the actual storage tank water exit temperature. The difference between the aforementioned expected and actual temperatures may be attributed to the energy input from the solar energy collector 14.

[0047] It is possible for the controller 24 to obtain the aforementioned energy input information using sensor data that is stored in the memory 52. It is alternatively possible for the controller 24 to obtain at least some of the energy input information without use of sensors. For example, the power of the non-solar heating system 11 may be obtained without using any sensors. It may, for example, simply be a value that is stored in the memory 52 based on the model and type of water storage tank 11. As another example, the source water temperature sensor 56 may be omitted and the controller 24 may instead use an estimate of the temperature of the source water in its determination of Esolar. As yet another example, the source water flow meter 62 may be omitted and the controller 24 may instead use an estimate for the flow rate of the source water into the second fluid circuit 22.

[0048] Information relating to the energy input from the solar energy collector 14 may be displayed on a display 74 that may be provided as part of the controller 24. The information displayed on the display 74 may include, for example,

the energy saved, the amount of carbon saved, and/or the money saved by using the solar energy water heating system 22. The display 74 may be positioned with the other components of the controller 24 or may be remotely positioned for convenient viewing by a user of the solar energy water heating system 22. For example, the display 74 may be in a main floor hallway of a house, and may communicate wirelessly (or by electrical conduit) with the rest of the controller 24 which may be positioned proximate the pump 20 and water storage tank 11 in a furnace room on a basement level of the house.

[0049] The controller 24 may include an output 54 through which it controls the operation of the pump 20 based on signals from one or more of the sensors. For example, the controller 24 may be configured to start the pump 20 if the temperature of the water leaving the water storage tank 11 is less than a predetermined low storage tank water exit temperature. Starting the pump 20 initiates flow in the first fluid circuit 18, which generates heat transfer from the solar energy collector 14 into the heat transfer fluid, which in turn generates heat transfer from the first fluid circuit 18 to the water in the second fluid circuit 22 through the heat exchanger 16. In embodiments wherein the thermostat 33 is operational and is operatively connected to the non-solar heating element 32, the predetermined low storage tank water exit temperature is higher than the temperature at which the thermostat 33 activates the non-solar heating element 32.

[0050] The controller 24 may check for one or more of a plurality of conditions when determining whether or not to turn on or turn off the pump 20. For example, if the controller 24 receives signals from the solar energy collector temperature sensor 60 and the heat exchanger secondary inlet water temperature sensor 58 and determines that the temperature difference therebetween is less than a predetermined threshold temperature difference, the controller 24 may prevent operation of the pump 20. Because the operation of the pump 20 itself consumes energy, the amount of energy saved by heating the storage tank water using the solar energy collector 14 only offsets the energy consumed by the pump 20 if the temperature difference is sufficiently large between the heat transfer fluid and the water. The predetermined threshold temperature difference may be any suitable amount, such as, for example, about 10 degrees Celsius.

[0051] As another example, if the controller 24 receives signals from the storage tank water exit temperature sensor 55 indicating that the water leaving the water storage tank 11 exceeds a predetermined high storage tank water exit temperature, the controller 24 is configured to prevent operation of the pump 20 to inhibit any further heating of the water by the solar energy collector. The predetermined high storage tank water exit temperature may be about 85 degrees Celsius.

[0052] As another example, if the controller 24 receives signals from the solar energy collector temperature sensor 60 indicating that the solar energy collector 14 is less than a predetermined low solar energy collector temperature, or if the controller 24 receives signals from the source water temperature sensor 56 indicating that the source water is less than a predetermined low source water temperature, then the controller 24 may prevent operation of the pump 20 to inhibit exposure of the solar energy collector 14 and the heat exchanger 16 respectively to freezing conditions. The predetermined low solar energy collector temperature may be any suitable temperature, such as, for example, about 4 degrees Celsius. Below this temperature, there is a risk of the heat transfer fluid thickening in consistency (becoming gel-like) and becoming difficult to pump using the pump 20. In a

thickened state, the heat transfer fluid could possibly cause damage to the pump 20 if an attempt were made by the pump 20 to pump it.

