(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 265 994 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
25.10.2023 Bulletin 2023/43

(21) Application number: **22169252.8**

(22) Date of filing: **21.04.2022**

(51) International Patent Classification (IPC):
F28D 20/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F28D 20/0043; F28D 2020/0026

(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

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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) METHOD AND SYSTEM FOR TRANSPORTING THERMAL ENERGY IN A STORAGE MEDIUM

(57) The present invention relates to a method for transporting thermal energy in a storage medium via a sea route, the method comprising the following steps in the given order a) receiving solar energy; b) converting the received solar energy to thermal energy using a first conversion station; c) storing the thermal energy in a storage medium by heating the storage medium; d) placing the heated storage medium in one or more containers comprised by a movable unit and moving the movable unit from a first location to a second location via a sea route;
e) at the second location, converting the thermal energy in the heated storage medium to electrical energy using a second conversion station or supplying the thermal energy in the heated storage medium to a user.

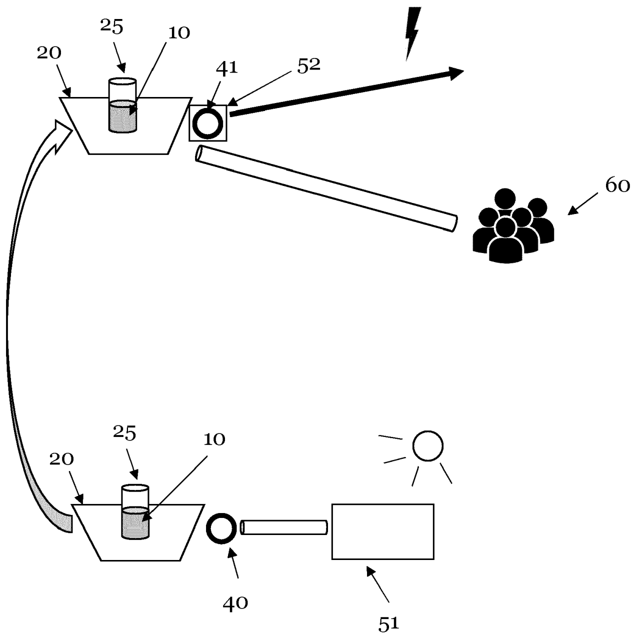

Fig. 1

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Description

Technical field

[0001] The present invention relates to a method for transporting thermal energy in a storage medium via a sea route. The invention further relates to a vehicle for transporting thermal energy in a storage medium via a sea route.

Technical background

[0002] Primary energy is naturally present in a multitude of different forms, for instance, energy is stored as chemical bonding energy in fossil hydrocarbons. To make such primary energy accessible to a benefit, the energy needs to be converted in a usable energy form, for instance in electrical or thermal energy.

[0003] Primary fossil energy sources are available in a limited amount and have the unfortunate disadvantage of substantially increasing an amount of green-house gas emission when being converted in a usable energy form. This has given rise to explore renewable energy sources as an alternative to fossil energy sources in order to provide for a usable energy form in a more ecologically friendly manner. For instance, wind, solar, biomass or tidal energy may be used as renewable energy sources. These energy forms are considered to be abundantly available for a substantially unlimited time with respect to a long time scale.

[0004] However, usage of renewable energies has the disadvantage that their availability varies from one location to another location of the earth and/or from day to night time. Further, their availability at one location cannot be predicted accurately, which complicates energy management. Further, it complicates to ensure a safe and reliable energy supply. Further still, the possibility of controlling an availability and/or an accessibility of renewable energies is key factor in deciding exploration of said renewable energy. Oftentimes it renders promising sources of renewable energies ineffective.

[0005] Renewable energies, such as solar or wind energy, are known to be predominantly available in some locations of the earth. Thus, renewable energies must be converted, stored and/or transported from one location, where it is known to be available, to another location, where a high demand of energy exists. In particular, solar energy may be available in sub-tropic locations, however, in direct proximity, the energy demand may be considered low. Thus, measures must be taken to transport renewable energies received in one location to another location.

[0006] This calls for appropriate and efficient methods for transporting energy. It is known to transport energy via electrical power lines, using gaseous or liquid hydrogen or using LOHCs, i.e. liquid organic hydrogen carrier.

[0007] Electrical power lines are expensive and are typically required to cross numerous countries starting from a first location to a second location. Thereby, political instabilities could influence operation of such electrical power lines. This may have a detrimental effect upon a safe and reliable energy supply.

[0008] Hydrogen as a carrying medium entails substantial energy losses during conversion from water into hydrogen and oxygen by using electrical energy, for instance from solar or wind energy. Further, transportation of hydrogen is technically challenging and requires to drastically increase a pressure or to drastically cool down a temperature of the hydrogen for liquification. Cooled, liquified hydrogen gives rise to substantial boil-off effects, i.e. to energy loss during transportation. Still, the energy density of hydrogen is low. Both ways of transporting hydrogen, i.e. applying an increased pressure and/or cooling down a temperature of the hydrogen, necessitate a vast amount of energy, which renders usage of hydrogen as a carrying medium ineffective.

[0009] LOHCs, i.e. liquid organic hydrogen carriers, absorb hydrogen in an exothermic hydrogenation reaction, i.e. while releasing heat. The stored hydrogen may be released in an endothermic de-hydrogenation reaction to be used in a fuel cell to produce electrical energy. The reactions and the transport of LOHCs is associated with substantial energy losses and is generally considered inefficient. Further, the LOHCs are generally toxic, e.g. benzene, or volatile, e.g. benzene/cyclohexane, toluene/methylcyclohexane, such that they are of low practical relevance.

[0010] The following prior art documents briefly describe a part of the technical background of the present disclosure.

[0011] Document DE 10 2019 108 392 A1, relates to method for supplying electrical energy, wherein a heat accumulator is charged with heat energy in a heat charging station. The heat energy is converted into electrical energy in a conversion station. The heat accumulator in the heat charging station is charged with heat energy at a first location, is transported to a second location different from the first location, wherein the heat energy is converted into electrical energy in the conversion station at the second location. However, merely distances of about 1 km to 10 km via a land route are addressed and the method is not efficient enough for transportation of thermal energy. Further, a land route is not a flexible and conveniently accessible way for energy transportation, in particular for large amounts of energy and/or amounts of energy that are transported over large distances.

[0012] Document WO 2016/081944 A1 is directed to a system for receiving, transferring, and storing solar thermal energy. The system includes a concentrating solar energy collector, a transfer conduit, a thermal storage material, and an insulated container. The insulated container contains the thermal storage material, and the transfer conduit is configured to transfer solar energy collected by the solar energy collector to the thermal storage material through a wall of the insulated container. This has for instance the disadvantage that a separate medium, e.g. a solid material, for transporting thermal energy is required.

[0013] Document DE 20 2021 101 305 U1 relates to a heat transfer station for the transfer of heat energy by means of a fluidic heat transfer medium from a heat source to a heat store and from a heat store to a heat consumer, comprising the following components: a loading unit for heat transfer from a heat source to a heat storage, a discharge unit for heat transfer from a heat storage device to a heat consumer, at least one control unit for controlling and regulating both units and their components as well as for performing measurements of at least pressure and temperature by means of sensors of the heat transfer station. This has the disadvantage that several heat exchangers are necessary to exchange heat, which adversely affects the efficiency.

