



(11) **EP 4 253 847 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.10.2023 Bulletin 2023/40

(51) International Patent Classification (IPC):
F24D 17/02 ^(2006.01) **F24D 19/10** ^(2006.01)

(21) Application number: **22164659.9**

(52) Cooperative Patent Classification (CPC):
F24D 17/02; F24D 19/1054; F24D 2200/08;
F24D 2200/12; F24D 2200/20; F24D 2220/08;
F24D 2220/10

(22) Date of filing: **28.03.2022**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicants:
• **MITSUBISHI ELECTRIC CORPORATION**
Chiyoda-ku
Tokyo 100-8310 (JP)
Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GR
HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL
PT RO RS SE SI SK SM TR
• **Mitsubishi Electric R&D Centre Europe B.V.**
Livingston EH54 5DJ (GB)
Designated Contracting States:
GB

(72) Inventors:
• **OLKIS, Christopher**
Livingston, EH54 5DJ (GB)
• **FREEMAN, James**
Livingston, EH54 5DJ (GB)
• **KAWALEY, Georgeanna**
Livingston, EH54 5DJ (GB)
• **WU, Duan**
Livingston, EH54 5DJ (GB)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) **SYSTEM AND METHOD FOR PROVIDING DOMESTIC HOT WATER**

(57) A system for providing domestic hot water and a method using the system is provided. The system comprises a heat pump, a mains water supply, a heat exchanger establishing a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump, a thermal energy storage device connected to the heat pump, and a controller having different operation modes and being configured to select between them and control the heat pump based on a

selected operation mode. In a first operation mode, thermal energy is provided from the heat pump to the thermal energy storage device, but not to the heat exchanger, whereas in a second operation mode, thermal energy is provided from the heat pump to the heat exchanger. The configuration of the controller to switch to the second operation mode allows the system and method to provide domestic hot water continuously, i.e. without downtimes.

EP 4 253 847 A1

Description

[0001] A system for providing domestic hot water and a method using the system is provided. The system comprises a heat pump, a mains water supply, a heat exchanger establishing a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump, a thermal energy storage device connected to the heat pump, and a controller having different operation modes and being configured to select between them and control the heat pump based on a selected operation mode. In a first operation mode, thermal energy is provided from the heat pump to the thermal energy storage device, but not to the heat exchanger, whereas in a second operation mode, thermal energy is provided from the heat pump to the heat exchanger. The configuration of the controller to switch to the second operation mode allows the system and method to provide domestic hot water continuously, i.e. without downtimes.

[0002] Combi boilers have high heat outputs, where even small models can provide a heat output of 25 kW to provide domestic hot water (DHW), while the requirement to heat mains water from 10°C to 40°C is about 15 to 20 kW (for a typical D supply flow rate of 7-10 liters per minute). Thus, combi boilers can directly provide domestic hot water without a thermal energy storage (TES).

[0003] If a system to provide domestic hot water has no combi boiler, but only a residential heat pump with a heat output of approximately 4 to 10 kW, the residential heat pump alone is insufficient to heat domestic hot water (DHW) directly within the heat pump. Thus, in these systems, a TES, specifically a domestic hot water TES (DHW-TES), is required for providing domestic hot water. However, once the DHW-TES is fully discharged, the system cannot provide hot water anymore and it takes about two hours to fully recharge the DHW-TES again.

[0004] US 9,581,340 B2 discloses a preheat tank to which a heat exchanger is operatively coupled and which receives water from a distribution subsystem. A controller has a first mode in which fluid is routed through the heat exchanger to pass heat to the preheat tank and a second mode, in which the fluid is routed through an evaporator of a refrigerator to pass heat to the refrigerant. A water storage tank is coupled to the preheat tank to receive water therefrom and is coupled to a condenser of the refrigerator such that heat rejected by the condenser is passed to the contents of the water storage tank.

[0005] US 2006/0196955 A1 discloses a domestic water tank pre-heating system to pre-heat domestic water within a domestic water tank and a water saver system is provided for limiting the wasting of clean but tepid water.

[0006] GB 2464162 A discloses an auxiliary heat exchange unit used in conjunction with a hot water cylinder of a hot water supply system and which comprises a first tank, a second tank and a central tank.

[0007] WO 2020/227216 A1 discloses a domestic hot water preheater operable to supply domestic hot water

to a structure and/or to preheat a cold return of a space heating system.

[0008] In heat pump systems known in the prior art, the heat pump and domestic hot water are separated, because mains water enters the domestic hot water thermal energy storage device directly and is heated within the domestic hot water thermal energy storage device. Furthermore, in heat pump systems known in the prior art, heating of the domestic hot water thermal energy storage device is independent from domestic hot water demand and all thermal energy from the heat pump is directed to the domestic hot water thermal energy storage device for charging.

[0009] The problem with the system known in the prior art is that in cases in which the domestic hot water thermal energy storage device (DHW-TES) is fully discharged, the system cannot provide hot water anymore and it can take several hours until the DHW-TES is fully charged again, i.e. the systems cannot provide hot water for quite a long time, i.e. until the charge of the DHW-TES has reached a level suitable for heating mains water to a desired temperature. This leads to considerable downtimes in providing domestic hot water.

[0010] Starting therefrom, it was the object of the present application to provide a system and a method which does not have the disadvantages of prior art systems and methods. Specifically, it should be possible with the system and method to provide hot water without downtimes in providing domestic hot water.

[0011] The object is solved by the device having the features of claim 1 and the method having the features of claim 9. The dependent claims illustrate advantageous embodiments of the invention.

[0012] According to the invention, a system for providing domestic hot water is provided, comprising

- a) a heat pump,
- b) a mains water supply;
- c) a heat exchanger establishing a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump;
- d) a thermal energy storage device connected to the heat pump;
- e) a first operation mode in which thermal energy is provided from the heat pump to the thermal energy storage device, but not to the heat exchanger;
- f) a second operation mode in which thermal energy is provided from the heat pump to the heat exchanger, and
- g) a controller configured to select at least between the first operation mode and the second operation mode and configured to control the pump based on a selected operation mode.

[0013] The system according to the invention allows the provision of providing domestic hot water without downtimes and allows an extension of the domestic hot water discharge capacity. The reason is that the system

according to the present invention can switch between the first operation mode and second operation mode and thus link a heat pump operation with a degree of domestic hot water demand. If there is no demand of domestic hot water, the system can switch to the first operation mode. If there is a (high) demand for domestic hot water, the system can switch to the second operation mode.

[0014] In the first operation mode (i.e. when there is no demand for domestic hot water), the controller of the system controls the heat pump to provide thermal energy from the heat pump to the thermal energy storage device, but not to the heat exchanger, i.e. the controller effectuates a charging of the thermal energy storage device. In the second operation mode (i.e. when demand for domestic hot water is high), the controller of the system controls the heat pump to provide thermal energy from the heat pump to the heat exchanger of the system, i.e. the controller effectuates a heating of the mains water in the heat exchanger. This heating can be a preheating of the mains water before it enters the thermal energy storage device of the system or can be a postheating of the mains water after it exits the thermal energy storage device. Thus, the heat exchanger can be located upstream of the thermal energy storage device or downstream of the thermal energy storage device in the system according to the invention (used in the method according to the invention).

[0015] It becomes clear that the additional heating of mains water by the heat exchanger in the second operation mode reduces the heating burden which is put on the thermal energy storage device, especially during periods of a high demand of domestic hot water, in this operation mode. In other words, a higher volume of domestic hot water at a target temperature can be provided or, put differently, domestic hot water at a target temperature can be provided for a longer period of time, thus abolishing downtimes.

[0016] Briefly, the second operation mode has the following advantages:

- Increased domestic hot water output from the thermal energy storage device is possible as the total required instantaneous heat load is split between heat pump and the thermal energy storage device;
- Faster recharging of the thermal energy storage device after large domestic hot water draw offs are possible because the heat pump is already running and no start up time is required including less frequent re-charging cycles;
- High heat pump efficiency (coefficient of performance) is possible during the second operation mode because of low temperature lift between ambient air temperature and preheated mains water outlet temperature;
- If the thermal energy storage device is fully charged and a large domestic hot water demand is predicted based on a user behaviour (e.g. all household members shower in the morning), downtimes of domestic

hot water provision can be mitigated.