[0053] The predetermined low source water temperature may be any suitable temperature, such as, for example, about 4 degrees Celsius.

[0054] Optionally, a suitable flow cut-off valve 78 may be provided between the source water inlet 48 and the second storage tank port 30. Periodically, the flow cut-off valve 78 may be closed and the source water flow control valve 50 may be opened to direct source water to flow through the heat exchanger 16 and into the water storage tank 11 through the third port 20, to flush the heat exchanger 16 of deposits of minerals and the like, such as calcium carbonate, that can build up therein. The flow cut-off valve 78 may be closed whenever the source water flow control valve 50 is opened, and the operation of the flow cut-off valve 78 may be related to the operation of the source water flow control valve 50, such that when the valve 50 opens, the valve 78 closes and when the valve 50 closes the valve 78 opens. The flow cut-off valve 78 may be controlled by any suitable means. For example, the cut-off valve 78 may be electrically connected to the source water flow control valve 50 so that when the valve 50 is open, the electrical connection is configured to close the valve 78 and when the valve 50 is closed, the electrical connection is configured to open the valve 78. The structure, control and operation of the flow cut-off valve 78 may be as described in U.S. Pat. No. 6,827,091 (Harrison). It is optionally possible for the controller 24 to include an output 54 (FIG. 2) through which it controls the operation of the flow cut-off valve 78.

[0055] Reference is made to FIG. 3, which shows a solar energy water heating system 100 in accordance with another embodiment of the present invention. The solar energy water heating system 100 may be similar to the solar energy water heating system 10 (FIG. 1) except that the solar energy water heating system 100 includes a controller 102 instead of the controller 24 (FIG. 1), which controls the operation of both the pump 20 and the non-solar heating system shown at 104. The non-solar heating system 104 includes a non-solar heating element 106 that may be similar to the non-solar heating element 32 (FIG. 1).

[0056] There are many features that can be provided to the solar energy water heating system 100 as a result of controlling both the pump 20 and the non-solar heating system 104 with the controller 102, in addition to having the features described with respect to the controller 24 of FIG. 2. For example, the controller 102 may be configured to control the first non-solar heating system 104 and the pump 20 based on signals from the storage tank water exit temperature sensor 55. As an example of how this control of both heating means (ie. of both the pump 20 and the non-solar heating system 104) could be carried out, if the storage tank water exit temperature sensor 55 senses a temperature that is lower than a first predetermined low storage tank water exit temperature, then the controller 102 may start the pump 20. If the storage tank water exit temperature sensor 55 senses a temperature that is lower than a second predetermined low storage tank water exit temperature that is lower than the first predetermined low storage tank water exit temperature, then the controller 102 may turn on the non-solar heating system 104.

[0057] The controller 102 may select which of the heating means (ie. which of the pump 20 and the non-solar heating system 104) to use to heat water in the water storage tank 11 based on one or more conditions. One such condition is the amount of time to heat the water in the water storage tank 11. For example, the controller 102 may be configured to deter-

mine the expected length of time required to heat up water in the water storage tank 11 from a current temperature to a target temperature using only energy from the solar energy collector 14. If the expected length of time is not more than a predetermined maximum acceptable length of time, then the controller 102 may start the pump 20 and heat the water in the water storage tank 11 using only energy from the solar energy collector 14. If, however, the expected length of time exceeds the predetermined maximum acceptable length of time, then the controller 102 may heat the water using the non-solar heating system 104 and optionally also using energy from the solar energy collector 14.

[0058] The controller 102 may be configured to control the operation of the pump 20 and the first non-solar heating system 104 differently at different times of the day. For example, during daytime hours the electrical demands on a utility company may be higher than the demands at night. The hours during which demand is higher may be referred to as peak hours. During these peak hours, energy may be more expensive and there is therefore incentive to reduce energy consumption during peak hours. During these peak hours, the maximum acceptable length of time may be increased to increase the range of situations in which the controller 102 will opt to heat the water in the water storage tank 11 solely with energy from the solar energy collector 14. During off-peak hours, the maximum acceptable length of time may be reduced to accelerate the heating of the water in the water storage tank 11 without incurring excessive energy costs. Even in jurisdictions wherein a local utility company does not charge higher rates for energy during peak hours, the controller 102 may still increase the maximum acceptable length of time during at least some daytime hours, since in a typical home the rate of consumption of hot water may be low relative to the rate of consumption during the early morning and during the evening.