[0014] Against this background, an object of the present invention is to improve the deficiencies of the prior art and the previous attempts. It is particularly an object to provide an improved method and an improved system for transporting thermal energy in a storage medium. It is an object to provide a method and a system for improving and facilitating the energy transportation via a sea route to provide and ensure an independent, safe and reliable energy supply in a cost-effective manner. It is a further object to provide a method and a system to improve and control availability of renewable energies.

[0015] These and other objects, which become apparent from the following description, are solved by the subject-matter of the independent claims.

Summary of the invention

[0016] An aspect of the invention relates to a method for transporting thermal energy in a storage medium via a sea route, the method comprising the following steps in the given order:

a) receiving solar energy;
b) converting the received solar energy to thermal energy using a first conversion station;
c) storing the thermal energy in a storage medium by heating the storage medium;
d) placing the heated storage medium in one or more containers comprised by a movable unit and moving the movable unit from a first location to a second location via a sea route,

> wherein the first location is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and the second location is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or
>
> wherein the first location and the second location have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location and the second location have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km;

e) at the second location, converting the thermal energy in the heated storage medium to electrical energy using a second conversion station or supplying the thermal energy in the heated storage medium to a user.

[0017] The method for transporting thermal energy in a storage medium may advantageously be applied in the field of energy economy and/or energy management to improve and/or ensure safe and reliable energy supply. In particular, the method may advantageously provide for energy in locations of the earth, where a demand, potentially a high demand, for energy exists. This may be achieved by transporting thermal energy to these locations from locations where energy such as renewable energy may largely be available. It will be appreciated that the method provides for a low dependency on external factors that could detrimentally affect energy supply. For instance, it will be recognized that the transportation of thermal energy according to the method is largely independent on complex transportation means that are typically required to cross numerous countries.

[0018] In step a) the method comprises the step of receiving solar energy. Solar energy may be understood as the energy by radiation from the sun, that may be capable of producing heat. It may also be possible produce electrical energy from solar energy as understood by the skilled person. In one example, producing electrical energy from solar energy may be achieved by photovoltaic cells. Receiving solar energy may be stablished by way of parts of solar towers, parabolic troughs, linear Fresnel reflectors, part of solar cells or mirrors or any other suitable parts. As an alternative, wind energy may also be used as a source of renewable energy. Wind may be triggered in part by the sun, e.g. by the solar energy. Wind may be established by way of the sun heating and/or cooling certain regions of the earth. In one example, wind energy may thereby be comprised by the terminology of solar energy. Preferably, solar energy and wind energy may be used as separate terms describing two distinct sources of renewable energies.

[0019] In step b) the received solar energy is converted to thermal energy using a first conversion station. In step c) the thermal energy is stored in a storage medium by heating the storage medium. Conversion to thermal energy may be provided by heating the storage medium. The storage medium may be heated directly without an intermediate medium, for instance by directly heating the storage medium using parabolic troughs. For example, the storage medium may flow through an absorbing pipe of a parabolic trough and may be heated by the solar energy. In one example, the first conversion station is a solar power plant, for instance a solar thermal power plant, in which the storage medium may be heated by the solar energy. In another example, a separate initial conversion station may first convert solar energy to electrical energy, which may then be converted to thermal energy by heating the storage medium in the first conversion station. In such an example, the first conversion station may be a heater, which may be operated by electrical energy. Further, in such an example, the first conversion station may be located away from the initial conversion station.

[0020] The storage medium may be understood as a medium capable of storing thermal energy. Preferably, the storage medium is a liquid medium, more preferably the storage medium is a thermo oil medium. Thermo oil may have the advantage that it can be heated to a temperature of at least 300°C, preferably at least 350°C, most preferably at least 400°C without substantially changing its physical (or aggregate) state at ambient pressure. In one example, the storage medium is liquid throughout the method according to the aspect of the invention without substantially changing to a gas-like state. Advantageously, the one or more containers may not be pressurized, which reduces costs and risks and further provides for a cost-effect method.

[0021] In step d) the heated storage medium is placed in one or more containers comprised by a movable unit. A movable unit may be a vehicle, preferably a ship or a tank ship, that may be capable of encompassing one or more containers and may be capable of allowing seafaring from the first location to the second location via a sea route. The one or more containers may be vessels or tanks, preferably one or more containers have the shape of spheres. In a preferred example, the surface to volume ratio of the one or more containers may be at most 8, preferably at most 6, more preferably at most 2, even more preferably at most 1, further more preferably of at most 0.4, still further more preferably of at most 0.2, most preferably of at most 0.1. Thus, a loss of thermal energy of the heated storage medium may advantageously be reduced. In one example, the one or more containers may be distinct containers that are separate from storage containers usually available on a movable unit, such as a ship. Preferably, the one or more containers may be suitable to carry large amounts of a storage medium, such as a thermo oil.

[0022] In one example, the movable unit may be a ship capable of transporting 200,000 tons of storage medium. For example, the storage medium may be placed in one or more containers, which have a transporting capacity of 200,000 tons. The ship may have an average velocity during moving in step d) of approximately 28 km/h. In another example, the movable unit may be a ship capable of transporting 300,000 tons of storage medium. Preferably the movable unit may be capable of transporting at least 100,000 tons of storage medium. In one example, 100,000 tons, 200,000 tons and/or 300,000 tons may refer to the tons deadweight. As an example, tons deadweight may represent the difference of the overall movable unit's mass when a highest amount of storage medium is placed in as compared to a movable unit in which no storage medium is placed in.

[0023] The movable unit is moved from a first location to a second location. Preferably, the first and the second location are accessible by a sea route. In one example, the first and the second location are harbors, and the movable unit may dock at the harbors. The first location and the second location may be distantly away as described by way of northern/southern latitudes. The northern/southern latitudes may be the northern or north/southern or south latitudes of the globe or earth, which may be perpendicular to the longitudes of the globe or earth. For instance, the equator may have a northern/southern latitude of 0°. The north pole may be located at a northern latitude of 90°, the south pole may be located at a southern latitude of 90°. The term "between 10° to 35° northern/southern latitude" may be understood as between 10° to 35° northern latitude and/or between 10° to 35° southern latitude.

[0024] In an example, the first location may be located between 0° to 40° northern/southern latitude, between 2° to 38° northern/southern latitude, between 4° to 36° northern/southern latitude, between 6° to 34° northern/southern latitude, between 8° to 32° northern/southern latitude, between 10° to 30° northern/southern latitude, between 12° to 28° northern/southern latitude, between 14° to 26° northern/southern latitude, between 16° to 24° northern/southern latitude, between 18° to 22° northern/southern latitude, or between 19° to 21° northern/southern latitude. It may also be possible to combine one lower limit of the northern/southern latitude with another upper limit of the northern/southern latitude.

[0025] In an example, the second location may be located at at least 41° northern/southern latitude, at least 42° northern/southern latitude, at least 43° northern/southern latitude, at least 44° northern/southern latitude, at least 45° northern/southern latitude, at least 46° northern/southern latitude, at least 47° northern/southern latitude, at least 48° northern/southern latitude, at least 49° northern/southern latitude, at least 50° northern/southern latitude and the second location may be located at at most 70° northern/southern latitude, at most 69° northern/southern latitude, at most 68° northern/southern latitude, at most 67° northern/southern latitude, at most 66° northern/southern latitude, at most 65° northern/southern latitude, at most 64° northern/southern latitude, at most 63° northern/southern latitude, at most 62° northern/southern latitude, at most 62° northern/southern latitude, at most 61° northern/southern latitude, or at at most 60° northern/southern latitude.