[0017] The controller of the system can be configured to, in the second operation mode, allow heated mains water to flow from the heat exchanger into the thermal energy storage device. Preferably heated mains water is allowed to flow such that thermal energy of the thermal energy storage device is transferred to the heated mains water (= further heating of the mains water, e.g. if the thermal energy storage device is a PCM-TES) or such that thermal energy of the heated mains water is transferred to the thermal energy storage device (= charging of the thermal energy storage device, e.g. if the thermal energy storage device is a water storage tank).

[0018] The controller of the system can be configured to switch to the first operation mode if there is no active demand for domestic hot water and a state of charge of the thermal energy storage device is below a preset threshold.

[0019] Furthermore, the controller of the system can be configured to switch to the second operation mode if there is a high active demand for domestic hot water and the heat pump is running or not running, or if there is a low demand for domestic hot water and the heat pump is running.

[0020] The system can comprise a third operation mode in which no thermal energy is provided from the heat pump to the thermal energy storage device and to the heat exchanger. In the third operation mode, the system is configured to provide domestic hot water only by heat energy stored in the thermal energy storage device, i.e. only the thermal energy storage device is used for heating mains water to domestic hot water. The controller is preferably configured to switch to the third operation mode if there is a low active demand for domestic hot water and/or if a state of charge of the thermal energy storage device is at or above a preset threshold and the heat pump shall not be operated. In the third operation mode (when demand for domestic hot water is low), the controller of the system controls the heat pump to provide no thermal energy from the heat pump to the thermal energy storage device and no thermal energy of from the heat pump to the heat exchanger of the system, i.e. the controller effectuates that the mains water is only heated by thermal energy stored in the thermal energy storage device, which is thereby discharged.

[0021] The system can further comprise a fluid flow detection sensor which is suitable for detecting a volume flow of fluid from the thermal energy storage device to a domestic hot water discharge of the system.

[0022] Besides, the system can further comprise a resistance heater for heating water of the mains water supply. The controller is preferably configured to activate the resistance heater if there is a high active demand for domestic hot water. The resistance heater allows a further heating of the mains water and allows a quicker response to a heating demand than the heat pump, because the heat pump needs a moment to run at full ca-

capacity. The resistance heater can be located upstream or downstream of the thermal energy storage device. A location upstream of the thermal energy storage device has the advantage that the resistance heater can contribute to charging the thermal energy storage device (with thermal energy). Moreover, the resistance heater can be located upstream or downstream of the heat exchanger. Preferably, the resistance heater is located downstream of the heat exchanger and upstream of the thermal energy storage device. It is also possible that the resistance heater and the heat pump together provide warm potable water at temperatures that are not perceived as very cold by the user. This allows bypassing the thermal energy storage device to avoid its discharge or provides a further measure to avoid downtimes if the thermal energy storage device is fully discharged and there is still a high demand for domestic hot water.

[0023] The system can comprise a means for heating water of the mains water supply by energy recovered from waste water. Said means is preferably located upstream of the heat exchanger in the system.

[0024] The system can further comprise a state of charge device which is configured to determine the state of charge of the thermal energy storage device. Preferably, the controller is configured to control the heat pump based on a state of charge determined by the state of charge device. Moreover, the controller can be configured to switch to the first operation mode if the determined state of charge of the thermal energy storage device is below a preset threshold. Furthermore, the controller can be configured to switch to the second operation mode if the determined state of charge of the thermal energy storage device is below a preset threshold. Besides, the controller can be configured to switch to a third operation mode, in which no thermal energy is provided from the heat pump to the thermal energy storage device and to the heat exchanger, if the state of charge of the thermal energy storage device is at or above a preset threshold.

[0025] The controller can be configured to switch into the second operation mode if there is a need of a large amount of domestic hot water by a hot water consuming device. The hot water consuming device is preferably configured to communicate a need of a large amount of hot water to the controller. The hot water consuming device is particularly preferably selected from the group consisting of kitchen sink, bathtub, washing machine, dishwasher and combinations thereof.

[0026] Furthermore, the controller can be configured to switch into the second operation mode if a domestic hot water demand prediction predicts a need of a large amount of domestic hot water. Preferably, the controller is configured to perform said prediction.

[0027] Moreover, the controller can be configured to switch into the second operation mode if a volume flow from the thermal energy storage device to a domestic hot water discharge of the system falls above a certain threshold and the domestic hot water discharge of the system is associated to large domestic hot water dis-

charges. The volume flow is preferably detected by a fluid flow detection sensor of the system which is configured to communicate a detected volume flow to the controller. The fluid flow detection sensor can be selected from the group consisting of flowmeter, pressure sensor, temperature sensor and combinations thereof.

[0028] Besides, the controller can be configured to switch into the second operation mode if a direct user input communicates a need of a large amount of domestic hot water. The direct user input is preferably detected by an input device of the system which is configured to communicate a need of a large amount of domestic hot water to the controller.

[0029] In a preferred embodiment, the thermal energy storage device is a phase change material thermal energy storage device (PCM-TES). The phase change material thermal energy storage device can comprise a heat exchanger embedded into it which promotes transfer of heat from the heat pump to the phase change material thermal energy storage device. A PCM-TES as thermal energy storage device is beneficial from an energy perspective. The PCM-TES stores most of its energy content by utilising the heat of fusion of the phase change material (PCM), meaning that almost all the energy is stored and released at the melting temperature of the PCM (e.g. 50°C). Hence, water entering at a higher inlet temperature will lead to a lower discharge heat flow rate from the PCM to the water. The lower discharge rate increases the amount of water that can be extracted from the heat stored in the PCM at 50°C.

[0030] Alternatively, the thermal energy storage device can be a water storage tank, preferably a water storage tank containing an encapsulated phase change material.

[0031] According to the invention, a method for providing domestic hot water is provided, comprising the steps

a) providing a system comprising

a heat pump,
a mains water supply;
a heat exchanger establishing a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump;
a thermal energy storage device connected to the heat pump;
a first operation mode in which thermal energy is provided from the heat pump to the thermal energy storage device, but not to the heat exchanger, a second operation mode in which thermal energy is provided from the heat pump to the heat exchanger, and
a controller configured to select at least between the first operation mode and the second operation mode;

b) controlling the heat pump by the controller based on a selected operation mode.

[0032] With the inventive method, domestic hot water can be provided without downtimes and the domestic hot water discharge capacity can be extended.

[0033] In the method, the controller can be configured to, in the second operation mode, allow heated mains water to flow from the heat exchanger into the thermal energy storage device. Preferably the heated mains water is allowed to flow from the heat exchanger into the thermal energy storage device such that thermal energy of the thermal energy storage device is transferred to the heated mains water or thermal energy of the heated mains water is transferred to the thermal energy storage device.

[0034] In the method, the controller can be configured to switch to the first operation mode if there is no active demand for domestic hot water and a state of charge of the thermal energy storage device is below a preset threshold.

[0035] Furthermore, in the method, the controller can be configured to switch to the second operation mode if there is a high active demand for domestic hot water and the heat pump is running or not running, or if there is a low demand for domestic hot water and the heat pump is running.

[0036] The system provided in the method can comprise a third operation mode in which no thermal energy is provided from the heat pump to the thermal energy storage device and the heat exchanger. In the third operation mode, the system is configured to provide domestic hot water only by heat energy stored in the thermal energy storage device, i.e. only the thermal energy storage device is used for heating mains water to domestic hot water. The controller is preferably configured in the method to switch to the third operation mode if there is a low active demand for domestic hot water and/or if a state of charge of the thermal energy storage device is at or above a preset threshold and the heat pump shall not be operated.

[0037] The system which is provided in the method can further comprise a fluid flow detection sensor which is suitable for detecting a volume flow of fluid from the thermal energy storage device to a domestic hot water discharge of the system.