[0059] The controller 102 may be configured to operate on a rate basis. For example, the controller 102 may compare the rate at which hot water is being drawn from the water storage tank 11 with the rate at which water in the water storage tank 11 can be heated to a target temperature solely using energy from the solar energy collector 14. If the result of the comparison indicates that the water in the water storage tank 11 would increase in temperature at an acceptable rate over time, then the controller 102 may heat the water in the water storage tank 11 solely using energy from the solar energy collector 14. Conversely, if the result of the comparison indicates that the temperature of water in the first water storage tank 112 would decrease over time or would not increase sufficiently quickly, then the controller 102 may activate the non-solar heating system 104, and may optionally also activate the pump 20.

[0060] The controller 102 may be configured to heat the water in the first water storage tank 112 using a control algorithm. For example, the controller 102 may be configured to heat the water using a PID-based (ie. a proportional integral-derivative-based) control algorithm, a PI-based (ie. a proportional integral-based) control algorithm, a P-based (ie. a proportional-based) control algorithm, fuzzy logic or any other suitable algorithm.

[0061] Reference is made to FIG. 4, which shows a schematic illustration of the controller 102. The controller 102 may be similar to the controller 24 (FIG. 2), except that the input 53 (FIG. 2) that is connected to a non-solar heating system state sensor 64 is replaced by an output 54 that is connected to the non-solar heating system 104.

[0062] Reference is made to FIG. 5, which shows a solar energy water heating system 110 in accordance with another

embodiment of the present invention. The solar energy water heating system 110 may be similar to the solar energy water heating system 10 except that the solar energy water heating system 110 includes a water storage tank 112 with no non-solar heating system associated therewith, upstream from a pre-existing, second water storage tank 114.

[0063] The solar energy water heating system 110 includes the water storage tank 112, which may be referred to as a first water storage tank 112, the solar energy collector 14, the heat exchanger 16, the first fluid circuit 18 between the solar energy collector 14 and the heat exchanger 16, the pump 20, a second fluid circuit 116 between the first water storage tank 112 and the heat exchanger 16, and a controller 117.

[0064] The pre-existing, second water storage tank 114 may be a typical water storage tank and may have a consumption outlet 118, a second storage tank port 120 and a third storage tank port 122. Water in the pre-existing water storage tank 114 may be heated by a non-solar heating system 124, which may include a first non-solar heating element 126 and a second non-solar heating element 128. The first and second non-solar heating elements 126 and 128 may be controlled by a thermostat 130.

[0065] The first water storage tank 112 includes a consumption port 132, a second storage tank port 134 and a third storage tank port 136. A consumption fluid conduit 138 may connect the consumption port 132 to either the second storage tank port 120 or the third storage tank port 122 on the pre-existing, second water storage tank 114. The temperature sensor 55 may be positioned on the consumption fluid conduit 138, preferably proximate the consumption port 118.

[0066] The second fluid circuit 116 may be similar to the second fluid circuit 22 in FIG. 1. The second storage tank port 134 may be positioned on the top of the first water storage tank 112 instead of being about $\frac{2}{3}$ of the way up. The third storage tank port 136 may be positioned proximate the bottom of the tank 112. As a result of the positions of the second and third storage ports 134 and 136, a temperature gradient is set up throughout the entire height of the tank 112 to drive the flow of water through the second fluid circuit 116.

[0067] The controller 117 may be similar to the controller 24 (FIG. 1). The solar energy water heating system 110 may lack a non-solar heating system sensor however. Thus, it is possible that the controller 117 may not receive information regarding the state of the non-solar heating system 124. The controller 117 may nonetheless be capable of determining the energy contributed to the water stored in the first water storage tank 112 since there is no non-solar heating system associated with that tank.