[0026] Preferably the first location, the location of the initial conversion station and/or the first conversion station is/are located in an area of the earth, which is exposed to high solar energy, such as the Sahara Desert. Preferably the second location is located in an area of the earth, in which a demand of energy pertains.

[0027] Alternatively or in addition to the northern/southern latitude, the first location and the second location have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location and the second location have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km.

[0028] The distance between the first location and the second location may be understood as a direct distance, e.g. by connecting both locations with a straight line or as the shortest distance that the movable unit may need, preferably on a sea route, from the first location to the second location. In one example, the movable unit may be in proximity to the province of Granada, Spain, as the first location. Andasol as understood by the skilled person, may be a solar thermal power plant and may be in the province of Granada, Spain. During step d) of the inventive method, the movable unit may be in proximity to Rotterdam, Netherlands, as the second location. The distance from the first to the second location on a sea route may be about 2000 km to 4000 km.

[0029] The first location may be in the following countries/regions of the earth as an exemplary list: Namibia, South Africa, USA, Mexico, United Arab Emirates, South Arabia, Oman, Kuwait, Australia, Tunisia, Mauritania, Morocco, Jordanian, Israel, Algeria, Egypt, Turkey, Spain, Portugal, Australia, Norway, Sweden. The method may also be applied to the northern/southern latitudes that the exemplary countries, which may comprise the first location, have.

[0030] The second location may be in the following countries/regions of the earth as an exemplary list: West Africa, Canada, India, Sri Lanka, Republic Korea, New Zealand, Malaysia, Japan, Indonesia, China, Poland, Netherlands, Croatia, Italy, Ireland, Great-Britain, Greece, France, Germany, Denmark, Belgium, India, USA. The method may also be applied to the northern/southern latitudes that the exemplary countries, which may comprise the second location, have.

[0031] Thus, the method may advantageously be applied to improve and/or ensure safe and reliable energy supply.

[0032] In a first option of step e) the thermal energy in the heated storage medium is converted to electrical energy using a second conversion station. Conversion to electrical energy may be established by a steam turbine process. For instance, the heated storage medium may be used to heat another medium, such as water, which is used in a steam turbine process to expand across a turbine and to produce electrical energy, for instance by a generator. In one example, the steam turbine process may be the second conversion station. The second conversion station may be located at the second location or in proximity to the second location. In one example, the second conversion station may be located away from the second location, accessible via a land route from the second location.

[0033] In a second option of step e) the thermal energy in the heated storage medium may be supplied to a user. A user could be a consumer, an industrial unit or plant, operators of an energy network or the like. The user may benefit from the heated storage medium as district heating. For example, the heated storage medium may have a temperature of at least 100°C, 200°C, 300°C or at least 350°C, such that it has a sufficiently high inlet or supply temperature to advantageously enable district heating.

[0034] In a non-exhaustive list, the method according to the present invention allows for several advances. In particular, the method advantageously provides for a largely independent and flexible transportation of thermal energy via a sea route. Transportation may be independent on local influences of one or more, in particular by several countries by way of a convenient sea route. Further, it is appreciated that controlling the availability of energy, preferably of renewable energies such as solar energy, at locations of the earth is improved. Thus, the inventive method allows for a flexible, independent and convenient distribution of renewable energies. These advances have not been achieved by the prior art.

[0035] In a preferred embodiment, step b) of the method further comprises converting the received solar energy to electrical energy using an initial conversion station separate from the first conversion station and converting the electrical energy to thermal energy using the first conversion station.

[0036] The initial conversion station may be a solar power plant, for instance a solar thermal power plant or photovoltaic cells and may convert the received solar energy to electrical energy. The electrical energy may then be provided to the first conversion station, in which the electrical energy may be converted to thermal energy, for instance by heating the storage medium. Advantageously, the electrical energy may be transmitted from the initial conversion station to the first conversion station efficiently without substantial losses, for instance by a high-voltage grid, in case the initial conversion station is located away from the first conversion station. In one example, the first conversion station may be located at or in proximity to a harbor at the first location.

[0037] In a preferred embodiment, step c) of the method further comprises carrying the heated storage medium from the first conversion station to the first location over a distance of at most 250 km, preferably at most 180 km, more preferably at most 120 km, even more preferably at most 80 km, further preferably at most 50 km, most preferably over a distance of substantially 0 km.

[0038] Carrying the heated storage medium may be established by pipes or tubes that preferably connect the first conversion station and the first location by a land route. The pipes may be thermally insulated such that thermal losses during carrying the heated storage medium are reduced to a substantial minimum. Preferably, the first conversion station is at most 250 km away from the first location, such that thermal losses are reduced. Preferably, the heated storage medium is carried and placed into the one or more containers of the movable unit, which is located at the first location, which may be a harbor. Subsequently, the movable unit may be moved from the first location to the second location.

[0039] In a preferred embodiment, step c) of the method further comprises increasing a temperature of the storage medium by at least 10 K, preferably by at least 60 K, more preferably by at least 120 K, even more preferably by at least 180 K, most preferably by at least 250 K; increasing a temperature of the storage medium by at most 390 K, preferably by at most 35° K, more preferably by at most 320 K, even more preferably by at most 290 K, most preferably by at most 250 K.

[0040] Increasing the temperature of the storage medium may promote storage of thermal energy. The amount of thermal energy stored in the heated storage medium may substantially proportionally increase with a temperature difference between a temperature of the storage medium after heating and a temperature of the storage medium prior to heating. The proportionally may depend on the temperature dependency of the heat capacity of the storage medium. The temperature may not be increased too much, because otherwise, the temperature difference of the heated storage medium to an ambient temperature may unduly increase, which may induce thermal losses and/or may promote changing the physical state of the storage medium from a liquid to a gas-like state in one example. Further, the temperature may not be increased too much, because this may damage the thermo oil. As an example, thermal degradation of organic compounds may occur at too high temperatures. Thus, an optimal temperature of the storage medium may be provided.

[0041] In a preferred embodiment, the movable unit is a vehicle, such as a ship, and wherein the movable unit further comprises the first conversion station and optionally the second conversion station.

[0042] In this embodiment, the first conversion station is comprised by the movable unit. Thus, in one example, the ship may have the one or more containers and the first conversion station and optionally the second conversion station. In an example, the initial conversion station is provided to convert solar energy to electrical energy, and the first conversion station, comprised by the movable unit, converts the electrical energy to thermal energy by heating the storage medium, which may take place at, on or within the movable unit. Electrically heating the storage medium may be established by thermo oil heaters in one example. If the second conversion station is comprised by the movable unit, the conversion of electrical energy to thermal energy and back to electrical energy may advantageously take place at, on or within the movable unit. This may have the advantage that the storage medium may not need to be carried on a land route for the purpose of being heated or for the purpose of releasing heat but may be maintained within the movable unit.

[0043] In a preferred embodiment, step d) of the method further comprises insulating the heated storage medium using the one or more containers; using at least partially the thermal energy of the heated storage medium to provide for movement of the movable unit.