[0038] Moreover, the system which is provided in the method can further comprise a resistance heater for heating water of the mains water supply. The controller is preferably configured in the method to activate the resistance heater if there is a high active demand for domestic hot water. The resistance heater allows a further heating of the mains water and allows a quicker response to a heating demand than the heat pump, because the heat pump needs a moment to run at full capacity. The resistance heater can be located upstream or downstream of the thermal energy storage device. A location upstream of the thermal energy storage device has the advantage that the resistance heater can contribute to charging the thermal energy storage device (with thermal energy). Moreover, the resistance heater can be located

upstream or downstream of the heat exchanger. Preferably, the resistance heater is located downstream of the heat exchanger and upstream of the thermal energy storage device. It is also possible that the resistance heater and the heat pump together provide warm potable water at temperatures that are not perceived as very cold by the user. This allows bypassing the thermal energy storage device to avoid its discharge or provides a further measure to avoid downtimes if the thermal energy storage device is fully discharged and there is still a high demand for domestic hot water.

[0039] The system which is provided in the method can comprise a means for heating water of the mains water supply by energy recovered from waste water. Said means is preferably located upstream of the heat exchanger in the system of the method.

[0040] The system which is provided in the method can further comprises a state of charge device which is configured to determine the state of charge of the thermal energy storage device. The controller is preferably configured in the method to control the heat pump based on a state of charge determined by the state of charge device. Moreover, the controller is preferably configured in the method to switch to the first operation mode if the determined state of charge of the thermal energy storage device is below a preset threshold. Furthermore, the controller is preferably configured in the method to switch to the second operation mode if the determined state of charge of the thermal energy storage device is below a preset threshold. Besides, the controller is preferably configured in the method to switch to a third operation mode, in which no thermal energy is provided from the heat pump to the thermal energy storage device and to the heat exchanger, if the determined state of charge of the thermal energy storage device is at or above a preset threshold.

[0041] The controller can be configured in the method to switch into the second operation mode if there is a need of a large amount of domestic hot water by a hot water consuming device. The hot water consuming device is preferably configured in the method to communicate a need of a large amount of hot water to the controller. The hot water consuming device can be selected from the group consisting of kitchen sink, bathtub, washing machine, dishwasher and combinations thereof.

[0042] Moreover, the controller can be configured in the method to switch into the second operation mode if a domestic hot water demand prediction predicts a need of a large amount of domestic hot water. Preferably, the controller is configured in the method to perform said prediction.

[0043] Furthermore, the controller can be configured in the method to switch into the second operation mode if a volume flow from the thermal energy storage device to a domestic hot water discharge of the system falls above a certain threshold and the domestic hot water discharge of the system is associated to large domestic hot water discharges. The volume flow is preferably de-

tected by a fluid flow detection sensor of the system which is configured in the method to communicate a detected volume flow to the controller. The fluid flow detection can be selected from the group consisting of flowmeter, pressure sensor, temperature sensor and combinations thereof.

[0044] Besides, the controller can be configured in the method to switch into the second operation mode if a direct user input communicates a need of a large amount of domestic hot water. The direct user input is preferably detected by an input device of the system which is configured in the method to communicate a need of a large amount of domestic hot water to the controller.

[0045] In a preferred embodiment, the thermal energy storage device of the system provided in the method is a phase change material thermal energy storage device. The phase change material thermal energy storage device preferably comprises a heat exchanger embedded into it which promotes transfer of heat from the heat pump to the phase change material thermal energy storage device.

[0046] Alternatively, the thermal energy storage device can be a water storage tank, preferably a water storage tank containing an encapsulated phase change material.

[0047] With reference to the following figures and examples, the subject according to the invention is intended to be explained in more detail without wishing to restrict said subject to the specific embodiments shown here.

[0048] Figure 1 illustrates schematically a simple rule-based control of the controller of a system and method according to the present invention. The controller is configured to determine whether the system should operate in a first operation mode (charging mode) or a second operation mode (preheating mode). In this embodiment, the controller is also configured to determine whether the system should operate in a third operation mode (Cold mains heated only by DHW-TES mode). Preheating may be activated when active demand for domestic hot water is high, or if active demand for hot water is low and the heat pump is already running. The controller may return to the first operation mode (charging mode) when a domestic hot water (DHW) demand has finished. In addition, the control activates DHW preheating mode, if a large DHW demand is detected or the state of charge (SOC) of the thermal energy storage device (TES) falls below a minimum threshold.

[0049] Figure 2 illustrates schematically a first system according to the present invention. In this embodiment, the thermal energy storage device is a phase change material thermal energy storage device (PCM-TES). Domestic hot water exiting the mains water supply 2 flows in a fluid line through the heat exchanger 3 in which it can receive thermal energy from a fluid line exiting the heat pump 1. On its way to the thermal energy storage device 4 (in this case: a PCM-TES) the preheated mains water can further be heated by a resistance heater 13. In the thermal energy storage device, the preheated mains water is further heated to domestic hot water 10

which can flow to the kitchen sink 14 or to the bath tub 15. The controller 5 of the system is configured to control the heat pump 1. The illustrated system also comprises a state of charge device 6 configured to determine the state of charge of the thermal energy storage device 4 and a flow detection sensor 7. For directing the flow of mains water, the system also comprises a switching valve 12 which allows switching the mains water to flow either through the heat exchanger 3 via the resistance heater 13 to the thermal energy storage device 4, or to the local space heating system 8. The heat exchanger 3, resistance heater 13, controller 5 and switching valve are comprised by an indoor unit 9.

[0050] Figure 3 illustrates schematically a further system according to the present invention in the first operation mode (charge mode). In this system, the thermal energy storage device 4 is a water storage tank. Domestic water exiting the mains water supply 2 flows in a fluid line through the heat pump 1 in which it can receive thermal energy from the heat pump 1. In this first operation mode, there is no discharge from the thermal energy storage device 4 (see greater line thickness), i.e. no domestic hot water 10 is provided to the kitchen sink 14 and/or to the bath tub 15. Moreover, no mains water enters the thermal energy storage device 4, but a second pipe actively extracts water from the thermal energy storage device 4, where it flows through heat exchanger 3 and then resistance heater 13, before returning back to the thermal energy storage device. The controller 5 of the system is configured to control the heat pump 1. The illustrated system also comprises a state of charge device 6 configured to determine the state of charge of the thermal energy storage device 4 and a flow detection sensor 7. For directing the flow of mains water, the system also comprises a switching valve 12. The heat exchanger 3, resistance heater 13, controller 5 and switching valve are comprised by a cylinder unit 11 for domestic hot water.

[0051] Figure 4 illustrates schematically the system illustrated in Figure 3, but in the second operation mode (preheating water discharge mode). Domestic water exiting the mains water supply 2 flows in a fluid line through the heat exchanger 3 in which it can receive thermal energy from a fluid line exiting the heat pump 1. On its way to the thermal energy storage device 4 (in this case: a water storage tank) the preheated mains water transfers heat to the thermal energy storage device 4. Water heated in the thermal energy storage device 4 to domestic hot water 10 can flow to the kitchen sink 14 or to the bath tub 15. The controller 5 of the system is configured to control the heat pump 1. The illustrated system also comprises a state of charge device 6 configured to determine the state of charge of the thermal energy storage device 4 and a flow detection sensor 7. For directing the flow of mains water, the system also comprises a switching valve 12. The heat exchanger 3, resistance heater 13, controller 5 and switching valve are comprised by a cylinder unit 11 for domestic hot water.

[0052] Figure 5 illustrates schematically a further sys-

tem according to the present invention in the second operation mode (postheating water discharge mode). Some components of the system shown in Figures 2 to 4 have been omitted for clarity reasons. In this embodiment, mains water exiting a thermal energy storage device 4 of the system is heated by the heat exchanger 3 which receives thermal energy from the heat pump 1 and is located downstream of the thermal energy storage device 4 in this case. This allows domestic hot water 10 at a target temperature to be provided to a kitchen sink 14 and/or a bath tub 15 even if the thermal energy storage device has a low thermal capacity or is fully discharged.

