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(71) Applicant: **Ariston S.p.A.**
60044 Fabriano (AN) (IT)

(72) Inventors:
 • **CARROZZO, Vincenzo**
60044 Fabriano (IT)
 • **PIERSIGILLI, Dino**
60015 Falconara Marittima (IT)

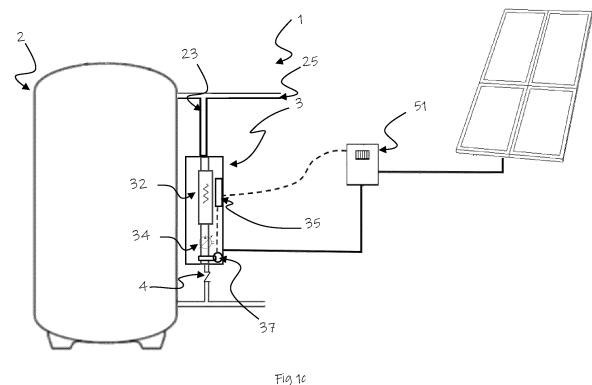
(74) Representative: **Meloni, Francesca et al**
MAR.BRE S.R.L.
Via San Filippo, 2
60044 Fabriano (AN) (IT)

(54) IMPROVED STRATIFICATION WATER HEATER

(57) The object of the present invention is a storage water heating system comprising a heating apparatus external to the storage tank. The external apparatus is configured to receive a liquid coming from a lower portion of the tank, heat it and deliver it to a top portion of the tank, where the hot water outlet is located. In this way, the natural thermocline of temperatures in the storage is maintained, the water delivered is that at a greater temperature, the efficiency is increased by reducing heat standing losses and there is greater control over the quantity of energy stored.

The external apparatus may be activated in response to a heating demand for the storage or for outlet water, or even in response to a power surplus from photovoltaic equipment and in the absence of withdrawal. A control system may modulate the power of the instan-

taneous water heater to track the surplus power of the photovoltaic system.



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Description

[0001] The object of the present disclosure is a storage water heating system with water inlet at the bottom and outlet at the top. More in detail, the present disclosure refers to a water heating system in a storage tank, which can comprise internal heating elements and is further associated with a heating apparatus external to the tank.

[0002] An advantage the storage water heaters is that they allow for the accumulation of sufficient hot water to meet demand over several hours, while using relatively low-power heating elements, while one of the main drawbacks is due to the fact that the storage tank is subject to heat losses.

[0003] Generally, the hot water coming out of the water heater is mixed with cold water from the water supply to reach the user at a comfort temperature, this measure allows the volume of hot water that can may be delivered to be further increased by increasing the temperature of the water of the storage tank, but this involves a further increase in heat standing losses. The prior art provides for various solutions to limit such heat standing losses in the storage water heaters.

[0004] A first solution is that the hottest water is the one drawn for use, this is achieved by using the natural water thermocline, given by the temperature trend in the tank, whereby the water for use is drawn from the upper part, the hotter portion of the tank, while the cold water is fed into the lower part, i.e. the colder portion of the tank. Water heaters with vertical development storage tank are known, in which the temperature thermocline is controlled by an upper heating element configured to heat an upper portion, and a lower one configured to heat the remaining portion. The upper portion is regulated at a suitable temperature to deliver volumes of hot water typical of small withdrawals, the lower portion is heated in anticipation of a period characterised by withdrawals of greater volume, for example several showers.

[0005] Water heaters equipped with algorithms capable of predicting the amount of hot water withdrawals during the day are known, having learnt them from past events. Therefore, when periods of lower withdrawal are expected, the storage tank is maintained at an average low temperature wherein only the water in an upper portion has a temperature that meets hot water demand, while when high withdrawals are expected the temperature of the storage tank is kept at a temperature wherein also the water in a lower portion has a temperature high enough to meet demand.

[0006] In recent years a new need has emerged in the control of water heaters. The progressive introduction of energy generation systems from renewable sources, often intermittent and uncontrollable by nature, has led to a strong interest in adapting, at least in part, the energy demand to the availability.

[0007] It is not always possible to store renewable energy in a cost-effective way; all flexible consumption systems that may adapt their consumption profile to the availability of renewable energy are therefore useful. The electricity market attributes a value to the ability to change the profile of the demand based on the availability of energy. This ability is known in the industry as "demand response" enablement. Storage water heaters are known in which the heating element management algorithms take into account the availability of energy on the electricity distribution network (hereinafter referred to as the electricity grid) and/or the availability energy locally produced from renewable sources. Demand response enabled water heaters have at least electric heating elements (resistances or heat pump), the ability to receive signals from the electricity grid or a local meter and the ability to modify the control of the heating elements based on these signals, therefore at least the ability to activate or deactivate the heating elements.

[0008] For example, patent EP3662210B1 describes an electric storage water heater, where the heating is controlled by an electronic regulator that takes into account the habits of the user. The water heater keeps the thermostating temperature low during the periods in which a withdrawal is not expected. The learning of the withdrawal profiles is based on an estimate of the withdrawals made according to the temperature variations. The method provides significant reductions in consumption in normal operation but does not teach how to respond to signals from the electricity grid in an optimised way.

[0009] Document US11300325B2 describes a vertical developed storage water heater with an electrical resistance in an upper zone and one in a lower zone of the storage tank. The management of the resistances is entrusted to an electronic regulator, where in conditions of energy overabundance (imbalance towards the production), the water heater raises the temperature threshold for switching off the resistances in order to prolong the heating and thus drawing more electrical energy from the grid and store it as thermal energy.

[0010] Therefore, in vertically developed water heaters, with an upper and lower heating element, the consumption reduction strategies require that the upper part is normally at a temperature sufficient to meet a demand for a small volume of water, the lower part is normally at a lower temperature and is heated in anticipation of a withdrawal of greater volume. When these water heaters have to respond to conditions of energy overabundance by storing heat, they store energy mainly in the lower zone, the one that contains water not intended for an immediate withdrawal, but which for this reason is generally at a lower temperature and therefore has a greater residual capacity of thermal energy. The heating thus modified is no longer optimised to meet the expected withdrawals, and therefore the additional energy stored partly translates into a loss due to heat standing losses. Instead, it is preferred that the stored energy may be stored to a greater extent to allow for a subsequent reduction in consumption.

[0011] The request to store energy may come from the electricity grid, when this is in a temporary condition of energy overabundance. In case a user has power supplied by the electricity grid as well as power from a renewable energy source

generated locally, a power surplus may occur. Electric power, or surplus power, refers to the share of power from local renewable sources that exceeds the local consumption; in these cases, the power which is not consumed locally is fed back into the electricity grid as energy contribution. Generally, the grid pays for the energy fed into the grid a lower price than the sale price, so there is an interest in consuming self-produced electricity locally.

[0012] Self-consumption applications are known in which a domestic energy storage system receives a request to store energy to self-consume a surplus of power produced locally from renewable sources that would otherwise be fed back into the electricity grid. In this case, it is very useful to vary the power absorption by a value as close as possible to the surplus power in order to minimise the amount of power fed back into the electricity grid.

[0013] Demand response enabled storage water heaters are at least able to activate or deactivate the heating elements based on external signals; therefore, they can also perform self-consumption functions. However, to perform the self-consumption function, it is much preferable for water heaters to be able not only to switch on and off, but also to regulate their consumption in order to track and adapt to the surplus electrical power.

[0014] Document EP2610999A2 provides for supplying energy to a heating resistance of a storage water heater by modulating the power in order to use only the surplus power.

[0015] A further example of consumption regulation is document EP3117158B1 which provides for the use of three resistances of a storage water heater, one of which may be controlled in power via a diode and two resistances that may only be controlled in switching on and off, the total adjustable power is equal to the sum of the powers of the three resistances and with an appropriate control it is possible to track the surplus power.

[0016] Document EP3064858B1 discloses a heat storage system comprising a storage, a hydraulic circuit, circulation pump, at least one electric heater, and target temperature sensor. A power sensor is connected between house network and the grid; a heating control function modulates the power supplied to the electric heater based on the surplus power measurements.

[0017] US20230136851A1 discloses a heat storage system comprising a storage, a hydraulic circuit, circulation pump, a heat pump for heating water passing through the hydraulic circuit; the water in the heat storage has a thermocline from the top, where it is hottest, to the bottom where it is colder.

[0018] Retrofit systems to enable the self-consumption with traditional storage water heaters are known; such systems essentially vary the power sent to the water heater and/or bypass the control mechanism of electric heating resistances.

[0019] The amount of surplus power that may be self-consumed is limited by the total power of the storage water heater, which generally reaches up to 2kW while instantaneous water heaters may have higher power values.

[0020] Storage water heaters may also be gas-fired, or in some areas oil-fired. This is traditionally the least expensive solution. Consumers who have a storage water heater that is not powered by electricity have limited possibilities to use self-produced renewable energy.

[0021] The object of the present disclosure is to increase the capacity to store thermal energy and at the same time reduce heat standing losses.

[0022] A further object, at least of some embodiments, is to regulate the consumption of electrical power on the basis of surplus electrical power.

[0023] Another object, at least of some embodiments, is to provide for instantaneously heated water, if hot water is not available in the storage tank.

[0024] A further object, at least for one or more executive variants, is to increase the capacity to respond to the demand response by lowering the minimum temperature of the storage tank without affecting comfort.

[0025] A further object, at least for one or more executive variants, is to provide an apparatus and a method to enable traditional water heaters to the demand response and self-consumption.

[0026] A further object, at least for some embodiments, is to provide instantaneously heated water at a temperature greater than or equal to a usage temperature, possibly also detecting when a withdrawal is in progress without the need for a flowmeter. This may be useful, for example, when the temperature in the storage tank is lower than a usage temperature.

[0027] Another object of the disclosure, at least for one or more executive variants, is to provide greater flexibility and speed in adapting the consumptions to the surplus power.

[0028] A further object, at least for one or more executive variants, is to provide a retrofit solution for storage water heaters without control and communication capabilities, thus enabling the demand response or the self-consumption.

[0029] These and other objects, which shall appear clear hereinafter, are achieved with a heating system according to the independent claims. Other objects may also be achieved by means of the additional features of the dependent claims.