[0068] The controller 117 may include several of the features associated with the controller 24 (FIG. 1). For example, the controller 117 may be configured to prevent operation of the pump 20 if the temperatures sensed by the solar energy collector temperature sensor 60 and by the source water temperature sensor 56 are less than a predetermined low solar energy collector temperature and a predetermined low source water temperature respectively, both of which may be any suitable value, such as about 4 degrees Celsius.

[0069] It is optionally possible to provide a system similar to the system 110 wherein the thermostat 130 is disabled and the pre-existing non-solar heating system 124 is controlled by the controller 117.

[0070] Reference is made to FIG. 6, which illustrates a method 200 of heating water in a water storage tank in accordance with another embodiment of the present invention, which can be carried out using the system 100 shown in FIG. 3, or which may alternatively be carried out by any other suitable system.

[0071] The method 200 includes a step 202 wherein at least one heating means is selected from a group of heating means including a non-solar heating system and a solar energy collector, and a step 204 which includes heating water in the water storage tank using the selected heating means based at least in part on the temperature of water in the water storage tank.

[0072] At step 206, the expected length of time for water in the water storage tank to be heated using only energy from the solar energy collector to a target temperature is determined. If the expected length of time exceeds a predetermined maximum acceptable length of time then the water from the water storage tank may be heated using the non-solar heating element.

[0073] As noted with respect to the exemplary system 100 shown in FIG. 3, the at least one heating means selected in step 204 may be selected based on the time of day. For example, if the time of day falls within a first portion of the day, then at least the non-solar heating element is selected if the expected length of time determined in step 206 exceeds the predetermined maximum acceptable length of time. If the time of day falls within a second portion of the day, which may, for example, correspond to peak hours of energy demand, then at least the solar energy collector is selected regardless of the expected length of time assuming that other conditions do not preclude the operation of the pump, such as the temperature of the solar energy collector.

[0074] Prior to step 202, the method 200 may include a step 208 of determining the rate of consumption of hot water from the water storage tank and determining whether the solar energy collector is capable of heating the water in the water storage tank sufficiently quickly to compensate for the flow of source water into the water storage tank. The method 200 may further entail heating water in the water storage tank according to a control algorithm. The control algorithm may be any suitable type of control algorithm, such as a PID control algorithm.

[0075] Reference is made to FIG. 7, which shows a network of solar energy water heating systems 300 in accordance with another embodiment of the present invention. The network of solar energy water heating systems 300 includes a central control system 302, and a plurality of solar energy water heating systems 304. Each solar energy water heating system 304 may be similar to the solar energy water heating system 100 (FIG. 3), and includes the solar energy collector 14, the heat exchanger 16, the first fluid circuit 18 between the solar energy collector 14 and the heat exchanger 16, the pump 20, a second fluid circuit 22 between the heat exchanger 16 and the first water storage tank 11. Each solar energy water heating system 304 further includes a local controller 308 which is configured to control at least the operation of the pump 20 and the non-solar heating system 104 and which is configured to be controlled by the central control system 302. The communication between the central control system 302 and the local controllers 308 may be one-way communication from the local controllers 308 to the central control system 302, one-way communication from the central control system 302 to the local controllers 308, or may be two-way communication between the local controllers 308 and the central control system 302. For example, the central control system 302 may be configured to determine the availability of solar energy in the vicinity of the local controllers 308 and may be configured to act on that information. This information may be passed to users of the solar energy water heating systems 304 so that, for example, if the information indicates that little or no solar energy will be available the affected users can reduce their energy consumption or modify their energy consumption to

skew it towards off-peak hours. This information may be passed on automatically by the central control system **302** to the affected local controllers **308** for communication to associated users. For example, the information may be displayed on a display associated with each local controller **308**. Alternatively this information may be passed on manually, eg. by email, by a person who receives it from the central control system **302** to users of the affected solar energy water heating systems **304**.

[0076] Another function that could be carried out by the central control system **302** is to inform the utility company in situations where there is likely to be an increased demand for electric power due to low availability of solar energy. The central control system **302** may be configured to send control signals to the local controllers **308** to adjust the usage of the non-solar heating systems **104** according to the availability of solar energy.