Example 1 - Exemplary use of the system and method

[0053] For example, a shower requires water flow rates of about 7 liters per minute (LPM). To supply the shower with DHW, cold mains water enters the heat exchanger at 10°C, where it is heated by 5 kW from the heat pump to 20 °C in the heat exchanger, optionally also an additional 3 kW from a resistance heater, to 26°C. The preheated mains water is then further heated in the DHW-TES from 26°C to 40°C outlet temperature.

[0054] This leads to a discharge rate of 6.8 kW from the DHW-TES, which is significantly lower than the 15 kW that would have been required without preheating mode.

[0055] Thus, the DHW volume that can be supplied by the DHW-TES is doubled if the heating mode (second operation mode) is applied. In addition, the shower is still supplied with warm water at 26°C once the DHW-TES is fully discharged.

Example 2 - First embodiment (Figure 2)

[0056] A first embodiment of a system and a method according to the invention is shown in Figure 2. In this embodiment, the thermal energy storage device is a PCM-TES.

First operation mode (PCM-TES charge mode)

[0057] The first operation mode represents a mode in which the heat pump transfers heat to the PCM-TES (preferably via transfer of heat to a heat exchanger embedded into the PCM-TES), but does not transfer heat to water flowing through the heat exchanger which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump.

[0058] The first operation mode can be activated if there is no active DHW demand and the state of phase (SOC) of the PCM-TES is below a threshold.

Second operation mode (preheating water discharge mode)

[0059] The second operation mode represents a mode

in which the heat pump transfers heat to water flowing through the heat exchanger which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump. Mains water heated in the heat exchanger is then transported into the PCM-TES in which the mains water is further heated and acquires its final temperature.

[0060] As can be seen e.g. in Figure 2, mains water originating from the mains water supply will enter the heat exchanger (which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump) and will be heated in said heat exchanger by heat originating from the (fluid line of the primary circuit of the) heat pump. An optional resistance heater can further heat the mains water flow after exiting the heat exchanger. The preheated mains water enters the PCM-TES (preferably a heat exchanger embedded into the PCM-TES) at an intermediate temperature and is heated to its desired final temperature by the PCM-TES.

[0061] The second operation mode can be activated e.g. if

- a state of charge of the thermal energy storage device falls below a threshold value, wherein the state of charge is preferably detected by a state of charge device of the system which is configured to communicate a detected state of charge to the controller; and/or
- there is a need of a large amount of domestic hot water by a hot water consuming device, wherein the hot water consuming device is preferably configured to communicate a need of a large amount of hot water to the controller, wherein the hot water consuming device is particularly preferably selected from the group consisting of bathtub, washing machine and combinations thereof; and/or
- a domestic hot water demand prediction predicts a need of a large amount of domestic hot water, wherein preferably the controller is configured to perform the prediction; and/or
- a volume flow from the thermal energy storage device (4) to a domestic hot water discharge falls above a certain threshold, wherein the volume flow is preferably detected by a fluid flow detection sensor of the system which is configured to communicate a detected volume flow to the controller, wherein the fluid flow detection sensor is particularly preferably selected from the group consisting of flowmeter, pressure sensor, temperature sensor and combinations thereof; and/or
- a direct user input communicates need of a large amount of domestic hot water, wherein the direct user input is preferably detected by an input device of the system which is configured to communicate a need of a large amount of domestic hot water to the controller.

Third operation mode (regular water discharge mode)

[0062] The third operation mode represents a mode in which the heat pump transfers no heat to the PCM-TES and also no heat to the heat exchanger which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump. In this third operation mode, the heat pump is neither supplying thermal energy to the mains water (via the heat exchanger) nor to the PCM-TES (i.e. no charging of the PCM-TES occurs).

[0063] As can be seen e.g. in Figure 2, mains water originating from the mains water supply will enter the heat exchanger (which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump) and will not be heated in said heat exchanger. An optional resistance heater is switched off. The non-preheated mains water enters the PCM-TES (preferably a heat exchanger embedded into the PCM-TES) at its original temperature and is heated to its desired final temperature by the PCM-TES (alone).

[0064] Since all energy input to the mains water is provided by the PCM-TES, the third operation mode is advantageous if only small DHW discharges are required, e.g. discharges shorter than the start-up time needed by the heat pump. This configuration can further be advantageous, if other control decisions prohibit a heat pump DHW cycle at that moment, e.g. absence of inexpensive, renewable energy.

Example 3 - Second embodiment (Figures 3 and 4)

[0065] A second embodiment of the system and method according to the invention is shown in Figures 3 and 4. In this embodiment, the thermal energy storage device is a water storage tank.

First operation mode (water storage tank charge mode)

[0066] The first operation mode is illustrated in Figure 3 and represents a mode in which the heat pump transfers heat to the water storage tank, but does not transfer heat to mains water flowing through the heat exchanger which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump.

[0067] The first operation mode can be activated if there is no active DHW demand and the heating capacity of the water storage tank is below a threshold.

Second operation mode (preheating water discharge mode)

[0068] The second operation mode is illustrated in Figure 4 and represents a mode in which the heat pump transfers heat to mains water flowing through the heat exchanger which establishes a thermal connection between a fluid line exiting the mains water supply and a

fluid line exiting the heat pump. Mains water heated in the heat exchanger is then transported into the water storage tank in which the heated mains water transfers heat to the water storage tank.

[0069] As can be seen e.g. in Figure 4, mains water originating from the mains water supply will enter the heat exchanger (which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump) and will be heated in said heat exchanger by heat originating from the (fluid line of the primary circuit of the) heat pump. An optional resistance heater can further heat the mains water flow after exiting the heat exchanger. The preheated mains water enters the water storage tank and transfers heat to the water storage tank. The preheated mains water is transported into the water storage tank in a manner that it is not mixed. To this end, it is beneficial if the inlet for conducting preheated mains water into the water storage tank is located close to the bottom of the water storage tank, as shown in Figures 3 and 4. This helps to maintain the stratification, while allowing simultaneous re-charging of the tank.

[0070] The second operation mode can e.g. be activated (by the controller of the system) if

- a heating capacity of the water storage tank (e.g. detected by a temperature sensor) falls below a threshold; and/or
- at least one device consuming DHW (e.g. a bathtub and/or a washing machine) communicates a need of a large amount of DHW (e.g. to the controller of the system); and/or
- a DHW demand prediction (e.g. by a controller of the system) predicts a need of a large amount of DHW; and/or
- a volume flow from the water storage tank to a DHW discharge (e.g. detected by a fluid flow detection sensor) falls above a certain threshold (A suitable fluid flow detection sensor can be selected from the group consisting of flowmeter, pressure sensor, temperature sensor and combinations thereof); and/or
- a direct user input (e.g. a button pushed by a user in the kitchen or bathroom) signals a need of a large amount of DHW.

Third operation mode (regular water discharge mode)

[0071] The third operation mode represents a mode in which the heat pump transfers no heat to the water storage tank and also no heat to the heat exchanger which establishes a thermal connection between a fluid line exiting the mains water supply and a fluid line exiting the heat pump. In this third operation mode, the heat pump is neither supplying thermal energy to the mains water (via the heat exchanger) nor to the water storage tank (i.e. no charging of the water storage tank occurs).

[0072] Since all energy input to the mains water is provided by the water storage tank, the third operation mode

is advantageous if only small DHW discharges are required, e.g. discharges shorter than the start-up time needed by the heat pump. This configuration can further be advantageous, if other control decisions prohibit a heat pump DHW cycle at that moment, e.g. absence of inexpensive, renewable energy.

Example 4 - Third embodiment (not shown in Figures)

[0073] In a third embodiment, the mains water is additionally heated by energy recovered from waste water. For example, the additional heating can be arranged before the mains water enters the heat exchanger and is further heated in the heat exchanger (not shown in the Figures).

Example 5 - Fourth embodiment (Figure 5)

[0074] In the fourth embodiment, mains water exiting a thermal energy storage device of the system is further heated by using the heat pump in the second operation mode (postheating water discharge mode).