[0030] The disclosure solves the problem with a heating system comprising at least one storage water tank, hereinafter "storage tank", at least one heating apparatus external to the storage tank, the heating apparatus having an inlet connected to the lower portion and an outlet connected to the upper portion of the storage tank so that a liquid thrust by a pressure difference may be withdrawn from the storage tank, pass through the heating apparatus and be fed back into the upper portion of the storage tank, where the connection to the lower portion is located substantially at the base of the storage tank and the connection to the upper portion is located substantially at the top. An effect of this configuration is that the liquid in the storage tank may be heated starting from the top respecting and substantially guaranteeing the natural

thermocline of the temperature of a liquid in the storage tank, so that the liquid at higher temperature is the first to be withdrawn. The liquid in general is water for sanitary uses or any technical liquid for space heating.

[0031] The heating system may receive information on an available electrical power. The information on an available electrical power may concern electrical power fed into the electricity grid in an unbalanced quantity, therefore higher or lower than the power demand and/or produced locally from a renewable source in surplus with respect to the local consumption.

[0032] When a heating system configured in this way receives an information on an available electrical power, in response it can vary its electrical power consumption to adapt it to the available power offer and/or vary the thermostating temperature.

[0033] The variation in electrical power consumption in response to the information from the grid may be conditioned to meet a minimum range of admissible temperatures for the water exiting the heating system. For example, water must preferably reach a set temperature T_{target} , set by a user or at least a minimum comfort temperature and must not exceed a maximum safety temperature. In any case, the admissible temperature interval width is directly related to the consumption flexibility. Water mixing systems from a heating device allow the range of permissible temperatures to be expanded. Since an excessive storage temperature can be reduced to an outlet comfort temperature with a mixing valve, the proposed heating apparatus allows increasing the capacity to respond to information from the grid.

[0034] Varying the thermostating temperature may comprise:

- in the case of available electrical power in a quantity greater than the demand, increasing it to a "surplus temperature" T_{sur} higher than the set temperature T_{target} ,
- in the case of available electrical power in a lower quantity than the demand, reducing it to a lower temperature.

[0035] In any case, the heat produced in the heating system according to the disclosure is sent to the portion of water intended to be drawn first. This way, the thermocline is maintained and there is the effect that the water at the highest temperature is the one having less time to dissipate heat; therefore, the heat standing losses are reduced. An effect of the heating apparatus is that during a withdrawal, the water to be delivered may be heated in the heating apparatus as an alternative or in addition to be directly drawn from the storage tank.

[0036] It should be noted that the information on an available electrical power can contain quantitative information of available power because locally in excess or on the grid, or an indicative level of a quantity of power available due to an overabundance of energy on the grid, or it can also be just the information that there is an overabundance of energy on the grid.

[0037] Optionally, the inlet of the heating apparatus is connected to the storage tank via a direct connection to the inlet channel from the water supply to the storage tank and preferably the outlet is connected to the storage tank via a direct connection to the delivery channel from the storage tank to the users; in this way the heating system may be made by installing said heating apparatus between the inlet and outlet connections of a pre-existing storage water heater. The heating apparatus may also be an instantaneous water heater, the inlet whereof is connected to the lower portion and the outlet whereof is connected to the upper portion of a storage tank or a pre-existing storage water heater.

Description of the figures

[0038] The features of the present disclosure shall be better highlighted by the following description of a preferred embodiment, in accordance with the patent claims and illustrated, purely by way of a non-limiting example, in the annexed drawing tables, wherein:

Figure 1.a shows a heating system according to a possible executive embodiment of the disclosure, which receives power both from renewable sources and from the electricity grid.

Figure 1.b shows a heating system according to a second possible executive embodiment of the disclosure, with a different configuration of hydraulic connections relative to Figure 1.a.

Figure 1.c shows a possible heating system according to the disclosure with details of a possible embodiment of a heating apparatus according to the disclosure.

Figure 2 shows a possible embodiment of a heating system according to the disclosure wherein the storage tank comprises its own heating devices.

Figures 3.a and 3.b show a heating system according to further executive embodiments of the disclosure with a heating apparatus (seen in section) integrated with a storage tank, where its own heating devices may be provided in the storage tank as in figure 3.b or not provided as in figure 3.a.

Figure 4 schematically shows a section view of a possible embodiment of the heating apparatus.

Figure 5 shows a further possible embodiment of a heating system according to the disclosure comprising a flow sensor or a flow switch.

Figures 6.a and 6.b show a heating system according to further embodiments.

[0039] The parameters and the relative references used in the following description are listed:

5	P_{sur}	surplus power
	P	power absorbed by the heating element, also referred to as heating element power
	Q	heat delivered through the heating element
	m	flow rate through the piping connection
	m_{MAX}	maximum flow rate of the water pump
10	M	mass of water to be heated
	S	section of the water connection crossed by the flow inside the heating apparatus
	v	speed of water through the heating apparatus
	c	specific heat of water or a liquid
	T_{38}	water temperature measured by the outlet sensor
15	T_{sur}	maximum water temperature in self-consumption mode, then indicated with "surplus temperature"
	T_{inf}	water temperature measured by the lower sensor, if any
	T_{target}	set temperature of the water exiting the heating apparatus
	ΔT	increase in temperature of the water passing through the heating apparatus
	V_{conf}	maximum comfort speed for the temperature variation
20	T_{min}	minimum factory temperature of a thermostatic valve.

Detailed Description

[0040] The features of a preferred variant of the disclosure are now described, using the references contained in the figures. It should be noted that the above figures, although schematic, reproduce the elements of the disclosure according to proportions between the spatial dimensions and orientations thereof that are compatible with a possible executive embodiment.

[0041] It should also be noted that any dimensional and spatial term (such as "lower", "upper", "inner", "outer", "front", "rear" and the like) generally refers to the positions of the elements as shown in the annexed figures, without any limiting intent relative to the possible operating positions.

[0042] Without loss of generality, the heating system 1 can operate with liquids other than water and the water supply can be replaced by any liquid delivery system. Hereinafter, for simplicity and without loss of generality, reference shall be made to a heating system 1 for the water connected to a water supply.

[0043] With reference to the accompanying figures, the heating system 1 comprises at least one storage tank 2, 20, and at least one heating apparatus 3, 30. In accordance with a possible executive variant, shown as an example in Figure 4, the heating apparatus 3, 30 comprises:

- a piping connection 33, arranged between
- a first end herein referred to as 'inlet' 331 and a second end herein referred to as 'outlet' 332;
- 40 - at least one heating element 32, preferably arranged inside the connection 33 and in any case in a heat exchange relationship with at least one part of the piping connection 33.

[0044] According to a preferred embodiment, the heating element 32 is a variable power element capable of being managed and/or regulated by appropriate processing and control devices 35, such as a control unit 35, hereinafter for shortness control units 35 that may vary the absorbed power P thereof.

[0045] According to a possible embodiment the heating element 32 comprises a combination of independently controllable resistive heating elements. According to another possible embodiment the heating element 32 comprises a condenser of a variable power heat pump. According to another embodiment, the heating element 32 is a resistance configured to vary the consumed power P .

[0046] The storage tank 2, 20 is a tank for a liquid, for example water, the lower portion whereof is configured to be connected to an inlet connection 24 of a water supply, while the upper portion of the storage tank 2, 20 is configured to be connected to an outlet connection 25 towards a water delivery point to the user.

[0047] In addition to the at least one storage tank 2, 20, and the at least one heating apparatus 3, 30, the heating system 1 comprises:

- a lower hydraulic connection 22, 221, adapted to connect the lower portion of the storage tank 2, 20 to the inlet 331 of the piping connection 33,
- an upper hydraulic connection 23, 231, adapted to connect the upper portion of the storage tank 2, 20, to the outlet 332

of the piping connection 33,

- possible recirculation devices 34 adapted to convey the water through the piping connection 33,
- at least one control unit 35 adapted to control the heating element 32 and possibly the different devices/components of the heating system 1 and configured to receive, and possibly process, said information relating to the available electrical power.

[0048] Preferably, the inlet connection 24 of the storage tank 2, 20 to the water supply may be connected to the lower hydraulic connection 22, and the outlet connection 25 from the storage tank 2, 20 may be connected to the upper hydraulic connection 23 as shown in Figure 1.a.

[0049] It should be noted that it is also possible to implement an alternative solution shown in figure 1.b in which the storage tank 2, 20 has ad hoc connection points for the lower 221 and upper hydraulic connections 231, said hydraulic connections 221 and 231 being independent and separate from the inlet connection 24 to the water supply and from the outlet connection 25.

[0050] The control unit 35 may comprise:

- an electronic board forming part of the heating apparatus 3, 30;
- an electronic board forming part of the storage tank 2, 20 and capable of communicating at least with the heating element 32;
- an electronic board external to both the heating apparatus 3, 30 and the storage tank 2, 20 but still forming part of the heating system 1 and capable of communicating at least with the heating element 32;
- one or more electronic boards cooperating with each other, each forming part of the heating apparatus 3, 30 and/or the storage tank 2, 20 or in any case part of the heating system 1;
- a generic electronic board capable of taking at least one of the functions described here for the control unit 35.

[0051] Most preferably, the recirculation devices 34 comprise a pump 34 adapted to circulate a liquid coming from the lower hydraulic connection 22, 221, through the piping connection 33, from the inlet 331 to the outlet 332, and control devices may be provided for controlling the pump 34, said devices can be a control unit 35. According to some operating modes, a liquid may be conveyed from the lower hydraulic connection 22, 221, through the piping connection 33 by a pressure difference, which is therefore a recirculation device.

[0052] Hereinafter, reference shall be made for shortness to a pump 34. It is clear to the man skilled in the art that the pump 34 is not strictly necessary if alternative devices or effects, cause the passage of water through the piping connection 33.

[0053] Preferably, the heating system 1 also comprises an outlet temperature sensor 38 configured to measure the water temperature at the outlet of the heating apparatus 3, 30, said water being able to be fed into the storage tank 2, 20 or sent to the water delivery point.

[0054] Preferably, the outlet temperature sensor 38 is located in the heating apparatus 3, 30 in the proximity of the outlet end 332. The temperature measured by the outlet temperature sensor 38 is hereinafter referred to as outlet temperature T_{38} .

[0055] Figures 1 and 2 show a heating apparatus 3 connected to the storage tank 2, 20, via hydraulic connections, while figures 3.a and 3.b show a heating apparatus 30 integrated into the storage tank 2, 20, for example fixed, internally or externally, to the walls of the casing of the storage tank 2, 20.