[0044] Insulating the heated storage medium may reduce thermal losses of the heated storage medium. The thermal energy of the heated storage medium may least partially be used in a steam turbine process to produce steam to drive a turbine, which may provide for movement of the movable unit. The turbine may also be used to provide electrical energy using a generator to provide for operation of electrical components comprised by the movable unit. Thus, the movement of the movable unit may be ecologically improved in a cost-effect manner. In one example, the movable unit may be provided with a combustion engine capable of being fueled and/or operated by thermo oil. This may further enhance partially using the heated storage medium to provide for an ecologically and environmentally friendly movement of the movable unit. The thermal energy of the heated storage medium may only be used partially, such that the method advantageously provides for transporting a sufficient amount thermal energy to the second location.

[0045] In a preferred embodiment, step d) of the method further comprises receiving a solar energy portion and heating the storage medium by the received solar energy portion.

[0046] The movable unit may be provided with a solar power plant to receive a solar energy portion. In one example, this may happen while moving from the first location to the second location. This may increase the thermal energy of the heated storage medium. In one example, a solar power plant may be provided on the deck of the ship as the movable unit. For instance, solar cells may be provided, which may be expandable to increase a surface area for increasing the amount of the received solar energy portion. In one example the surface area exposed to solar energy after expanding with respect to prior to expanding may be at least 2, preferably at least 5, more preferably at least 10, most preferably of at least 40. In another example the surface area exposed to solar energy after expanding with respect to prior to expanding may be at most 200, preferably at most 100, more preferably at most 200, most preferably of at most 50.

[0047] In a preferred embodiment, step d) further comprises maintaining a temperature of the storage medium of at least 80°C, preferably of at least 120°C, more preferably of at least 160°C, even more preferably of at least 200°C, most preferably of at least 260°C; maintaining a temperature of the storage medium of at most 500°C, preferably of at most 460°C, more preferably of at most 420°C, even more preferably of at most 36o°C, most preferably of at most 300°C; maintaining an absolute pressure difference of the storage medium and an ambient pressure of at most 1 bar, preferably of at most 0.6 bar, more preferably of at most 0.4 bar, even more preferably of at most 0.2 bar, most preferably of substantially 0 bar.

[0048] Maintaining a temperature and/or an absolute pressure difference can be understood such that the temperature and/or the absolute pressure difference may not substantially vary.

[0049] In a preferred embodiment, the storage medium is a thermal storage medium, preferably a liquid thermal storage medium, most preferably a thermo oil medium.

[0050] As an exemplary thermo oil the following oils may be mentioned: mineral oils, synthetic oils, aromatic hydrocarbons such as a mixture of DP/DPO, i.e. diphenyl and diphenyl oxide, or biological oils. Preferably thermo oils such as "Dowtherm A", "Diphyl THT", "Diphyl", "Marlotherm SH", "Purity FG" or "Transcal N" may be applied. In particular, "Purity FG" is not toxic and can bear a high temperature without substantial degradation. A thermo oil may have the advantage that it can be heated without requiring substantially increased pressure to maintain the liquid physical state. In another example molten salt may be used as a storage medium. If molten salt is applied, the temperatures should not exceed about 455°C to a substantial degree, otherwise an onset of degradation may occur. However, maximum temperatures of about 540°C may be possible. As an example, a molten salt may be applied comprising about 53% of potassium nitrate, 40% of sodium nitrite and about 7 percent of sodium nitrate.

[0051] In a preferred embodiment, an amount of thermal energy in the heated storage medium at the second location with respect to an amount of thermal energy in the heated storage medium at the first location is at least 0.5, preferably at least 0.8, more preferably at least 0.9, even more preferably at least 1.0, most preferably at least 1.1.

[0052] According to this embodiment, the thermal energy is sufficiently high at the second location to provide for sufficient thermal energy at the second location. An amount of thermal energy in the heated storage medium at the second location with respect to an amount of thermal energy in the heated storage medium at the first location may be understood as a ratio of the amount of thermal energy in the heated storage medium at the second location with respect to an amount of thermal energy in the heated storage medium at the first location. This ratio may be, 0.8 or 80%. In another example, this ratio may be 1.1 or 110%. If the ratio is 1.1, the amount of thermal energy in the heated storage medium at the second location is greater than an amount of thermal energy in the heated storage medium at the first location.

[0053] In a preferred embodiment, step d) of the method further comprises substantially preventing any conversion of thermal energy in the storage medium to another energy form.

[0054] According to this embodiment, it may be ensured that the thermal energy in the heated storage medium is substantially not used as another energy form during step d). This may prevent a decrease of the amount of energy when the movable unit is moved from the first location to the second location. However, in some cases, it may still be possible to use a part of the thermal energy of the heated storage medium to provide for movement of the movable unit.

[0055] In a preferred embodiment, step d) of the method further comprises keeping the heated storage medium in the one or more containers for at least 4 hours, preferably at least 16 hours, more preferably at least 32 hours, even more preferably at least 80 hours, most preferably for at least 160 hours; keeping the heated storage medium in the one or more containers for at most 500 hours, preferably at most 400 hours, more preferably at most 300 hours, even more preferably at most 200 hours, most preferably for at most 160 hours.

[0056] The heated storage medium is kept within the one or more containers for a time that may be sufficient enough such that the movable unit can move from the first location to the second location. In some examples, the heated storage medium may be kept longer within the one or more containers, depending on a time that the movable unit prevails at the first location and/or second location while not moving. Part of the heated storage medium may, however, be used as described above to provide for movement of the movable unit, which may require withdrawing part of the heated storage medium from the one or more containers during movement from the first location to the second location. However, this part of the heated storage medium may be a small or minor part.

[0057] Depending on the arrangement of the first and the second conversion station, it may also be possible that the heated storage medium remains for a time within the one or more containers that is substantially longer than 500 hours. For example, if the first conversion station and the second conversion station are comprised by the movable unit, the storage medium may be kept for a substantially longer time than 500 hours within the one or more containers as understood by the skilled person. A preferred time may be for example 160 hours, if the first conversion station and the second conversion station are not comprised by the movable unit.

[0058] In a preferred embodiment, step e) further comprises carrying the heated storage medium from the second location to the second conversion station over a distance of at most 250 km, preferably at most 180 km, more preferably at most 120 km, even more preferably at most 80 km, further preferably at most 50 km, most preferably over a distance of substantially 0 km, and converting the thermal energy in the heated storage medium to electrical energy using a steam turbine process in the second conversion station; or

carrying the heated storage medium from the second location to the user for supplying the thermal energy in the heated storage medium to the user, wherein the user is at least 20 km, preferably at least 4° km, more preferably at least 60 km, even more preferably at least 80 km, most preferably at least 100 km away from the second location.

[0059] Carrying the heated storage medium may be established by pipes or tubes that preferably connect the second location and the second conversion station by a land route, or that connect the second location and the user by a land route. The pipes may be thermally insulated such that thermal losses during carrying the heated storage medium are beneficially reduced. Preferably, the second conversion station is at most 250 km away from the second location, such that thermal losses are reduced. Most preferably, the second conversion station may be located in proximity to the second location, such as a harbor. In an example, the second conversion station may be comprised by the movable unit. Thus, beneficially the thermal energy of the heated storage medium may be converted to electrical energy within the movable unit.