[0075] This is possible with one single thermal energy storage device, but also with more than one thermal energy storage device in the system. In one example, the system comprises a first low temperature PCM-TES having a storage capacity at 30-45°C, which is mainly used for space heating, and a second high temperature PCM-TES having a storage capacity of 40-60°C.

[0076] Assuming the second, high temperature PCM-TES is fully discharged and there is DHW demand, the heat pump can be used to post-heat the water coming from the first low temperature PCM-TES at an intermediate temperature to a suitable DHW outlet temperature. In other words, the mains water would be preheated in the first low temperature PCM-TES and then post-heated by the heat pump.

List of reference signs

[0077]

- 1: heat pump;
- 2: mains water supply;
- 3: heat exchanger (connected to the heat pump and to the mains water supply);
- 4: thermal energy storage device (e.g. a PCM-TES or a water storage tank);
- 5: controller configured to control the heat pump;
- 6: state of charge device configured to determine the state of charge of the thermal energy storage device (e.g. a state of phase device);
- 7: flow detection sensor;
- 8: local space heating system;
- 9: Indoor unit;
- 10: domestic hot water;
- 11: cylinder unit for domestic hot water;

- 12: switching valve;
- 13: resistance heater;
- 14: kitchen sink; and
- 15: bathtub.

Claims

1. System for providing domestic hot water (10), comprising

- a) a heat pump (1),
- b) a mains water supply (2);
- c) a heat exchanger (3) establishing a thermal connection between a fluid line exiting the mains water supply (2) and a fluid line exiting the heat pump (1);
- d) a thermal energy storage device (4) connected to the heat pump (1);
- e) a first operation mode in which thermal energy is provided from the heat pump (1) to the thermal energy storage device (4), but not to the heat exchanger (3);
- f) a second operation mode in which thermal energy is provided from the heat pump (1) to the heat exchanger (3), and
- g) a controller configured to select at least between the first operation mode and the second operation mode and configured to control the pump (1) based on a selected operation mode.

2. System according to the preceding claim, **characterized in that**, the controller is configured to, in the second operation mode, allow heated mains water to flow from the heat exchanger (3) into the thermal energy storage device (4), preferably such that

- i) thermal energy of the thermal energy storage device (4) is transferred to the heated mains water; or
- ii) thermal energy of the heated mains water is transferred to the thermal energy storage device (4).

3. System according to one of the preceding claims, **characterized in that** the controller (5) is configured to switch to the

- i) first operation mode if there is no active demand for domestic hot water and a state of charge of the thermal energy storage device (4) is below a preset threshold; and/or
- ii) second operation mode if there is a high active demand for domestic hot water and the heat pump (1) is running or not running, or if there is a low demand for domestic hot water and the heat pump (1) is running.

4. System according to one of the preceding claims, **characterized in that** system comprises a third operation mode in which no thermal energy is provided from the heat pump (1) to the thermal energy storage device (4) and to the heat exchanger, wherein the controller (5) is preferably configured to switch to the third operation mode if there is a low active demand for domestic hot water and/or if a state of charge of the thermal energy storage device (4) is at or above a preset threshold and the heat pump (1) shall not be operated.
 - i) a fluid flow detection sensor (7) which is suitable for detecting a volume flow of fluid from the thermal energy storage device (4) to a domestic hot water discharge of the system; and/or
 - ii) a resistance heater (14) for heating water of the mains water supply (2), wherein the controller is preferably configured to activate the resistance heater (14) if there is a high active demand for domestic hot water; and/or
 - iii) a means for heating water of the mains water supply (2) by energy recovered from waste water, wherein the means is preferably located upstream of the heat exchanger (3) in the system.
5. System according to one of the preceding claims, **characterized in that** the system further comprises
 - i) control the heat pump (1) based on a state of charge determined by the state of charge device (6); and/or
 - ii) switch to the first operation mode if the determined state of charge of the thermal energy storage device (4) is below a preset threshold; and/or
 - iii) switch to the second operation mode if the determined state of charge of the thermal energy storage device (4) is below a preset threshold; and/or
 - iv) switch to a third operation mode, in which no thermal energy is provided from the heat pump (1) to the thermal energy storage device (4) and to the heat exchanger, if the state of charge of the thermal energy storage device (4) is at or above a preset threshold.
6. System according to one of the preceding claims, **characterized in that** the controller (5) is configured to switch into the second operation mode if
 - i) there is a need of a large amount of domestic hot water by a hot water consuming device (14, 15), wherein the hot water consuming device (14, 15) is preferably configured to communicate a need of a large amount of hot water to the controller (5), wherein the hot water consuming device (14, 15) is particularly preferably selected from the group consisting of kitchen sink (14), bathtub (15), washing machine, dishwasher and combinations thereof; and/or
 - ii) a domestic hot water demand prediction predicts a need of a large amount of domestic hot water, wherein preferably the controller (5) is configured to perform said prediction; and/or
 - iii) a volume flow from the thermal energy storage device (4) to a domestic hot water discharge of the system falls above a certain threshold and the domestic hot water discharge of the system is associated to large domestic hot water discharges, wherein the volume flow is preferably detected by a fluid flow detection sensor (7) of the system which is configured to communicate a detected volume flow to the controller (5), wherein the fluid flow detection sensor is particularly preferably selected from the group consisting of flowmeter, pressure sensor, temperature sensor and combinations thereof; and/or
 - iv) a direct user input communicates a need of a large amount of domestic hot water, wherein the direct user input is preferably detected by an input device of the system which is configured to communicate a need of a large amount of domestic hot water to the controller (5).
7. System according to one of the preceding claims, **characterized in that** the thermal energy storage device (4) is
 - i) a phase change material thermal energy storage device, wherein the phase change material thermal energy storage device preferably comprises a heat exchanger embedded into it which promotes transfer of heat from the heat pump (1) to the phase change material thermal energy storage device; or
 - ii) a water storage tank, preferably a water storage tank containing an encapsulated phase change material.
8. System according to one of the preceding claims, **characterized in that** the thermal energy storage device (4) is
9. Method for providing domestic hot water (10), comprising the steps
 - a) providing a system comprising
 - a heat pump (1),
 - a mains water supply (2);
 - a heat exchanger (3) establishing a thermal connection between a fluid line exiting the

- mains water supply (2) and a fluid line exiting the heat pump (1);
 a thermal energy storage device (4) connected to the heat pump (1);
 a first operation mode in which thermal energy is provided from the heat pump (1) to the thermal energy storage device (4), but not to the heat exchanger (3),
 a second operation mode in which thermal energy is provided from the heat pump (1) to the heat exchanger (3), and
 a controller configured to select at least between the first operation mode and the second operation mode;
- b) controlling the heat pump (1) by the controller based on a selected operation mode.
10. Method according to claim 9, **characterized in that**, the controller is configured in the method to, in the second operation mode, allow heated mains water to flow from the heat exchanger (3) into the thermal energy storage device (4), preferably such that
- i) thermal energy of the thermal energy storage device (4) is transferred to the heated mains water; or
 ii) thermal energy of the heated mains water is transferred to the thermal energy storage device (4).
11. Method according to one of claims 9 or 10, **characterized in that** the controller (5) is configured in the method to switch to the
- i) first operation mode if there is no active demand for domestic hot water and a state of charge of the thermal energy storage device (4) is below a preset threshold; and/or
 ii) second operation mode if there is a high active demand for domestic hot water and the heat pump (1) is running or not running, or if there is a low demand for domestic hot water and the heat pump (1) is running.
12. Method according to one of claims 9 to 11, **characterized in that** the system provided in the method comprises a third operation mode in which no thermal energy is provided from the heat pump (1) to the thermal energy storage device (4) and to the heat exchanger, wherein controller (5) is preferably configured in the method to switch to the third operation mode if there is a low active demand for domestic hot water and/or if a state of charge of the thermal energy storage device (4) is at or above a preset threshold and the heat pump (1) shall not be operated.
13. Method according to one of claims 9 to 12, **characterized in that** the system which is provided in the method further comprises
- i) a fluid flow detection sensor (7) which is suitable for detecting a volume flow of fluid from the thermal energy storage device (4) to a domestic hot water discharge of the system; and/or
 ii) a resistance heater (14) for heating water of the mains water supply (2), wherein the controller is preferably configured in the method to activate the resistance heater (14) if there is a high active demand for domestic hot water; and/or
 iii) means for heating water of the mains water supply (2) by energy recovered from waste water, wherein the means is preferably located upstream of the heat exchanger (3) in the system.
14. Method according to one of claims 9 to 13, **characterized in that** the system which is provided in the method further comprises a state of charge device (6) which is configured to determine the state of charge of the thermal energy storage device (4), wherein the controller (5) is preferably configured in the method to
- i) control the heat pump (1) based on a state of charge determined by the state of charge device (6); and/or
 ii) switch to the first operation mode if the determined state of charge of the thermal energy storage device (4) is below a preset threshold; and/or
 iii) switch to the second operation mode if the determined state of charge of the thermal energy storage device (4) is below a preset threshold; and/or
 iv) switch to a third operation mode, in which no thermal energy is provided from the heat pump (1) to the thermal energy storage device (4) and to the heat exchanger, if the state of charge of the thermal energy storage device (4) is at or above a preset threshold.
15. Method according to one of claims 9 to 14, **characterized in that** the controller (5) is configured in the method to switch into the second operation mode if
- i) there is a need of a large amount of domestic hot water by a hot water consuming device (14, 15), wherein the hot water consuming device (14, 15) is preferably configured in the method to communicate a need of a large amount of hot water to the controller (5), wherein the hot water consuming device (14, 15) is particularly preferably selected from the group consisting of kitchen sink (14), bathtub (15), washing machine, dishwasher and combinations thereof; and/or