[0056] Storage tank 2, 20, piping connection 33 and lower 22, and upper 23 hydraulic connections 221, 231 are configured so as to form a hydraulic circuit in which the water, under the action of a pressure difference or preferably of the pump 34, may be withdrawn from the lower portion of the storage tank 2, 20, heated in the piping connection 33, and sent to the upper hydraulic connection 23, 231 from which water may be fed to the use or into the upper portion of the storage tank 2, 20.

[0057] Optionally, the heating system 1 may comprise a non-return valve 4, arranged:

- preferably on the branch of the lower hydraulic connection 22, 221; or
- on the upper hydraulic connection 23, 231 (Figure 1.a or 1.b); or
- along the piping connection 33, preferably downstream of the heating element 32 (figure 3.a).

[0058] Optionally, a shut-off valve 8 may be provided on the branch of the lower hydraulic connection 22, 221 (figure 2).

[0059] According to a preferred embodiment, the heating system 1 may comprise devices for varying the flow rate m of the water through the piping connection 33. The devices for varying the flow rate m of the water may be a controllable opening valve or even the same pump 34, which may be a variable flow rate or modulated revolution pump.

[0060] Optionally, the pump 34 may be part of the heating apparatus 3, 30 and the control unit 35 is configured to control the pump 34. Optionally, the control unit 35 is capable of controlling the devices for varying the flow rate m .

[0061] According to a possible embodiment, the heating system 1 comprises at least one lower temperature sensor 27, 37, capable of detecting the temperature of the water of the lower portion of the storage tank 2, 20 and of sending a measuring signal to the control unit 35. The temperature lower sensor 27, 37 may be positioned at any point in the lower portion of the storage tank 2, 20 and/or in the lower hydraulic connection 22, 221 and/or in the part of the piping connection 33 located between the heating element 32 and the inlet 331.

[0062] Preferably, the temperature lower sensor 27, 37 is located either in the lower portion of the storage tank 2, 20 (Figure 1.a) or in a part of the heating apparatus 3, 30 located between the heating element 32 and the inlet 331 of the piping connection 33 (figure 1.c).

[0063] The heating system 1 may heat the water contained in the storage tank 2, 20 by means of the heating apparatus 3, 30. Under the action of a pressure difference, for example caused by the pump 34, the colder water is withdrawn from the lower portion of the storage tank 2, 20, is heated with the heating element 32, and is fed back into the upper portion of the storage tank 2, 20.

[0064] This way the natural thermocline of the temperatures in the storage tank 2, 20 is maintained, since water in the storage tank is heated with a substantially monotonically increasing temperature gradient from the engagement point of the lower hydraulic connection 22, 221 to the engagement point of the upper hydraulic connection 23, 231. The gradient may deviate from a monotonically increasing trend due to turbulences, in particular in transients following withdrawals and/or to the triggering of a recirculation motion, without this causing any such embodiment to depart from what is stated and claimed.

[0065] Preferably, the engagement point of the lower hydraulic connection 22, 221 is positioned substantially at the base of the storage tank 2, 20, for example it can coincide with the inlet connection 24 to the water supply (Figure 1.a) and preferably the engagement point of the upper hydraulic connection 23, 231 is positioned substantially at the top of the storage tank 2, 20, for example it can coincide with the outlet connection 25 towards the use (Figure 1.a, 1.c).

[0066] In the absence of a withdrawal from the outlet connection 25, the heating occurs with the recirculation of water that, once heated, flows back to the storage tank 2, 20.

[0067] In presence of a withdrawal, part of the water that is heated in the piping connection 33 may come directly from the water supply and may be delivered directly to the use.

[0068] In general, the heating function may be activated to meet a self-consumption request or a demand response signal or a request for hot water. Six possible operating modes shall be described below, which are characterised by the reason for activation/deactivation, i.e. whether to meet a self-consumption request or a demand response signal or a request for hot water and based on whether or not a withdrawal occurs at the same time.

Mode 1	Self-consumption or demand response	Withdrawal absent
Mode 2	Self-consumption or demand response	Withdrawal present
Mode 3	Water heating request	Withdrawal absent
Mode 4	Water heating request	Withdrawal present
Mode 5	Request for reduction of consumptions	
Mode 6	Hot water delivery with a substantially cold tank	

[0069] The self-consumption and demand response functions shall notw be described. The heating system 1, according to the disclosure, can receive power:

- from renewable sources 5 only, when provided with a meter 51 adapted to detect at least the availability of power from a renewable energy plant 5;
- from the electricity grid being it able to be part of an electrical user 6 provided with a meter 61 that detects at least the electrical consumption of the user 6;
- both from renewable sources 5 and the electricity grid (user 6), the respective meters 51 and 61 being able to be provided.

[0070] According to a preferred embodiment, the heating apparatus 3, 30, and preferably the control unit 35, is able to receive a signal containing at least the information relating to the fact that:

- power from a renewable source is available in surplus; or
- there is a condition of overabundance of energy on the electricity grid. Preferably, the heating apparatus 3, 30 is able to receive a signal indicating the amount of surplus power P_{sur} .

[0071] Devices are known adapted to detect the surplus power P_{sur} by having available meters of consumed power coming from the electricity grid and meters of self-produced power, an exhaustive description being present in IT102021000000590 and EP 22700255.7 in the name of the same applicant. Such documents describe how a control unit can have a signal indicative of a condition of surplus power from a renewable source; similarly, the man skilled in the art knows how a control unit can have a signal of a condition of overabundance or scarcity of energy of the electricity on the electricity grid. By way of an example, in case of power from locally produced renewable energy, the signal of power from self-produced energy can be sent by a meter 51 located on the supply branch coming from a local renewable energy system 5.

[0072] If the control unit 35 is able to receive at least one signal indicative of a condition of overabundance of energy on the electricity grid, then the heating system 1 can operate in "Mode 1" for demand response.

[0073] If the control unit 35 is able to detect and/or receive information relating to the surplus power from a renewable source and fed back into the grid, then the heating system 1 can also operate in "Mode 1" for self-consumption.

[0074] "Mode 1" is now described: self-consumption or demand response in the absence of withdrawal. The control unit 35 enters Mode 1 in the case of self-consumption when it detects that there is power from an available renewable source, which is equivalent to a local surplus power signal P_{sur} or in case of demand response when it receives a signal of energy overabundance from the electricity grid. In Mode 1, the control unit 35 sets the set temperature T_{target} to a "surplus temperature" T_{sur} that is higher than the temperature normally required, expected or set to be reached with the heating: $T_{target} = T_{sur}$

[0075] In Mode 1, the control unit 35 activates and keeps the heating element 32 and the pump 34 active until the outlet temperature T_{38} reaches the surplus temperature T_{sur} .

[0076] In case of demand response, it is generally not necessary to adjust the power P .

[0077] In case of self-consumption, if the heating element 32 has variable power, the control unit 35 regulates the power P to a value close to and less than or equal to the surplus power P_{sur} .

[0078] Preferably, the heating system 1 is configured to vary the flow rate m , in particular, the control unit 35 can be configured to regulate the flow rate m .

[0079] The control unit 35 can regulate the flow rate m in a manner directly proportional to the power P , so as to maintain constant the increase in temperature of the water flowing through the piping connection 33.

[0080] According to an alternative embodiment the flow rate m can be regulated to control the outlet temperature T_{38} .

[0081] Per esempio the heating system 1 can be configured to vary the flow rate m of the liquid, as a function of the difference between a set temperature T_{target} and a measured temperature of the water contained in the heating system 1 (or in the storage tank 2.20). Depending on the measurement point of the water temperature, the method for regulating the flow rate m may be defined as open loop or feedback.

[0082] In one possible embodiment the flow rate m is controllable in a "feed forward" or open-loop control manner based on a requested temperature increase, ΔT , of the water at the outlet 332 with respect to the inlet 331 and the temperature of the water contained in the heating system 1 is a temperature measured upstream of the heating element 32.

[0083] Therefore:

$$Q = c * M * \Delta T = P * \Delta t$$

$$M = S * v * \Delta t = m * \Delta t$$

$$c * m * \Delta T = P$$

$$m = \frac{P}{\Delta T * c} \leq \frac{P_{sur}}{\Delta T * c}$$

where P is equal to or close to the surplus power P_{sur} ; by close it is meant a value that is substantially equal to the surplus power P_{sur} except for a low consumption value corresponding to small variations in consumption that are negligible for the purposes of the object, for example to the variations in consumption of the same control unit 35.

[0084] There are several options for calculating the requested temperature increase ΔT . According to one possible implementation, the heating system 1 has a lower temperature sensor 27, 37 configured to detect a temperature substantially equal to that of the water entering the heating system 3, 30 and/or equal to that of the water in the lower portion of the storage tank 2, 20, such temperature is indicated below as the lower temperature T_{inf} .

[0085] Otherwise, if the lower temperature T_{inf} cannot be detected with a specific sensor, this may be estimated: for the estimate, it is sufficient to activate the pump 34 without having activated the heating element 32 and detect the outlet temperature T_{38} which, in the absence of heating, is approximately equal to the lower temperature T_{inf} .

[0086] In any way the lower temperature T_{inf} is detected or estimated, the requested temperature increase is at most equal to $\Delta T = T_{sur} - T_{inf}$.

[0087] If the lower temperature T_{inf} is close to the surplus temperature T_{sur} , the heating apparatus 3, 30 deactivates the heating element 32 and suspends the self-consumption function.

$$T_{38} = T_{inf} + \frac{P}{m * c} \leq T_{sur}$$

[0088] According to a possible embodiment as T_{int} approaches T_{sur} , the power P is reduced and/or the flow rate m is increased. This allows to terminate smoothly the self-consumption mode while reducing the risk of a temperature overshoot. In case the flow rate m is increased prior to terminating the self-consumption mode, when the flow rate is equal to a maximum achievable value m_{max} , the control unit 35 may further reduce the temperature increase by lowering the power P to the maximum value that allows the surplus temperature T_{sur} not to be exceeded at the output.

$$\Delta T = \frac{P}{m_{MAX} * c}$$

$$P \leq m_{MAX} * \Delta T * c$$

[0089] When the power P is zero the self-consumption mode is terminated.

[0090] The flow rate m control, directly proportional to the power P , is a feed-forward type control and therefore less precise; however, high precision in controlling the temperature in the upper portion of the storage is not required. In fact, any temperature between the comfort temperature and the maximum temperature is acceptable for the device's purposes. Conversely, controlling the flow rate m to be directly proportional to the heating power P allows the heating to adapt to the surplus power P_{sur} almost instantaneously, without delays caused by the typical reading times of any temperature sensor.