[0060] The heated storage medium may be carried from the second location to a user, wherein the user is at least 20 km or 100 km away from the second location. In one example, the user may be close to the second location, thus, a low amount of energy may be lost during carrying the heated storage medium from the second location to the user. A user could be a consumer, an industrial unit or plant, operators of an energy network or the like. In one example, the user may benefit from the heated storage medium by district heating. For example, the heated storage medium may have a temperature of at least 100°C, 200°C, 300°C or 350°C, such that it has a sufficiently high inlet or supply temperature to advantageously enable district heating. In another example, a residual heat of the conversion process of thermal energy in the heated storage medium to electrical energy using a steam turbine process may be stored within the storage medium. The residual heat may be carried to a user.

[0061] In another preferred embodiment, after step e) the method further comprises f) carrying the storage medium to the second location, placing the storage medium in the one or more containers of the movable unit or in one or more containers of another movable unit, and moving the movable unit or the other movable unit from the second location to the first location.

[0062] Thus, the storage medium may be carried from the second conversion station or from a user's location back to the second location. It is understood that at this time, the heated storage medium has released a substantial amount of thermal energy at the second conversion station or the user's location, thus, it may not be regarded as heated anymore. The storage medium may be placed in the one or more containers of the movable unit, or the storage medium may be placed in different containers. For example, another vehicle, such as a ship, may be located at the second location, in which one or more containers are comprised and the storage medium is placed in these one or more containers of the other vehicle.

[0063] Another aspect of the invention relates to a computer program comprising instructions which, when executed by a computer, cause the computer to perform the method according to the present invention.

[0064] Devices described herein, such as the initial conversion station, the first conversion station, the movable unit, and/or the second conversion station may have a memory comprising a computer program for at least partially automatically controlling the devices, such as the initial conversion station, the first conversion station, the movable unit, and/or the second conversion station. The devices may further comprise means for executing the computer program. Alternatively, the computer program may be stored elsewhere (e.g., in a cloud) and the devices may only have means for receiving instructions resulting from execution of the program elsewhere. Either way, this may allow, for example, the method to be automated or to be autonomous within the devices. Thereby, complexity in operation can be reduced.

[0065] The computer program may alternatively or additionally include instructions for performing the method steps described herein or for performing or implementing the functionalities of the devices described herein, such as the initial conversion station, the first conversion station, the movable unit, and/or the second conversion station. For example, the computer program may cause certain elements of the device to operate. Thus, the inventive method may be controlled based on a computer program. The computer program may be stored in a cloud, in the first location, in the second location or within the movable unit. The skilled person appreciates the advances associated with such a computer program in that the inventive method may be controlled at least partially from one location, one device, or one region. Thereby, it is recognized that the operation of the method can be further enhanced and improved. For example, advanced control strategies may be comprised by the computer program to improve provision of renewable energies in regions where a demand pertains.

[0066] Another aspect of the invention relates to a vehicle for transporting thermal energy in a storage medium via a sea route, the vehicle comprising

a) a first conversion station for converting energy to thermal energy;
b) a storage medium for storing the thermal energy by heating the storage medium;
c) one or more containers for placing in the storage medium;
d) a second conversion station for converting the thermal energy in the heated storage medium to electrical energy;

wherein the vehicle is adapted to move from a first location to a second location via a sea route, wherein the first location is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and the second location is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or

wherein the first location and the second location have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location and the second location have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km.

[0067] The vehicle for transporting thermal energy in a storage medium may advantageously be used in the field of energy economy and/or energy management to improve and/or ensure safe and reliable energy supply. In particular, the vehicle may advantageously provide for energy in locations of the earth in which a demand for energy exists by transporting energy to these locations from locations where energy such as renewable energies may largely be available. Preferably the vehicle is a ship or a tank ship. It will be appreciated that the vehicle provides for a low dependency on external factors that could detrimentally affect energy supply. For instance, it will be recognized that the vehicle provides for advances for transportation of thermal energy, since it is largely independent on complex transportation means that are typically required to cross numerous countries.

[0068] Further, the vehicle according to the present disclosure may serve to perform one or some of the method steps as described above. It may be understood that advantages and features associated with the method described above are also applicable to the vehicle according to the present disclosure.

[0069] The vehicle is adapted to move from a first location to a second location via a sea route. In an example, the first location may be located between 0° to 40° northern/southern latitude, between 20 to 38° northern/southern latitude, between 4° to 36° northern/southern latitude, between 6° to 34° northern/southern latitude, between 8° to 32° northern/southern latitude, between 10° to 30° northern/southern latitude, between 120° to 28° northern/southern latitude, between 14° to 26° northern/southern latitude, between 160° to 24° northern/southern latitude, between 180° to 22° northern/southern latitude, or between 19° to 21° northern/southern latitude. It may also be possible to combine one lower limit of the northern/southern latitude with another upper limit of the northern/southern latitude.

[0070] In an example, the second location may be located at at least 41° northern/southern latitude, at least 42° northern/southern latitude, at least 43° northern/southern latitude, at least 44° northern/southern latitude, at least 45° northern/southern latitude, at least 46° northern/southern latitude, at least 47° northern/southern latitude, at least 48° northern/southern latitude, at least 49° northern/southern latitude, at least 50° northern/southern latitude and the second location may be located at at most 70° northern/southern latitude, at most 69° northern/southern latitude, at most 68° northern/southern latitude, at most 67° northern/southern latitude, at most 66° northern/southern latitude, at most 65° northern/southern latitude, at most 64° northern/southern latitude, at most 63° northern/southern latitude, at most 62° northern/southern latitude, at most 62° northern/southern latitude, at most 61° northern/southern latitude, or at at most 60° northern/southern latitude.

[0071] Alternatively or in addition to the northern/southern latitude, vehicle is adapted to move from a first location to a second location via a sea route, wherein the first location and the second location have a distance of at least 10 km, preferably at least 100 km as mentioned above.

[0072] In another preferred embodiment, in the method:

steps a) to d) are repeated such that the second conversion station is continuously provided with thermal energy in the heated storage medium to continuously convert the thermal energy in the heated storage medium to electrical energy, optionally by storing at least a part of the thermal energy in the storage medium in a stationary storage unit in proximity of the second location; or

steps a) to d) are repeated such that supplying the thermal energy in the heated storage medium to the user is continuously provided, optionally by storing at least a part of the thermal energy in the heated storage medium in a stationary storage unit in proximity of the second location.

[0073] Repeating the steps a) to d) may be advantageous to provide for a continuous supply of thermal energy. It may also be appreciated that this allows for an improved controlling of the availability of renewable energies, e.g. solar and/or wind energy, at the second location. Thus, beneficially the availability may be more independent of weather conditions at the second location. Continuous may be understood such the second conversion station may be in operation without substantially stopping the operation. In one example, if an amount of thermal energy stored in the heated storage medium is moved to the second location, wherein the amount of thermal energy may be high such that the second conversion station does not need all of the thermal energy stored in the heated storage medium for operation. Thereby, the additional energy may be temporarily stored, or temporarily buffered, for instance in a storage container in proximity of the second location. Storage may additionally be provided by means of molten salt or any other suitable means, for instance, the molten salt may be heated by the heated thermo oil. Thereby, continuous operation of the second conversion station may be ensured, thereby providing continuous electrical energy. This may be advantageous if severe environmental conditions prevail at the second location or in proximity to the second location. For instance, the movable unit may thereby not be able to be moved to the second location. Exemplarily, the weather conditions may prevent docking at a harbor at the second location. For such situations, it is beneficial to have thermal energy stored in a storage container at the second location or in proximity to the second location.