- ii) a domestic hot water demand prediction predicts a need of a large amount of domestic hot water, wherein preferably the controller (5) is configured in the method to perform said prediction; and/or 5
- iii) a volume flow from the thermal energy storage device (4) to a domestic hot water discharge of the system falls above a certain threshold and the domestic hot water discharge of the system is associated to large domestic hot water discharges, wherein the volume flow is preferably detected by a fluid flow detection sensor (7) of the system which is configured in the method to communicate a detected volume flow to the controller (5), wherein the fluid flow detection sensor is particularly preferably selected from the group consisting of flowmeter, pressure sensor, temperature sensor and combinations thereof; and/or 10 15
- iv) a direct user input communicates a need of a large amount of domestic hot water, wherein the direct user input is preferably detected by an input device of the system which is configured in the method to communicate a need of a large amount of domestic hot water to the controller (5). 20 25

- 16. Method according to one of claims 9 to 15, characterized in that** the thermal energy storage device (4) of the system provided in the method is 30

- i) a phase change material thermal energy storage device, wherein the phase change material thermal energy storage device preferably comprises a heat exchanger embedded into it which promotes transfer of heat from the heat pump (1) to the phase change material thermal energy storage device; or 35
- ii) a water storage tank, preferably a water storage tank containing an encapsulated phase change material. 40