[0091] As an alternative or in addition to the open-loop, feed-forward method of regulating the flow rate m , it is possible to perform a feedback regulation on the flow rate m based on the value of the outlet temperature T_{38} . A feedback control is advantageous because it makes the system robust with respect to errors, for example, errors in identifying the value of the flow rate m , which is typically known within an uncertainty range. In self-consumption Mode 1, the aim is to keep the outlet temperature T_{38} less than or equal to the surplus temperature T_{sur} , so it is very appropriate that the control unit 35 is configured to perform a feedback control on the flow rate m as a function of the outlet temperature T_{38} .

[0092] For such purpose, the control unit 35 can be configured to calculate a flow rate variation Δm , in order to maintain the outlet temperature T_{38} close to the surplus temperature T_{sur} , by performing a regulation of the flow rate m ; this may be done, for example, by acting on the pump 34 or on the devices to vary the flow rate m .

$$\Delta m = f(T_{sur} - T_{38})$$

where the function f represents a feedback control function and can comprise the proportional, derivative and/or integral components known to the man skilled in the art so that the control unit 35 reduces the flow rate m when the outlet temperature T_{38} approaches the surplus temperature T_{sur} .

[0093] It should be noted that it is not necessary to have a flow rate sensor m to regulate the flow rate m in this way.

[0094] In the implementations with feedback flow rate control m , it is not necessary to have a lower temperature sensor 27, 37 or an estimate of the lower temperature T_{inf} .

[0095] The self-consumption or demand response Mode 2 in presence of a withdrawal is described for the differences compared to the Mode 1 in absence of a withdrawal.

[0096] In presence of a withdrawal, the water in the heating system 3, 30 can come partly from the storage tank 2, 20 and partly from the water supply. In self-consumption Mode 2, if the lower temperature sensor 27 is located inside the storage tank 2, 20 in the tank, the lower temperature T_{inf} detected is different from the real water temperature in inlet 331 and is a value comprised between the temperature in the lower portion of the storage tank 2, 20 and that, generally lower, of the temperature of the water of the water supply. In Mode 2, to obtain a better operation, it is preferable to use a lower temperature sensor 37 located at the inlet 331 of the heating apparatus 3, 30.

[0097] For the embodiments of the heating system 1 in which the lower temperature sensor 27 is located inside the storage tank 2, 20, the temperature T_{inf} is generally overestimated. The flow rate set according to the formula

$$m = \frac{P}{\Delta T * c} \leq \frac{P_{sur}}{\Delta T * c}$$

is overestimated and the outlet temperature T_{38} is therefore lower than the surplus temperature T_{sur} . This error can be corrected with the feedback function in the flow control m.

[0098] A mixing valve generally stabilises the temperature of the water outlet to the user; for example, if the outlet water from the heating system 1 has a higher temperature than that required by the user, the mixing valve reduces the flow rate of the water withdrawn from the outlet connection 25; the flow rate in the outlet connection 25 may be lower than the flow rate m through the heating apparatus, in this case a portion of the heated water is fed back into the storage tank 2, 20. Therefore, Mode 2, for the purposes of the ability of self-consuming or taking part to the demand response by storing energy, is based on the same control and in part provides substantially the same result in the case of withdrawal as in the case of no withdrawal of Mode 1.

[0099] However, in case of a withdrawal in Mode 2, the activation and deactivation of the heating element 32 may cause sudden variations in the temperature at the outlet of the heating system 1, and even the presence of a mixing valve may not be able to compensate for them. Such sudden variations may entail the risk of scalding a user, reducing comfort and/or wasting the thermal energy that was intended to be stored.

[0100] The control unit 35 is equipped to receive information from devices configured s to detect whether a withdrawal is in progress (described below). When it is in Mode 1 and a withdrawal is in progress, it switches to Mode 2. In Mode 2 the control unit 35, to avoid sudden changes in the temperature of the outlet water:

- avoids activating the heating element 32 for self-consumption or demand response,
- alternatively, if the control unit 35 is configured to deactivate and/or activate the heating element 32 with a continuous variation of power, in Mode 2, in order to avoid sudden changes in the temperature at the outlet the control unit 35 keeps the variation speed of the power P lower than a maximum comfort speed V_{conf} . The maximum speed V_{conf} is a parameter that can be set by the factory and possibly adjusted via any user interface and corresponds to a variation speed of the power that does not significantly affect the comfort.

[0101] To activate Mode 2 of self-consumption with a withdrawal in progress, the control unit 35 must be able to detect whether a withdrawal is in progress.

[0102] According to a possible embodiment, the heating apparatus 3, 30 comprises devices 9, 35, 27, 37, 38, 34 to detect whether a withdrawal is in progress.

[0103] A device for detecting whether a withdrawal is in progress may be a flow switch 9 (in figure 5); according to a possible embodiment, a flow switch 9 is inserted on the inlet connection 24 to the water supply or alternatively on the outlet connection 25. In this case, the control unit 35 is configured to receive a signal from the flow switch 9.

[0104] According to some embodiments the heating system 1 can comprise alternative devices are possible to detect whether a withdrawal is in progress, for example from a temperature sensor 27 located in the storage tank 2, 20. To this end, the control unit 35 can determine the start of a withdrawal from a sudden change, generally a decrease, of said temperature in the storage tank, and can determine the end of the same from an increase in said temperature.

[0105] According to a further embodiment, it is possible to detect whether a withdrawal is in progress by a temperature sensor 37, 38 located inside the heating apparatus. For example, the control unit 35 activates the pump 34 without activating the heating element 32 and if it detects a water temperature lower than a preset expected value, it determines that a withdrawal is in progress. The control unit 35 can determine the end of the withdrawal if after an activation of the pump 34 it detects an increase in the water temperature.

[0106] If the control unit 35 is not able to detect that a withdrawal is in progress, it cannot activate Mode 2 other than Mode 1; in this case, if the heating element 32 has variable power, then each activation and deactivation of the self-consumption and/or demand response function, even in Mode 1, occurs with a variation speed of the absorbed power P lower than a maximum comfort speed.

[0107] The heating modes without and with a withdrawal are now described. The control unit 35 activates heating Mode 3 when it receives a signal indicating a temperature request, or when it detects that the water in the storage tank 2, 20 has a temperature lower than a set temperature T_{target} . Since the water temperature in the storage tank 2, 20 is subject to an increasing gradient from bottom to top, the set temperature T_{target} generally depends on the measurement point. In general, the set temperature T_{target} may also vary based on the hourly program and/or the operating mode.

[0108] Based on the different possible embodiments, and the possible presence of temperature sensors in different positions in the heating system 1, the signal indicative of a temperature request may be:

- i. a detection from the outlet temperature sensor 38 performed after activating the pump 34, while the heating element 32 is switched off, the outlet temperature sensor 38 detects a temperature substantially equal to that at the base of the

storage tank 2, 30; therefore the control unit 35 can be configured to activate the pump 34 in order to measure the temperature in the storage tank 2, 20;

ii. a detection from the lower sensor 27, 37, if present, in which the measurement via a temperature sensor inside the heating apparatus 3, 30 and located upstream of the heating element 32 occurs with the methods already described;

iii. according to a further possible embodiment, the heating system 1 comprises a plurality of temperature sensors placed at different heights inside the storage tank 2, 20, a detection from one or more of said sensors may constitute a temperature request;

iv. a detection made directly by the storage tank 2, 20 which may be equipped with its own sensors 27 and its own control system comprising a dedicated control unit and possibly able to send a signal to the control unit 35 of the heating system 1;

v. the start of a withdrawal if detectable;

vi. a combination of the signals i, ii, iii, iv, v and/or a weighted average thereof.

[0109] In heating Mode 3 the control unit 35 activates the heating element 32 and the pump 34. According to a possible embodiment, both the power P and the flow rate m are fixed and heating element 32 and pump 34 are both activated when there is a temperature request that can be according to any of the methods described.

[0110] According to a further possible embodiment, at least one of the flow rate m of the pump 34 and the power P of the heating element 32 is variable and is regulated with one or more proportional, derivative and/or integrative regulation functions. According to a possible embodiment, in which the flow rate m is variable, the control unit 35 regulates the flow rate m according to the formula:

$$m = \frac{P}{(T_{\text{target}} - T_{38}) * c}$$

where P is the power of the heating element 32 that is not necessarily variable for the heating mode. Alternatively, in case in which the power P is variable, the control unit 35 regulates the power P according to the formula:

$$P = m * (T_{\text{target}} - T_{38}) * c$$

since the flow rate m is not necessarily variable for the heating mode.

[0111] In heating Mode 4, i.e. during a withdrawal, the heating function works as in absence of a withdrawal. The activation and/or deactivation of the heating element 32 during a withdrawal, as above, may cause sudden changes in the output temperature; however, since the heating element 32 is activated by a temperature request, it is necessary for it to be activated. Therefore, in heating Mode 3, the start of a withdrawal can be detected as in Mode 1. If a withdrawal is in progress the control unit 35 switches to Mode 4 and activates and/or deactivates the heating element 32 maintaining the variation speed of the power P lower than a predefined maximum comfort speed.

[0112] A heating apparatus 3, 30 configured to operate in Modes 3 and 4 and heat even in absence of surplus power P_{sur} may be combined with a storage tank 2 otherwise devoid of own heating device.

[0113] A heating apparatus 3, 30, configured to operate at least in Mode 1, can be combined with a storage water heater 20 to equip it with a self-consumption and/or demand response function. With reference to figures 2 and 3.b, the storage tank 20 may be the tank of a water heater provided with its own heating elements 202.

[0114] An aspect of the present disclosure is a method for modifying a pre-existing gas or electric water heater 20 and equipping it with a self-consumption function. The method comprises the steps: providing the water heater 20 and a heating apparatus 3 comprising a piping connection 33 from an inlet 331 to an outlet 332, connecting the inlet 331 via a lower hydraulic connection 22, 221 to the lower portion of the storage tank 20 and connecting the outlet 332 via an upper hydraulic connection 23, 231 to the upper portion of the storage tank 20.

[0115] Preferably, the method comprises connecting the inlet 331 of the piping connection 33 to the inlet connection 24 to the water supply of the water heater 20 and connecting the outlet 332 of the piping connection 33 to the outlet connection 25.