[0077] The central control system **302** may be configured to receive information from the local controllers **308** regarding the amount of energy saved as a result of solar energy water heating activity and/or the amount of energy consumed by use of the non-solar heating element and may be configured to cooperate with a billing system to reward and/or penalize individual users based on their activity. Optionally the feature of rewarding and/or penalizing users may take into account the availability of solar energy during the time period being considered. Optionally, the central control system **302** can control the operation of the local controllers **308** based on the time of day, for example, to shift usage of non-solar heating elements to off-peak portions of the day. Instead of controlling the local controllers **308** based on the time of day, the central control system **302** could additionally or alternatively monitor the actual energy demand being place on the utility company in real time and can adjust the usage of non-solar heating elements **104** as a way of controlling the energy demand on the utility company.

[0078] Reference is made to FIG. 8, which illustrates a method **400** of heating water from a plurality of water storage tanks, in accordance with another embodiment of the present invention. The method **400** may be carried out using the network **300** shown in FIG. 7, or may alternatively be carried out by any other suitable means.

[0079] The method **400** includes a step **402** wherein a local controller is provided in association with each water storage tank. The local controllers are each operatively connected to a non-solar heating system for the associated water storage tank and to a solar energy collector system for the associated water storage tank. At step **404** a central control system is provided. At step **406**, a selection is made of at least one heating means from a group of heating means including the non-solar heating system and the solar energy collector. Step **408** includes heating water in each water storage tank using the selected heating means. At step **410**, signals are sent at least one way between the central control system and one or more local controllers, relating to the operation of the at least one local controller. These signals may be sent before, after or during the water in the water storage tanks is heated, or a combination thereof.

[0080] The signals may, for example, be instructions from the central control system to the local controllers and may be based at least in part on the availability of solar energy. The signals may, for example, be instructions from the central control system to the local controllers and may be based at least in part on time of day.

[0081] The signals may, for example, may be from one or more local controllers to the central control system and may relate to one or more data related to the group consisting of:

energy consumed by the non-solar heating system, and energy saved resulting from use of the solar energy collector.

[0082] In any of the embodiments described herein, in the event that excess solar energy is available and is not needed for heating, structure may be provided to divert the heat transfer fluid to another load, such as another heat exchanger associated with a heating system for a swimming pool, for example. The structure may include suitable valves which may be controlled by the controller **24** or **102** or which may be controlled by some other means, conduits to convey the heat transfer fluid to the other load and appropriate sensors.

[0083] In the embodiments described herein, the storage tank water exit temperature sensor has been described as being used to indicate the temperature of water in the water storage tank. In at least some embodiments however, it may be possible to use a different temperature sensor to obtain a suitable measurement. For example, when determining the amount of energy change that takes place in the water in the water storage tank, it may be possible to use the temperature history of the heat exchanger secondary inlet temperature sensor. It will be noted however, that this sensor may at certain times sense the temperature of water from the water source that is being sent to the water storage tank through the third storage tank port, which could affect the temperature history.

[0084] While the above description constitutes a plurality of embodiments of the present invention, it will be appreciated that the present invention is susceptible to further modification and change without departing from the fair meaning of the accompanying claims.

1. A solar energy water heating system, comprising:

- a water storage tank;
- a non-solar heating system configured to heat water in the water storage tank;
- a thermostat positioned to sense the temperature indicative of the temperature of water in the water storage tank, wherein the thermostat is operatively connected to the non-solar heating system;
- a solar energy collector;
- a heat exchanger;
- a first fluid circuit between the solar energy collector and the heat exchanger;
- a pump configured to pump fluid through the first fluid circuit;
- a second fluid circuit between the water storage tank and the heat exchanger, wherein the heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit, wherein the second fluid circuit is fluidically connectable to a water source; and
- a controller configured to control the operation of the pump, wherein the controller is further configured to receive non-solar heating system state signals indicative of whether the non-solar heating system is on and wherein the controller is configured to determine the amount of energy transferred from the solar energy collector to water in the water storage tank based at least in part on the non-solar heating system state signals.