45

50

55

Figure 1

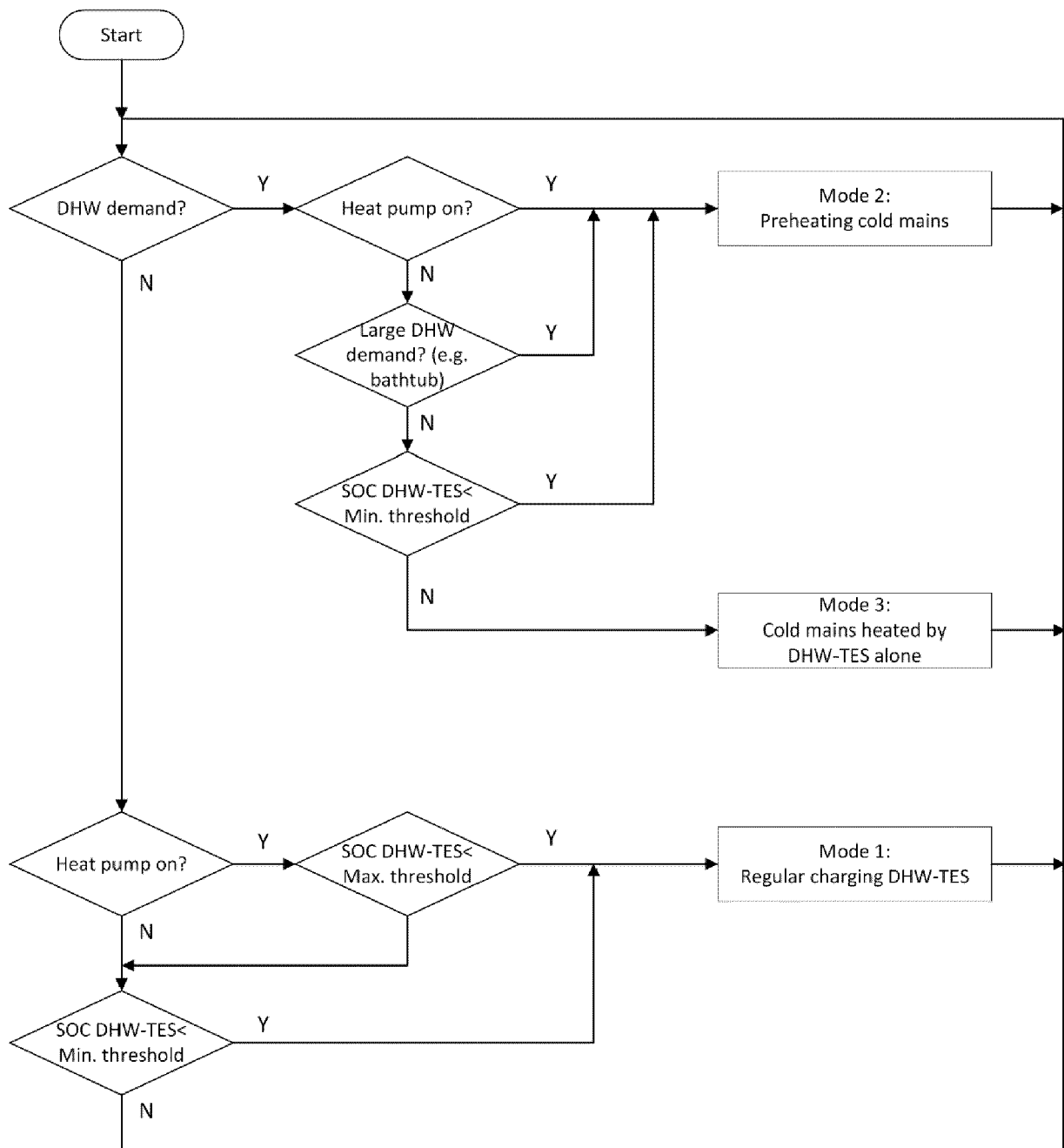


Figure 2

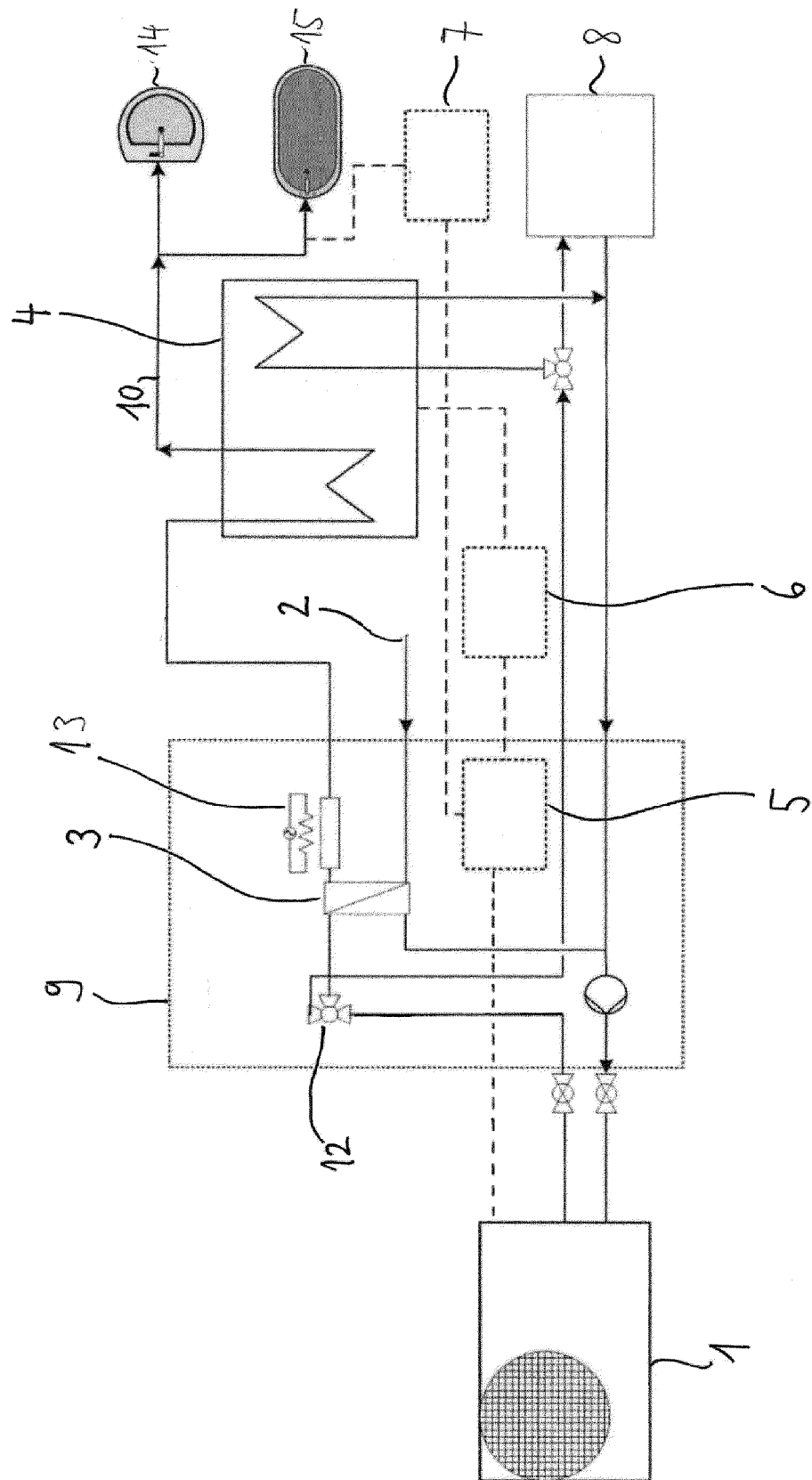


Figure 3

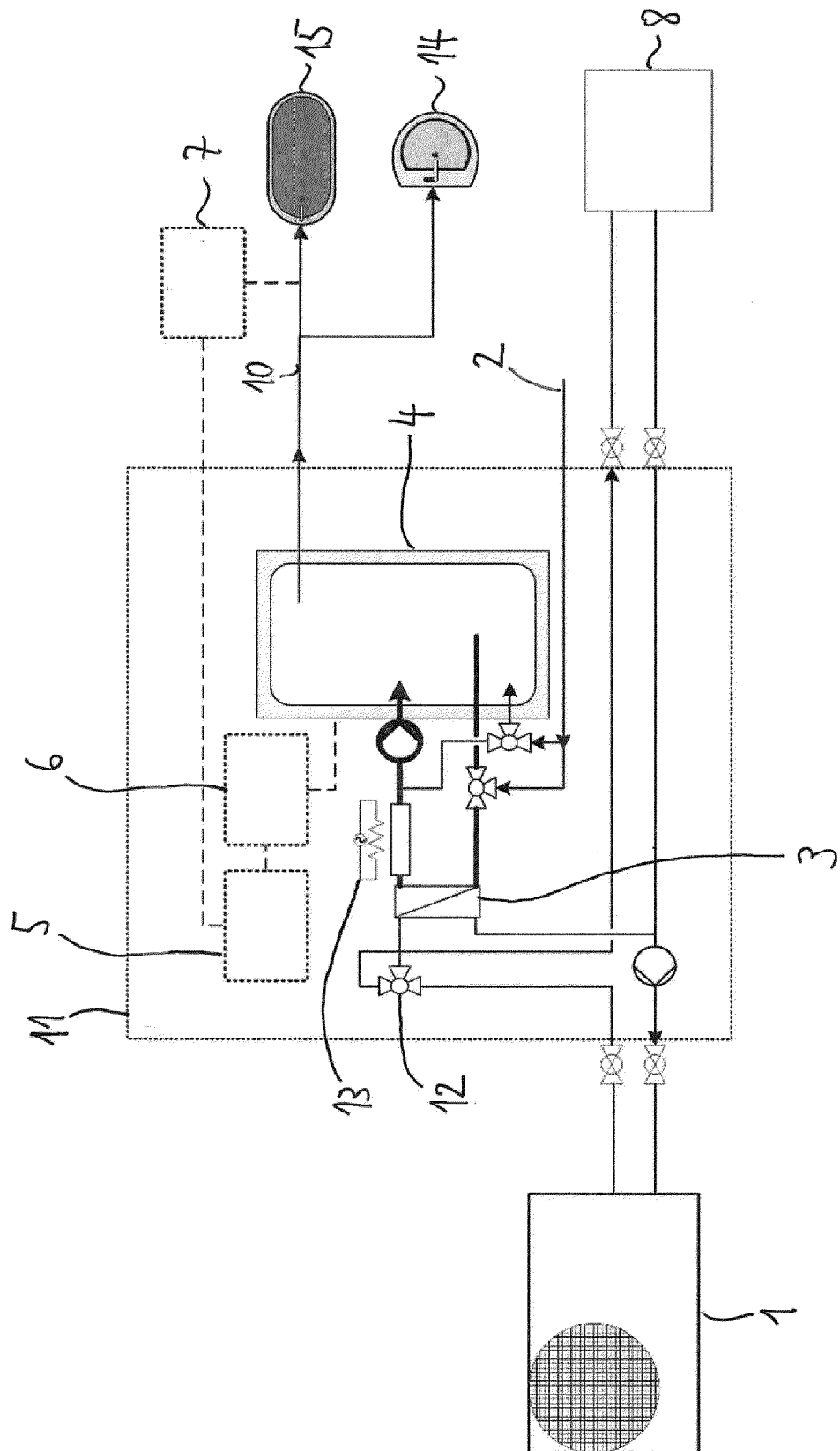


Figure 4

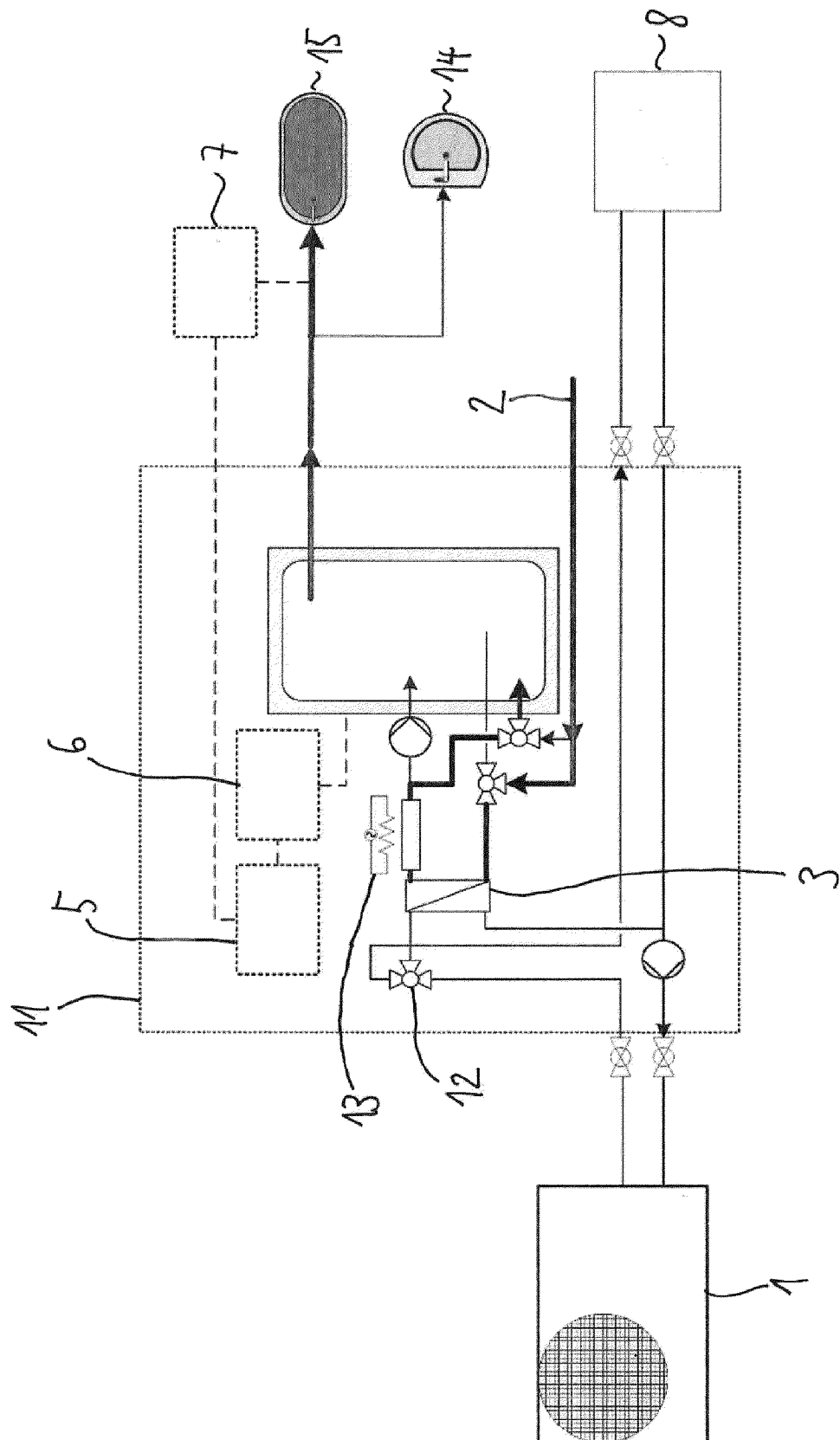
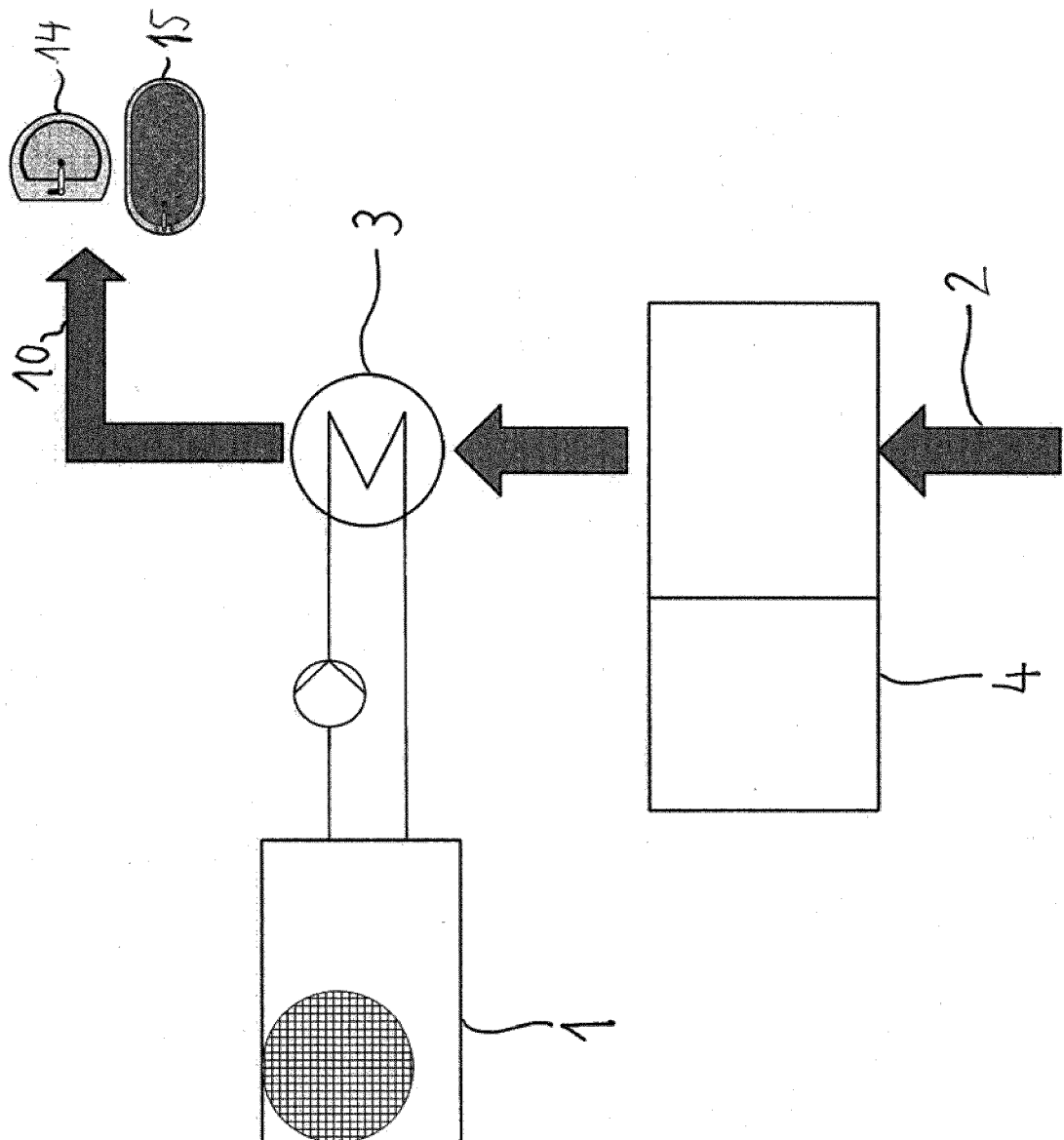


Figure 5





EUROPEAN SEARCH REPORT

Application Number

EP 22 16 4659

5

10

15

20

25

30

35

40

45

50

55

3

EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 032 181 A1 (VAILLANT GMBH [DE]) 15 June 2016 (2016-06-15) * paragraphs [0016] - [0027]; claims 4,7,8,9,10; figure 1 * -----	1-16	INV. F24D17/02 F24D19/10
X	CN 111 750 528 A (UNIV NORTHWESTERN POLYTECHNICAL) 9 October 2020 (2020-10-09) * paragraphs [0002] - [0031]; figure 1 * -----	1,2,5, 8-10,13, 16	
X	EP 2 515 050 A1 (HITACHI APPLIANCES INC [JP]) 24 October 2012 (2012-10-24) * paragraphs [0011] - [0091]; figure 7 * -----	1,8,9,16	
			TECHNICAL FIELDS SEARCHED (IPC)
			F24D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 8 September 2022	Examiner Hoffmann, Stéphanie
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 22 16 4659

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-09-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3032181 A1	15-06-2016	DE 102014225693 A1	16-06-2016
		DK 3032181 T3	23-04-2018
		EP 3032181 A1	15-06-2016
		ES 2665179 T3	24-04-2018

CN 111750528 A	09-10-2020	NONE	

EP 2515050 A1	24-10-2012	CN 102652244 A	29-08-2012
		EP 2515050 A1	24-10-2012
		JP 5452203 B2	26-03-2014
		JP 2011127773 A	30-06-2011
		KR 20120087957 A	07-08-2012
		US 2012255507 A1	11-10-2012
		WO 2011074596 A1	23-06-2011

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 9581340 B2 [0004]
- US 20060196955 A1 [0005]
- GB 2464162 A [0006]
- WO 2020227216 A1 [0007]