[0116] It should be noted that the temperature sensor 27, 37 is not an essential element of the heating system 1, since it is possible to measure the lower temperature also via the outlet temperature sensor 38 in a time interval in which the pump 34 has been active and the heating element 32 inactive.

[0117] The heating system 1 thus described, comprising a water circulation system configured to draw water from the bottom of the tank, to heat it and to send back heated water to the top of the tank has several advantages versus a storage water heater of prior art: it has a substantially perfect thermocline since the temperature gradient in the storage tank 2, 20 is increasing from bottom to top, therefore the water at greater temperature is the first to be drawn and this allows to minimise the heat standing losses even versus vertical development water heaters, in which heating is entrusted to elements

immersed in the storage tank or directly in contact with it.

[0118] Water heaters solely equipped with heating elements configured to heat directly the water in a tank are subject to a trade-off between a thermocline, reachable only if water is heated from the top of the tank, and the need to heat a sufficient volume of water within the tank, satisfiable only by heating water from a bottom portion of the tank. Water heaters comprising a plurality of heating elements positioned at different heights in the tank partly address this problem without solving it. A thermocline allows hotter water to be drawn first, which, for any amount of thermal energy, all other conditions being the same, minimises heat standing losses. Minimising said losses is particularly advantageous where additional thermal energy is stored in order to use surplus power P_{sur} .

[0119] Instantaneous water heaters have substantially no heat standing losses. Compared to said devices the heating system 1 according to at least some of the embodiments described adds some of the advantages of a storage water heater to an instantaneous water heater. In particular the disclosure offers flexibility in setting the time for heating water, the power consumption event, which does not have to forcibly coincide with the hot water delivery event.

[0120] In use, the heating apparatus 3, 30 is configured to control the heating element 32 so as to follow the surplus power P_{sur} and minimise the power fed into the electricity grid, or to respond to demand response signals. In this case, the activation of the heating element 32 can be independent of the water withdrawals.

[0121] Regardless of whether the storage tank 2, 20 comprises its own heating devices, the heating function can be delegated in whole or in part to the heating apparatus 3, 30 that, unlike an element 202 inside the storage tank, has the possibility of supplying heated water starting from the top of the storage tank 2, 20.

[0122] According to a possible embodiment, the heating system 1 is a storage water heater that comprises the storage tank 2, 20, optionally equipped with its own heating devices 202, and has the heating apparatus 30 integrated as in figure 3.a or 3.b.

[0123] According to a possible embodiment, the heating apparatus 3, 30 can contribute in whole or in part to heating the storage tank 2, 20, which may or may not be equipped with its own heating elements 202; in this case the heating apparatus 3, 30 can be configured to provide a minimum amount of heat to the storage tank 2, 20 and possibly increase the consumption to cancel the surplus power P_{sur} .

[0124] The heating system 1 allows for controlling the amount of energy stored as thermal energy more precisely than the prior art. In fact, by preserving the thermocline, the temperature gradient from the point of withdrawal of the lower hydraulic connection 22, 221 to the inlet point of the upper hydraulic connection 23, 231 has a monotonically increasing trend. Knowing the temperature at two different heights, it is possible to estimate with precision and known methods the amount of thermal energy stored and therefore the volume of water that can be delivered for a given temperature of use.

[0125] The heating apparatus 30 can be associated with a storage tank 2 and sold as an integrated product as in figure 3; alternatively, a storage tank 2, 20 and heating apparatus 3 can be a kit of single products. The heating system 1 can be assembled starting from a traditional storage water heater 20 and an instantaneous water heater equipped with a pump 34, preferably a variable flow pump 34. For example, the heating system 1 can be obtained by modifying a previously installed storage water heater 20. For such purpose, it is sufficient to connect the lower hydraulic connection 22 to the inlet pipe 24 and the upper connection 23 to the outlet pipe 25 of a storage water heater. Therefore, compared to other retrofit methods, there is the advantage of avoiding direct interventions on a previously installed storage water heater 20.

[0126] Modes 5 and 6 make it possible to reduce consumptions without affecting comfort.

[0127] In consumption reduction Mode 5, the heating system 1 responds to a condition of energy scarcity by deactivating the heating elements 32, 202 until the user withdraws hot water.

[0128] To carry out Mode 6 an embodiment of a heating system 1 must comprising devices 39, 41 configured to detect an upper water temperature, i.e. a temperature in the upper portion of the storage tank 2, 20, and devices 9, 35, 27, 37, 38, 34 configured to detect whether a withdrawal is in progress. Since the water temperature in the storage tank 2, 20 has a monotonous gradient increasing substantially from bottom to top, the upper temperature is understood to be the value detected by the upper temperature detection devices 39, 41. The devices 39, 41, for detecting a water temperature in the upper portion of the storage tank 2, 20 may be, by way of an example:

- an upper temperature sensor positioned in the upper part of the storage tank (not shown in the figure), an upper temperature sensor 39 positioned along an upper branch 23' or between the outlet of the storage tank 2, 20 and the connection with the outlet pipe as in figure 6.a, or - a thermostatic mixing valve 41 capable of detecting whether the temperature of the water passing through it is lower than a minimum factory value T_{min} .

[0129] In Mode 6, the heating system 1, via the control unit 35, detects that a withdrawal is in progress and that the water temperature in the upper portion of the storage tank 2, 20 has a value lower than a minimum comfort temperature, such minimum temperature being a function of the set temperature T_{target} , or a minimum factory value T_{min} of a thermostatic valve 41. In this situation, the control unit 35 activates the heating element 32 and possibly the pump 34 to supply heated water at a temperature higher than the minimum comfort temperature. Therefore, thanks to the presence of the heating apparatus 3, 30 that can function as an instantaneous heater, it is not necessary to maintain the water in the storage tank 2,

20 at a set temperature T_{target} , nor at a minimum comfort temperature.

[0130] The greater flexibility in consumption for heating translates into an important resource for balancing the electricity grid or for local self-consumption.

[0131] To implement Modes 5 and 6, the preferred embodiments are those in which the outlet 332 of the piping connection 33 is directly connected to the outlet connection 25 to the user (see e.g. Figures 1a, 1c, 2, 3a, 3b, 5); in these embodiments the heating system 1 can function particularly effectively as an instantaneous water heater. In fact, it can receive water from the water supply, heat it and send it directly through the outlet connection 25 to the user without the need for the passage through a storage tank 2, 20, since heating can take place outside the storage tank 2, 20.

[0132] In these embodiments, the heating system 1 can be equipped with devices 41, 42 to limit the temperature of the water delivered to the outlet connection 25 at a lower and/or higher level.

[0133] According to some embodiments, the heating system 1 can be equipped with devices 41, 42 configured to regulate the share of water flow coming from the storage tank 2, 20, versus that coming from the heating apparatus 3. According to an aspect a method is provided to regulate the outlet water temperature between the water temperature in the upper portion of the storage tank 2, 20 and the temperature at the outlet of the heating apparatus 3; therefore, it is possible to limit the temperature both above and below, in particular, it is possible to deliver water to the outlet pipe 25 at a temperature higher than the maximum temperature in the storage tank 2, 20.

[0134] Hereinafter, the upper branch 23' shall be referred to as the branch of the upper hydraulic connection 23 located between the outlet 10 of the storage tank and the connection with the outlet connection 25.

[0135] According to a possible embodiment, the heating system 1 can comprise devices 41, 42 for regulating and/or interrupting the flow in the upper branch 23'.

[0136] A device for regulating the water flows may be a mixing valve 41, preferably of the 3-way type, positioned at the intersection of the upper hydraulic connection 23 with the outlet connection 25, as in Figure 6a. Optionally the mixing valve 41 may be motorised and the heating system 1 may comprise an upper temperature sensor 39 positioned in the upper part of the storage tank 2, 20 or along the upper branch 23' i.e. between the outlet 10 of the storage tank 2, 20 and the mixing valve 41.

[0137] An alternative device for regulating the water flows along the upper branch 23', may be a valve 42 positioned along the upper branch 23' as in Figure 6b, for example a "low-cut" thermostatic valve 42.

[0138] A heating system 1 equipped with devices 41, 42 for regulating and/or interrupting the water flow along the upper branch 23' offers the additional benefit of being able to be used as an instantaneous heater without the need to activate recirculation devices such as the pump 34; in fact, during a withdrawal, water may flow through the piping connection 33, under the effect of the pressure difference that is created between the water supply pressure and the atmospheric pressure during a water withdrawal. It should be noted that the features illustrated in the embodiments are not necessarily available together. In other words, different embodiments may be imagined by the man skilled in the art, where not all of the illustrated features are jointly provided and/or implemented by the heating system 1. In general, the embodiments available in each figure and/or in the description can be combined with the embodiments of one or more of any embodiments of any other figure and/or previously described.

[0139] Furthermore, the retrofit method can be applied to any storage tank such as, for example, the storage tank of a gas or oil water heater.

[0140] According to some possible embodiments, the heating apparatus control unit 35 maintains a minimum temperature set in the storage tank 2, 20, for example an average temperature and in addition performs the self-consumption and demand response functions.

[0141] The heating system 1 finds application in the field of demand response being able to vary the electrical consumption based on external signals. The heating system 1 also finds application in the field of self-consumption, preferably in the version comprising a variable-power heating element 32.

[0142] It is clear that several variants to the disclosure described above are possible for the man skilled in the art, without departing from the novelty scopes of the inventive idea, as well as it is clear that in the practical embodiment of the disclosure the various components described above may be replaced with technically equivalent ones.