[0074] The term "carrying" or "carry" may be used to describe a transportation via a land route.

[0075] The term "moving" or "move" may be used to describe a transportation via a sea route.

[0076] A "land route" may be a route or path that is substantially based on a land or soil, such that it is not based on a sea or water regime.

[0077] A "sea route" may be a route or path that is substantially based on a sea, for instance the Atlantic Ocean, such that it is not based on a land or soil.

Brief description of the figures

[0078] In the following, the accompanying figures are briefly described:

Fig. 1 illustrates a method for transporting thermal energy in a storage medium according to an embodiment of the invention,

Fig. 2 illustrates a method for transporting thermal energy in a storage medium according to another embodiment of the invention,

Fig. 3 illustrates a method for transporting thermal energy in a storage medium according to yet another embodiment of the invention,

Fig. 4 illustrates a vehicle for transporting thermal energy in a storage medium via a sea route according to an embodiment of the invention, and

Fig. 5 illustrates a flow chart of a method for transporting thermal energy in a storage medium according to an embodiment of the invention.

Detailed description of the figures

[0079] In the following, the invention is described with reference to the accompanying figures in more detail.

[0080] While specific feature combinations are described in the following with respect to the exemplary embodiments of the present invention, it is to be understood that not all features of the discussed embodiments have to be present for realizing the invention, which is defined by the subject matter of the claims. The disclosed embodiments may be modified by combining certain features of one embodiment with one or more features of another embodiment. Specifically, the skilled person will understand that features, components and / or functional elements of one embodiment can be combined with technically compatible features, components and / or functional elements of any other embodiment of the present invention given that the resulting combination falls within the definition of the invention provided by the claims.

[0081] Fig. 1 illustrates a method for transporting thermal energy in a storage medium 10 according to an embodiment of the invention. Solar energy may be received and converted to thermal energy using a first conversion station 51. The first conversion station 51 may be close to the first location 4° or at the first location 40. The thermal energy is stored in a storage medium 10, which may be thermo oil, by heating the storage medium 10. This may also be established using the first conversion station 51, e.g. by directly heating the storage medium 10, without an intermediate medium. Thus, the storage medium 10 may be heated directly using parabolic troughs, in which the storage medium 10 may flow through an absorbing pipe. The first conversion station 51 may be a solar power plant. The heated storage medium 10 may be carried from the first conversion station 51 to the first location 4° over a distance of at most 250 km, most preferably the distance is small, such as substantially 0 km. Carrying the heated storage medium 10 may be established by thermally insulated pipes or tubes that preferably connect the first conversion station 51 and the first location 4° by a land route.

[0082] The heated storage medium 10 is placed in one or more containers 25. Beneficially, the containers 25 may have a rounded shape, preferably the containers 25 have the shape of spheres with a low surface to volume ratio. This advantageously reduces energy loss. A movable unit 20, which is a vehicle such as a ship, includes the one or more containers 25.

[0083] The movable unit 20 is moved from the first location 4° to the second location 41. The first location 4° is located between 0° to 40° norther latitude and/or between 0° to 40° southern latitude. Alternatively or in addition to the northern/southern latitude, the first location and the second location have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km. The first location 4° may be located in proximity to locations where a high amount of solar energy is available. The second location 41 is located between 41° to 90° norther latitude and/or between 41° to 90° southern latitude. Beneficially, the second location 41 is located in proximity to locations where an energy demand, potentially a high energy demand, pertains. Harbors may be located at the first location 4°

and at the second location 41, such that the movable unit 20, e.g. a ship may conveniently dock at the harbors via a sea route.

[0084] At the second location 41, the thermal energy in the heated storage medium 10 is converted to electrical energy using a second conversion station 52. It may be converted using a steam cycle process. The electrical energy may be conveniently distributed. Further, the thermal energy in the heated storage medium 10 may alternatively or simultaneously be supplied to a user 60. For instance, it may be used for district heating and carried via a land route to a user 60 in close proximity to the second location 41 or to a user 60 at a distance of about 50 km or even 250 km away from the second location 41.

[0085] Fig. 2 illustrates a method for transporting thermal energy in a storage medium 10 according to another embodiment of the invention. This embodiment is similar to the embodiment described before. An initial conversion station 50 is provided, in which solar energy is received and converted to electrical energy. It may be possible to provide for conversion from solar energy to electrical energy using a solar thermal power plant or using photovoltaic cells. Exemplarily, it may also be possible to convert wind energy to electrical energy. The electrical energy is used to heat the storage medium 10 at the first location 40 using the first conversion station 51. The heated storage medium 10 is placed in one or more containers 25 of the movable unit 20, which is moved from the first location 40 to the second location 41. The heated storage medium 10, e.g. the heated thermo oil is carried from the second location 41 to a second conversion station 52, which may be at most 250 km away from the second location 41. At the second conversion station 52 the heated storage medium 10, e.g. the heated thermo oil is converted to electrical energy.

[0086] Fig. 3 illustrates a method for transporting thermal energy in a storage medium 10 according to yet another embodiment of the invention. This embodiment is similar to the embodiments described before. The first conversion station 51 and the second conversion station 52 are both comprised by the movable unit 20. Thus, conversion from electrical energy to thermal energy by heating the storage medium 10, may be established within the movable unit 20 by using the first conversion station 51. Thermo oil heaters may be used as the first conversion station 51 for electrically heating the storage medium 10. This configuration may have the advantage that the storage medium 10 does not need to be carried on a land route but may be maintained within the one or more containers comprised by the movable unit 20. Further, substantially no exchange of the storage medium 10 across the movable unit 20 may be required. At the second location 41, the thermal energy stored in the heated storage medium 10 is converted to electrical energy using the second conversion station 52. The electrical energy may conveniently be distributed starting from the second location 41, as indicated in Fig. 3.

[0087] Fig. 4 illustrates a vehicle 20 for transporting thermal energy in a storage medium 10 via a sea route according to an embodiment of the invention. The vehicle 20 of this embodiment is the movable unit 20 described with reference to the embodiment according to Fig. 3. Although the one or more containers 25 are represented as one cylinder, it is understood that multiple containers may be present. In particular, it may be beneficial to place heated storage medium 10 in one or more containers 25. Further, it may be beneficial to place storage medium 10 which may have a lower temperature than the heated storage medium 10 in different containers 25. The storage medium 10 which may not be heated storage medium 10 may be understood as heated storage medium 10 that has been supplied to a user 60 and/or which thermal energy has been provided to the second conversion station 52.

[0088] The vehicle 20 is adapted to move from the first location 40 to the second location 41 via a sea route. The first location 40 and the second location 41 may be described by way of the norther/southern latitudes and/or by way of the distance between the first location 40 and the second location 41 as understood in view of the general disclosure of the present invention.