2. A solar energy water heating system as claimed in claim 1, wherein the controller is further configured to determine the amount of energy transferred from the solar energy collector to water in the water storage tank based on the temperature of water in the water storage tank, on the flow rate and temperature of any water introduced to the second fluid circuit from the water source, and on a determination of the amount of energy introduced to the water in the storage tank by the non-solar heating system.

3. A solar energy water heating system as claimed in claim 2, wherein the controller is further configured to determine the amount of energy introduced to the water in the storage tank by the non-solar heating system based on the amount of time the non-solar heating system is on and on the power of the non-solar heating system.

4. A solar energy water heating system as claimed in claim 2, further comprising a storage tank water temperature sensor, wherein the controller is further configured to receive from the storage tank water temperature sensor signals indicative of the temperature of water in the water storage tank, and wherein the controller is further configured to determine the amount of energy transferred from the solar energy collector to water in the water storage tank based in part on the temperature of water in the water storage tank.

5. A solar energy water heating system as claimed in claim 4, wherein the water storage tank has a consumption outlet and wherein the storage tank water temperature sensor is positioned downstream from the consumption outlet.

6. A solar energy water heating system as claimed in claim 2, further comprising a source water temperature sensor, wherein the controller is further configured to receive signals from the source water temperature sensor indicative of the temperature of water from the water source.

7. A solar energy water heating system as claimed in claim 2, further comprising a flow meter, wherein the controller is configured to receive flow meter signals from the flow meter indicative of the flow rate of water into the second fluid circuit from the water source.

8. A solar energy water heating system as claimed in claim 1, wherein the controller includes a display and is configured to output on the display a value indicative of the amount of energy saved by heating water from the water storage tank with energy from the solar energy collector.

9. A solar energy water heating system, comprising:

- a water storage tank having a consumption outlet;
- a non-solar heating system configured to heat water in the water storage tank;
- a solar energy collector;
- a heat exchanger;
- a first fluid circuit between the solar energy collector and the heat exchanger;
- a pump configured to pump fluid through the first fluid circuit;
- a second fluid circuit between the water storage tank and the heat exchanger, wherein the heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit, wherein the second fluid circuit is fluidically connectable to a water source;
- a storage tank water temperature sensor positioned downstream from the consumption outlet; and

a controller configured to receive signals from the storage tank water temperature sensor indicative of the temperature of water leaving the water storage tank, wherein the controller is configured to prevent operation of the pump if the signals from the storage tank water temperature sensor indicate the temperature of water in the water storage tank exceeds a predetermined high storage tank water temperature.

10. A solar energy water heating system as claimed in claim 9, wherein the predetermined high storage tank water temperature is about 85 degrees Celsius.

11. A solar energy water heating system, comprising:

- a water storage tank;
- a solar energy collector;
- a heat exchanger;
- a first fluid circuit between the solar energy collector and the heat exchanger;
- a pump configured to pump fluid through the first fluid circuit;
- a second fluid circuit between the water storage tank and the heat exchanger, wherein the heat exchanger is configured to transfer heat from fluid in the first fluid circuit to water in the second fluid circuit, wherein the second fluid circuit is fluidically connectable to a water source;
- a solar energy collector temperature sensor positioned to sense temperature indicative of the temperature of the solar energy collector;
- a source water temperature sensor positioned to sense temperature indicative of the temperature of water from the water source; and
- a controller configured to receive solar energy collector temperature sensor signals from the solar energy collector temperature sensor and source water temperature sensor signals from the source water temperature sensor, wherein the controller is configured to prevent operation of the pump if either the solar energy collector temperature sensor signals indicate a solar energy collector temperature that is below a predetermined low solar energy collector temperature or if the source water temperature sensor signals indicate a source water temperature that is below a predetermined low source water temperature.

12. A solar energy water heating system as claimed in claim 11, wherein the predetermined low solar energy collector temperature is about 4 degrees Celsius and wherein the predetermined low source water temperature is about 4 degrees Celsius.

13. A solar energy water heating system as claimed in claim 12, wherein the first fluid circuit contains a fluid that is a mixture of propylene glycol and water.

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