Claims

1. Heating system (1) connected to an electricity grid (6), the heating system (1) comprising: a storage tank (2, 20) for a liquid, a heating apparatus (3, 30), a control unit (35), hydraulic connections (22, 221, 23, 231), and recirculation devices (34) the storage tank (2, 20) being a tank for a liquid, the lower portion of which is configured to be connected to an inlet connection (24) of a liquid distribution network, and the upper portion of which is configured to be connected to an outlet connection (25) to a liquid delivery point, the heating apparatus (3, 30) comprising at least:

- a piping connection (33) arranged between a first end called an inlet (331) and a second end called an outlet (332),
 - a heating element (32) in a heat exchange relationship with the piping connection (33),
 the hydraulic connections (22, 221, 23, 231) include:

- a lower hydraulic connection (22, 221) between a lower portion of the storage tank (2, 20) and the inlet (331),
 - an upper hydraulic connection (23, 231) between an upper portion of the storage tank (2, 20), and the outlet (332),

the recirculation devices (34) are arranged to convey the liquid through the piping connection (33),
 the control unit (35) is configured for:

- receiving an information about a power supplied into the electric grid (6), in a quantity unbalanced versus a power demand and/or about a power produced locally from renewable sources (5) in surplus versus local consumption, and in response to that information,
 - varying the electric power consumption P of the heating element (32) and/or varying a thermostating temperature, from a set temperature T_{target} , to a higher "surplus temperature" T_{sur} , in the case of an available electric power surplus, and to a lower temperature in the case of an available electric power short of demand,

the storage tank (2, 20), the piping connection (33) and the hydraulic connections (22, 221, 23, 231) are arranged to form a hydraulic circuit in which the liquid, under the force of a pressure difference, can be drawn from the lower portion of the storage tank (2, 20), heated in the piping connection (33), and sent to the upper hydraulic connection (23, 231), so that the liquid in the storage tank (2, 20) can be heated with a substantially monotonically increasing temperature gradient from the engagement point of the lower hydraulic connection (22, 221) to the engagement point of the upper hydraulic connection (23, 231),
 so that heating system (1) is configured to store the heat generated in the portion of the water that is substantially likely to be withdrawn first.

2. Heating system (1) as in claim 1 wherein the engagement point of the lower hydraulic connection (22, 221) is positioned substantially at the base of the storage tank (2, 20), and the engagement point of the upper hydraulic connection (23, 231) is positioned substantially at the top of the storage tank (2, 20).
3. Heating system (1) as in claim 1 or 2, which when installed in a facility equipped with electrical power from a local system (5) of renewable energy, is capable of receiving a signal indicative of an amount of a surplus electrical power P_{sur} received from the local system (5) and fed into the electrical grid (6) and varying the power P dissipated by the heating element (32) to a value equal to or close to and in any case less than or equal to the surplus power P_{sur} .
4. Heating system (1) as in any of claims 1 to 3, further comprising devices for varying the flow rate m of the liquid through the piping connection (33).
5. Heating system (1) as in any of claims 1 to 4, configured to vary the flow rate m of the liquid through the piping connection (33) in a manner directly proportional to the power P.
6. Heating system (1) as in any claims 1 to 5, wherein the recirculation devices are a pump (34) adapted to pump a liquid through the piping connection (33) from the inlet (331) to the outlet (332) and devices (35) for controlling the pump (34).
7. Heating system (1) as in any of claims 1 to 6, configured for varying the flow rate m of the liquid through the piping connection (33) as a function of the difference between a set temperature T_{target} and a measured temperature of the liquid T_{38} at the outlet end (332) according to the formula:

$$m = \frac{P}{(T_{\text{target}} - T_{38}) * c}$$

or for varying the power P of the heating element (32) according to the formula

$$P = m * (T_{\text{target}} - T_{38}) * c.$$

8. Heating system (1) as in any of claims 1 to 7 further configured for activating the heating element (32) according to a temperature demand corresponding to at least one of the following conditions:

- a detection from any outlet temperature sensor (38), configured to measure the water temperature at the outlet of the heating apparatus (3, 30), the detection performed after activating the pump (34);
- a detection from a lower temperature sensor (27, 37) if present;
- a detection from one or more temperature sensors located, inside the storage tank (2, 20) if present;
- the start of a liquid withdrawal;
- a detection made directly from the storage tank (2, 20) which may be equipped with its own sensors and control system.

9. Heating system (1) as in any one of claims 1 to 8, further comprising devices (9, 35, 27, 37, 38, 34) for detecting whether a water withdrawal is in progress.

10. Heating system (1) as in any one of the previous claims, further comprising devices (41, 42) for regulating or interrupting a flow through the upper branch (23') of the upper hydraulic connection (23) located between the outlet of the storage tank (10) and the connection with the outlet connection (25).

11. Heating system (1) as in any one of the previous claims, wherein the outlet (332) of the piping connection (33) is engaged directly on the outlet connection (25).

12. Heating system (1) as in claims 9, 10 and 11, configured to deliver a liquid directly onto the outlet connection (25) at a temperature above the maximum temperature in the storage tank (2, 20).

13. Heating system (1) as in any of claims 9 to 12 configured to detect whether a water withdrawal is in progress from the detection of the temperature change, the temperature measurement performed by a lower temperature sensor (27, 37) or an outlet temperature sensor (38).

14. A method of retrofitting a storage tank water heater (20) connected in a lower portion thereof, via a lower hydraulic connection (22), to an inlet connection (24) to the water supply and in an upper portion thereof, via an upper hydraulic connection (23), to the outlet connection (25), the method comprising the following steps:

- obtaining a heating apparatus (3), as in claim 1
- connecting the inlet (331) via a lower hydraulic connection (22, 221) to the lower portion of the storage tank (20),
- connecting the outlet (332) via an upper hydraulic connection (23, 231) to the upper portion of the storage tank (20).

15. Retrofit method in accordance with the previous claim further comprising the steps:

- connecting the inlet (331) via the lower hydraulic connection (22) to the inlet connection (24) to the water supply of the storage water heater (20),
- connecting the outlet (332) via the upper hydraulic connection (23) to the outlet connection (25) of the storage tank water heater (20).