[0089] In one exemplary embodiment, the vehicle of 10 is a ship, which is capable of transporting 200,000 tons of storage medium 10, which may be thermo oil. The storage medium 10 is placed in one or more containers 25, in particular in multiple containers. In sum the one or more containers 25 may have a capacity of 200,000 tons. The ship 10 is adapted to move at an average velocity during of approximately 28 km/h. In an example of a distance of the first location to the second location of 5,000 km, the ship 10 may need about 357 hours or about 14.9 days for moving from the first location to the second location and moving from the second location to the first location. Including one day at each location, the ship may provide for about 23 movements from the first location to the second location per year. The thermo oil may have a specific heat capacity of 2.83 kJ/(kg K) (kilo Joule per kilogram and Kelvin) at 300°C. The thermo oil may have a density of 691 kg/m^3 (kilogram per cubic meter). The volume of the one or more containers may in this example be approximately 289.000 m^3. In this example, the temperature of the storage medium 10 may be increased of about 200 K. The thermal capacity of the heated storage medium 10 may thus be 113.200 GJ equaling 31.4 GWh. An average power usage, such as an electrical power usage, of a household, e.g. at proximity of the second location 41, may be about 3000 kWh per year. Accordingly, one ship may provide for energy supply of 72,270 households per year. The skilled person understands that the number of households that may be supplied by one ship per year may depend on a conversion efficiency. In one example, an efficiency of 0.3 may be applied.

[0090] If a molten salt is applied as storage medium 10, the density may be about 2000 kg/m^3 at about 150°C, the specific heat capacity may be 1.55 kJ/(kg K).

[0091] Fig. 5 illustrates a flow chart of a method 1 for transporting thermal energy in a storage medium 10 according to an embodiment of the invention. The method 1 comprises the steps of receiving 100 solar energy; converting 200 the received solar energy to thermal energy using a first conversion station 51; storing 300 the thermal energy in a storage medium 10 by heating the storage medium 10; placing 400 the heated storage medium 10 in one or more containers 25 comprised by a movable unit 20 and moving the movable unit 20 from a first location 40 to a second location 41,

> wherein the first location 40 is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and the second location 41 is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or
> wherein the first location 40 and the second location 41 have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location 40 and the second location 41 have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km;

at the second location 41, converting 500a the thermal energy in the heated storage medium 10 to electrical energy using a second conversion station 52 or supplying 500b the thermal energy in the heated storage medium 10 to a user 60.

[0092] In the above-described embodiments, the storage medium 10 is approximately heated to a temperature of about 385°C or about 390°C or about 395°C. Beneficially, the storage medium 10 is heated without pressurization. Thereby, the pressure difference between an inside of the one or more containers 25, wherein the heated storage medium 10 is placed, and an ambient pressure is substantially 0 bar.

List of reference signs

[0093]

1	method
100	method step: receiving
200	method step: converting
300	method step: storing
400	method step: placing and moving
500a	method step: converting
500b	method step: supplying
10	storage medium
20	movable unit
25	one or more containers
40	first location
41	second location
50	initial conversion station
51	first conversion station
52	second conversion station
60	user

Claims

1. A method (1) for transporting thermal energy in a storage medium (10) via a sea route, the method comprising the following steps in the given order

> a) receiving (100) solar energy;
> b) converting (200) the received solar energy to thermal energy using a first conversion station (51);
> c) storing (300) the thermal energy in a storage medium (10) by heating the storage medium (10);
> d) placing (400) the heated storage medium (10) in one or more containers (25) comprised by a movable unit (20) and moving the movable unit (20) from a first location (40) to a second location (41) via a sea route,
>
> > wherein the first location (40) is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and the second location (41) is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or
> > wherein the first location (40) and the second location (41) have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location (40) and the second location (41) have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km;

e) at the second location (41), converting (500a) the thermal energy in the heated storage medium (10) to electrical energy using a second conversion station (52) or supplying (500b) the thermal energy in the heated storage medium (10) to a user (60).

2. The method of claim 1, wherein step b) further comprises

- converting the received solar energy to electrical energy using an initial conversion station (50) separate from the first conversion station (51) and converting the electrical energy to thermal energy using the first conversion station (51).

3. The method of any preceding claim, wherein step c) further comprises

- carrying the heated storage medium (10) from the first conversion station (51) to the first location (40) over a distance of at most 250 km, preferably at most 180 km, more preferably at most 120 km, even more preferably at most 80 km, further preferably at most 50 km, most preferably over a distance of substantially 0 km.

4. The method of any preceding claim, wherein step c) further comprises

- increasing a temperature of the storage medium (10) by at least 10 K, preferably by at least 60 K, more preferably by at least 120 K, even more preferably by at least 180 K, most preferably by at least 250 K;
- increasing a temperature of the storage medium (10) by at most 390 K, preferably by at most 350 K, more preferably by at most 320 K, even more preferably by at most 290 K, most preferably by at most 250 K.

5. The method of any preceding claim, wherein the movable unit (20) is a vehicle, such as a ship, and wherein the movable unit (20) further comprises the first conversion station (51) and optionally the second conversion station (52).

6. The method of any preceding claim, wherein step d) further comprises

- insulating the heated storage medium (10) using the one or more containers (25);
- using at least partially the thermal energy of the heated storage medium (10) to provide for movement of the movable unit (20).

7. The method of any preceding claim, wherein step d) further comprises

- receiving a solar energy portion and heating the storage medium (10) by the received solar energy portion.

8. The method of any preceding claim, wherein step d) further comprises

- maintaining a temperature of the storage medium (10) of at least 80°C, preferably of at least 120°C, more preferably of at least 160°C, even more preferably of at least 200°C, most preferably of at least 260°C;
- maintaining a temperature of the storage medium (10) of at most 500°C, preferably of at most 460°C, more preferably of at most 420°C, even more preferably of at most 360°C, most preferably of at most 300°C;
- maintaining an absolute pressure difference of the storage medium (10) and an ambient pressure of at most 1 bar, preferably of at most 0.6 bar, more preferably of at most 0.4 bar, even more preferably of at most 0.2 bar, most preferably of substantially 0 bar.

9. The method of any preceding claim, wherein the storage medium (10) is a thermal storage medium (10), preferably a liquid thermal storage medium (10), most preferably a thermo oil medium.

10. The method of any preceding claim, wherein an amount of thermal energy in the heated storage medium (10) at the second location (41) with respect to an amount of thermal energy in the heated storage medium (10) at the first location (40) is at least 0.5, preferably at least 0.8, more preferably at least 0.9, even more preferably at least 1.0, most preferably at least 1.1.

11. The method of any preceding claim, wherein step d) further comprises

- substantially preventing any conversion of thermal energy in the storage medium (10) to another energy form.

12. The method of any preceding claim, wherein step d) further comprises

- keeping the heated storage medium (10) in the one or more containers (25) for at least 4 hours, preferably at least 16 hours, more preferably at least 32 hours, even more preferably at least 80 hours, most preferably for at least 160 hours;
- keeping the heated storage medium (10) in the one or more containers (25) for at most 500 hours, preferably at most 400 hours, more pref-

erably at most 300 hours, even more preferably at most 200 hours, most preferably for at most 160 hours.