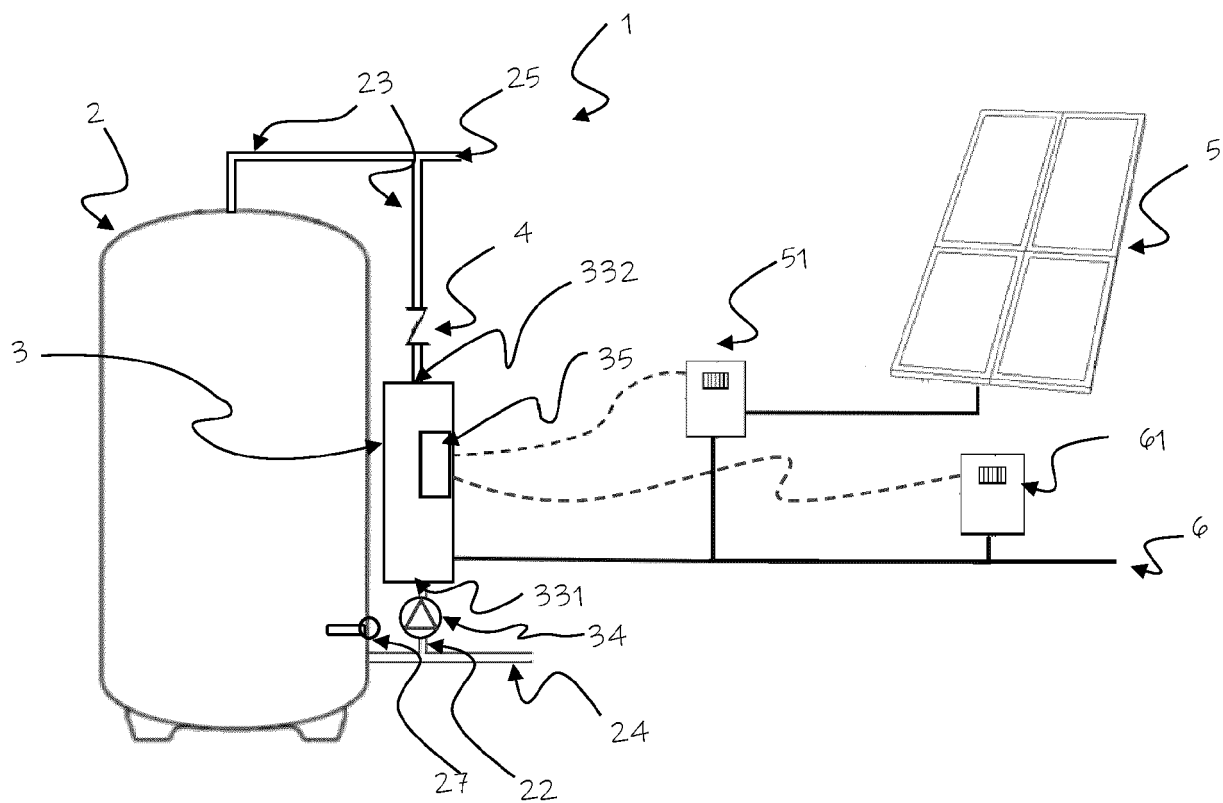


Fig 1a

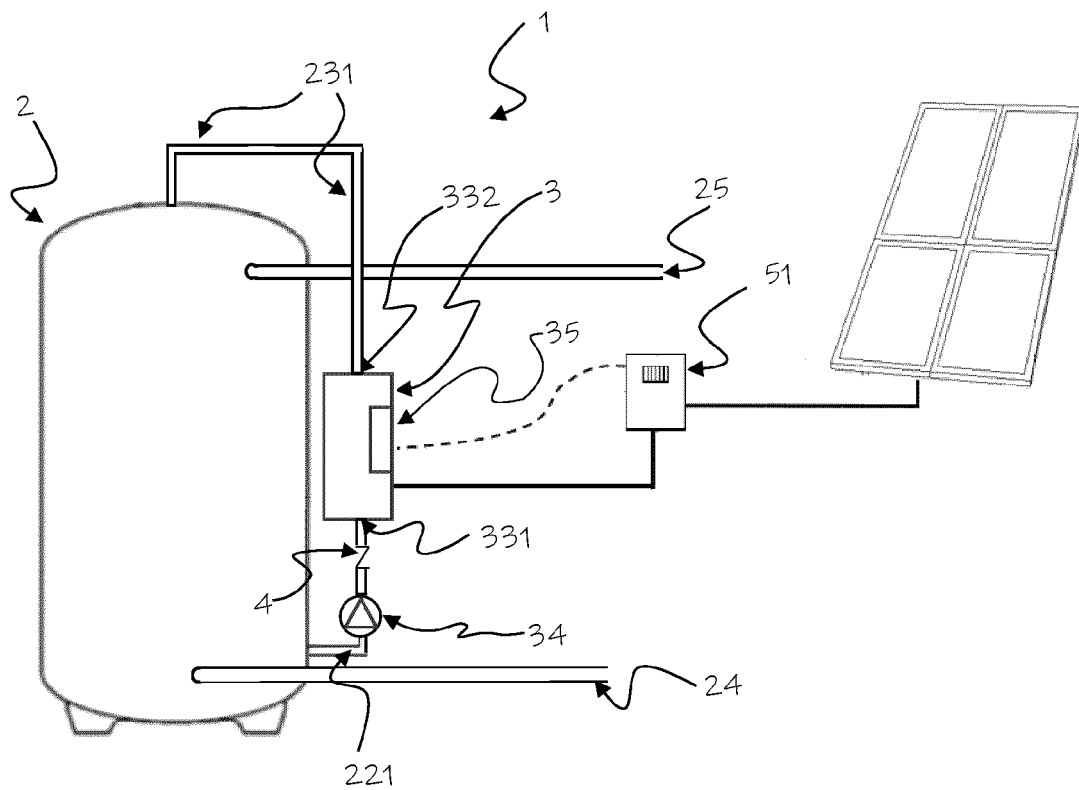


Fig 1b

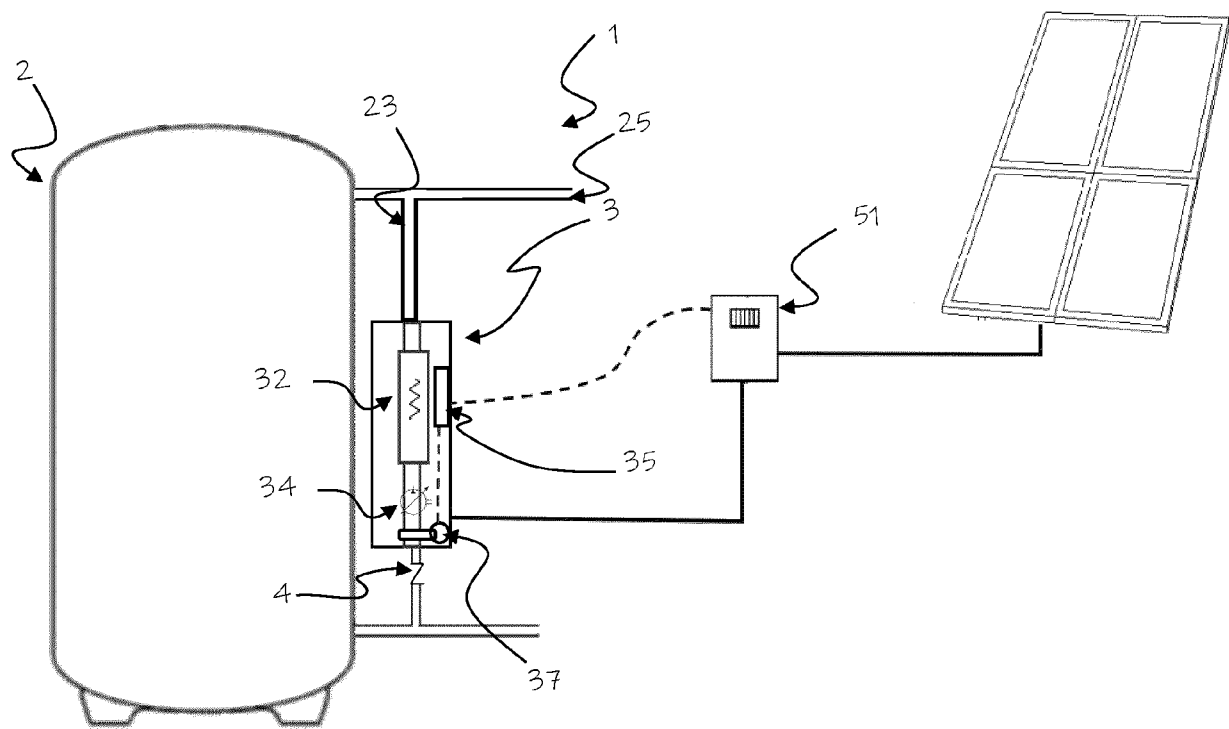


Fig. 10

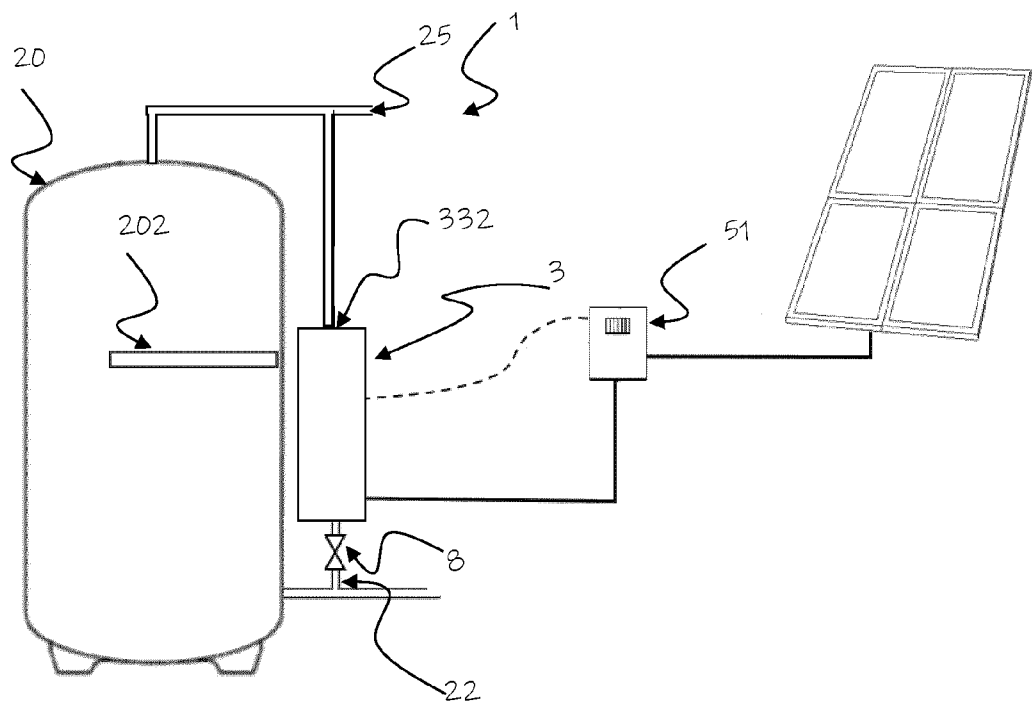


Fig. 2

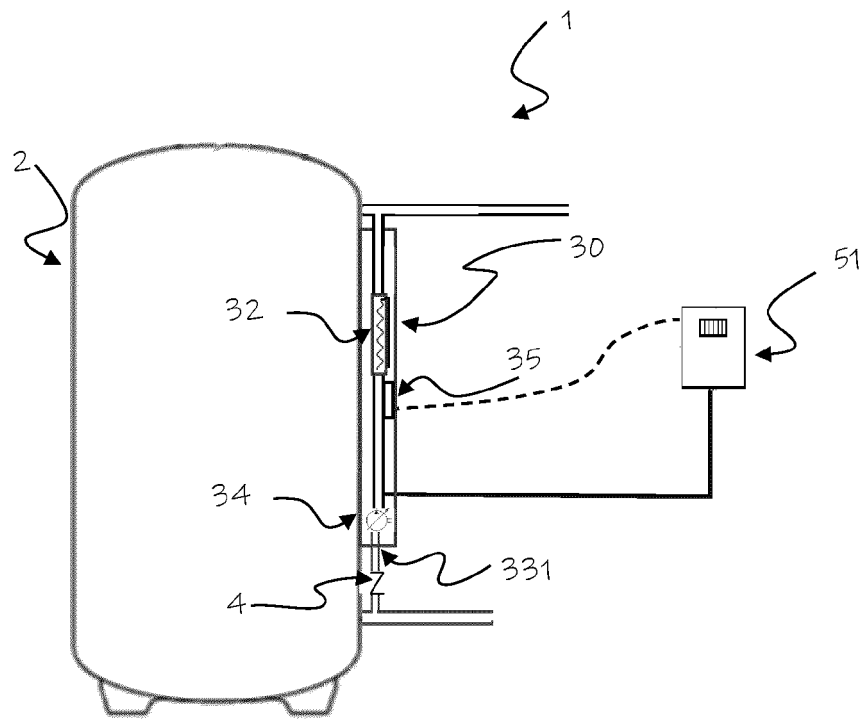


Fig. 3.a

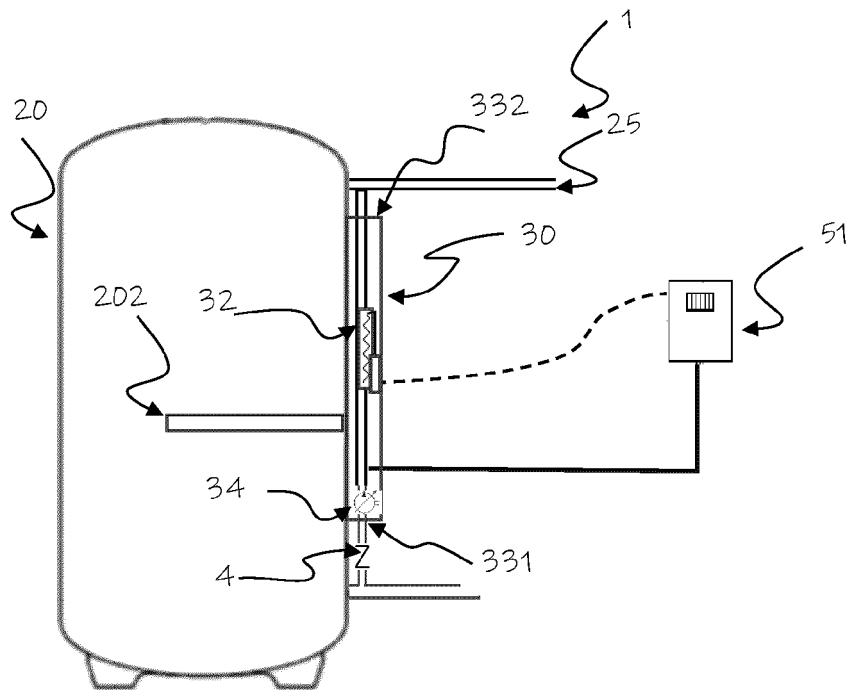


Fig. 3.b

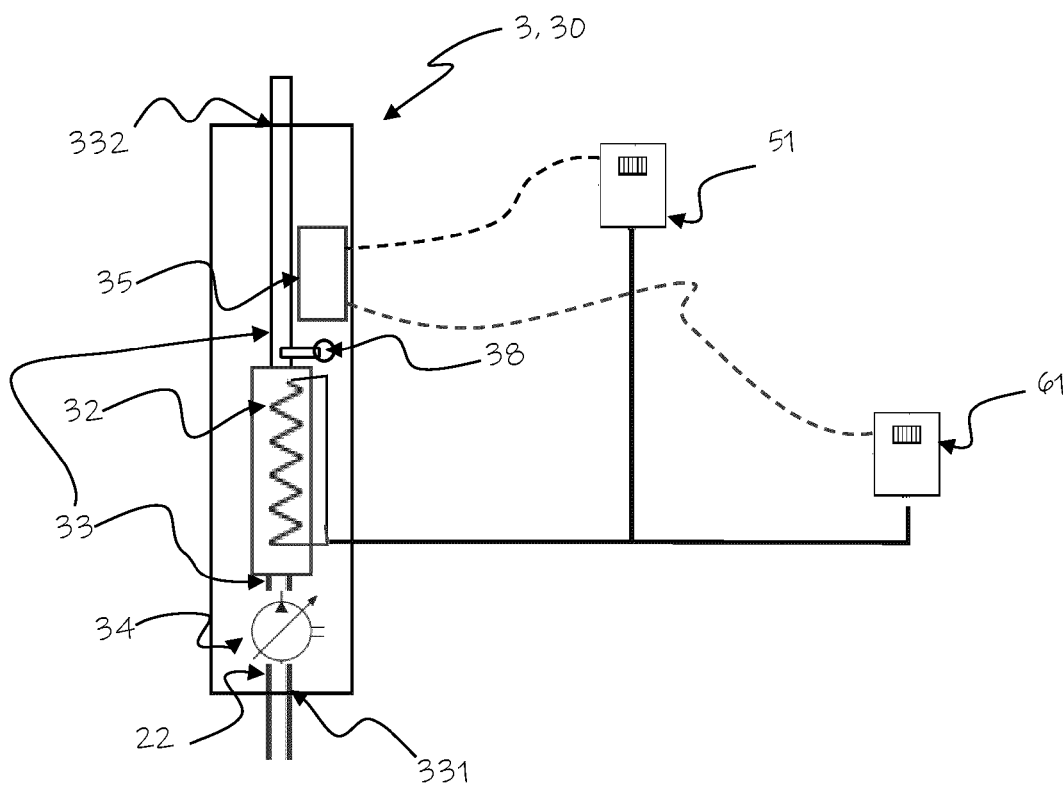


Fig. 4

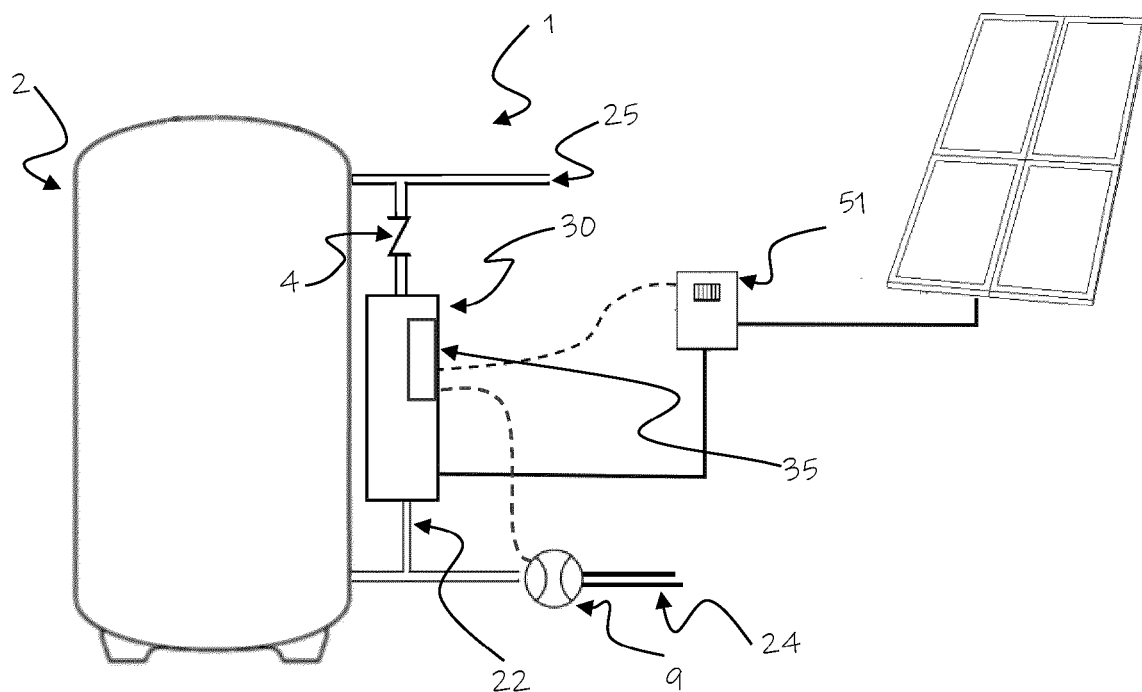


Fig. 5

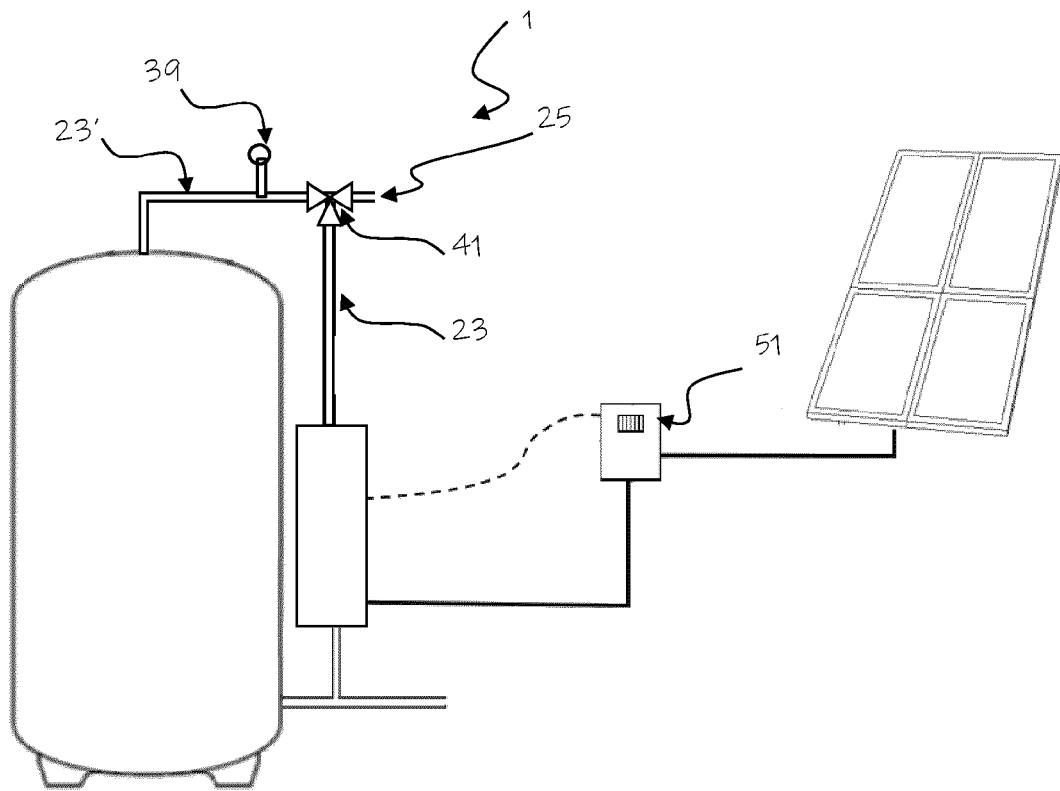


Fig. 6a

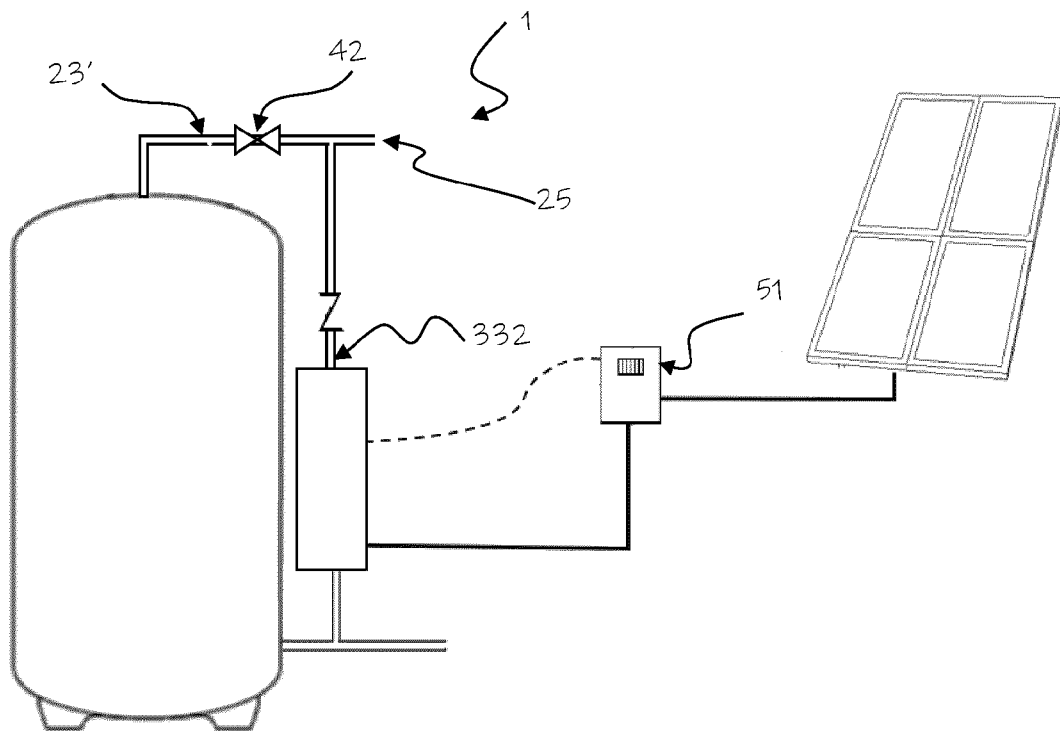


Fig. 6b



EUROPEAN SEARCH REPORT

Application Number

EP 24 21 5253

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Place of search		Date of completion of the search	Examiner
Munich		17 March 2025	Schwaiger, Bernd
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