13. The method of any preceding claim, wherein step e) further comprises

- carrying the heated storage medium (10) from the second location (41) to the second conversion station (52) over a distance of at most 250 km, preferably at most 180 km, more preferably at most 120 km, even more preferably at most 80 km, further preferably at most 50 km, most preferably over a distance of substantially 0 km, and converting the thermal energy in the heated storage medium (10) to electrical energy using a steam turbine process in the second conversion station (52); or
- carrying the heated storage medium (10) from the second location (41) to the user (60) for supplying the thermal energy in the heated storage medium (10) to the user (60), wherein the user (60) is at least 20 km, preferably at least 40 km, more preferably at least 60 km, even more preferably at least 80 km, most preferably at least 100 km away from the second location (41).

14. A computer program comprising instructions which, when executed by a computer, cause the computer to perform the method according to any preceding claim.

15. A vehicle (20) for transporting thermal energy in a storage medium (10) via a sea route, the vehicle (20) comprising

a) a first conversion station (51) for converting energy to thermal energy;
b) a storage medium (10) for storing the thermal energy by heating the storage medium (10);
c) one or more containers (25) for placing in the storage medium (10);
d) a second conversion station (52) for converting the thermal energy in the heated storage medium (10) to electrical energy;

wherein the vehicle is adapted to move from a first location (40) to a second location (41) via a sea route,
wherein the first location (40) is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and the second location (41) is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or
wherein the first location (40) and the second location (41) have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location (40) and the second location (41) have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km.

Amended claims in accordance with Rule 137(2) EPC.

1. A method (1) for transporting thermal energy in a storage medium (10) via a sea route, the method comprising the following steps in the given order

a) receiving (100) solar energy;
b) converting (200) the received solar energy to thermal energy using a first conversion station (51);
c) storing (300) the thermal energy in a storage medium (10) by heating the storage medium (10);
d) placing (400) the heated storage medium (10) in one or more containers (25) comprised by a movable unit (20) and moving the movable unit (20) from a first location (40) to a second location (41) via a sea route,
e) at the second location (41), converting (500a) the thermal energy in the heated storage medium (10) to electrical energy using a second conversion station (52) or supplying (500b) the thermal energy in the heated storage medium (10) to a user (60); **characterized in that**
the storage medium (10) is a thermo oil medium; and
the first location (40) is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and
the second location (41) is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or

the first location (40) and the second location (41) have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location (40) and the second location (41) have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km.

2. The method of claim 1, wherein step b) further comprises

- converting the received solar energy to electrical energy using an initial conversion station (50) separate from the first conversion station (51) and converting the electrical energy to thermal energy using the first conversion station (51).

3. The method of any preceding claim, wherein step c) further comprises

- carrying the heated storage medium (10) from the first conversion station (51) to the first location (40) over a distance of at most 250 km, preferably at most 180 km, more preferably at most 120 km, even more preferably at most 80 km, further preferably at most 50 km, most preferably over a distance of substantially 0 km.

4. The method of any preceding claim, wherein step c) further comprises

- increasing a temperature of the storage medium (10) by at least 10 K, preferably by at least 60 K, more preferably by at least 120 K, even more preferably by at least 180 K, most preferably by at least 250 K;
- increasing a temperature of the storage medium (10) by at most 390 K, preferably by at most 350 K, more preferably by at most 320 K, even more preferably by at most 290 K, most preferably by at most 250 K.

5. The method of any preceding claim, wherein the movable unit (20) is a vehicle, such as a ship, and wherein the movable unit (20) further comprises the first conversion station (51) and optionally the second conversion station (52).

6. The method of any preceding claim, wherein step d) further comprises

- insulating the heated storage medium (10) using the one or more containers (25);
- using at least partially the thermal energy of the heated storage medium (10) to provide for movement of the movable unit (20).

7. The method of any preceding claim, wherein step d) further comprises

- receiving a solar energy portion and heating the storage medium (10) by the received solar energy portion.

8. The method of any preceding claim, wherein step d) further comprises

- maintaining a temperature of the storage medium (10) of at least 80°C, preferably of at least 120°C, more preferably of at least 160°C, even more preferably of at least 200°C, most preferably of at least 260°C;
- maintaining a temperature of the storage medium (10) of at most 500°C, preferably of at most 460°C, more preferably of at most 420°C, even more preferably of at most 360°C, most preferably of at most 300°C;
- maintaining an absolute pressure difference of the storage medium (10) and an ambient pressure of at most 1 bar, preferably of at most 0.6 bar, more preferably of at most 0.4 bar, even more preferably of at most 0.2 bar, most preferably of substantially 0 bar.

9. The method of any preceding claim, wherein an amount of thermal energy in the heated storage medium (10) at the second location (41) with respect to an amount of thermal energy in the heated storage medium (10) at the first location (40) is at least 0.5, preferably at least 0.8, more preferably at least 0.9, even more preferably at least 1.0, most preferably at least 1.1.

10. The method of any preceding claim, wherein step d) further comprises

- substantially preventing any conversion of thermal energy in the storage medium (10) to another energy form.

11. The method of any preceding claim, wherein step d) further comprises

- keeping the heated storage medium (10) in the one or more containers (25) for at least 4 hours, preferably at least 16 hours, more preferably at least 32 hours, even more preferably at least 80 hours, most preferably for at least 160 hours;
- keeping the heated storage medium (10) in the one or more containers (25) for at most 500 hours, preferably at most 400 hours, more preferably at most 300 hours, even more preferably

at most 200 hours, most preferably for at most 160 hours.

12. The method of any preceding claim, wherein step e) further comprises

- carrying the heated storage medium (10) from the second location (41) to the second conversion station (52) over a distance of at most 250 km, preferably at most 180 km, more preferably at most 120 km, even more preferably at most 80 km, further preferably at most 50 km, most preferably over a distance of substantially 0 km, and converting the thermal energy in the heated storage medium (10) to electrical energy using a steam turbine process in the second conversion station (52); or
- carrying the heated storage medium (10) from the second location (41) to the user (60) for supplying the thermal energy in the heated storage medium (10) to the user (60), wherein the user (60) is at least 20 km, preferably at least 40 km, more preferably at least 60 km, even more preferably at least 80 km, most preferably at least 100 km away from the second location (41).

13. A vehicle (20) for transporting thermal energy in a storage medium (10) via a sea route, the vehicle (20) comprising

a) a storage medium (10) for storing the thermal energy by heating the storage medium (10);
b) one or more containers (25) for placing in the storage medium (10); wherein the vehicle is adapted to move from a first location (40) to a second location (41) via a sea route; **characterized in that** the vehicle further comprises
c) a first conversion station (51) for converting energy to thermal energy;
d) a second conversion station (52) for converting the thermal energy in the heated storage medium (10) to electrical energy;
wherein the storage medium (10) is a thermo oil medium; and
wherein the first location (40) is located between 0° to 40° northern/southern latitude, preferably between 10° to 35° northern/southern latitude, more preferably between 15° to 35° northern/southern latitude, most preferably between 20° to 30° northern/southern latitude, and the second location (41) is located between 41° to 90° northern/southern latitude, preferably between 42° to 80° northern/southern latitude, more preferably between 43° to 75° northern/southern latitude, most preferably between 45° to 70° northern/southern latitude; and/or wherein the first location (40) and the second location (41) have a distance of at least 10 km, preferably at least 100 km, more preferably at least 500 km, even more preferably at least 1000 km, most preferably of at least 4000 km, and the first location (40) and the second location (41) have a distance of at most 18000 km, preferably at most 16000 km, more preferably at most 12000 km, even more preferably at most 10000 km, most preferably of at most 8000 km.

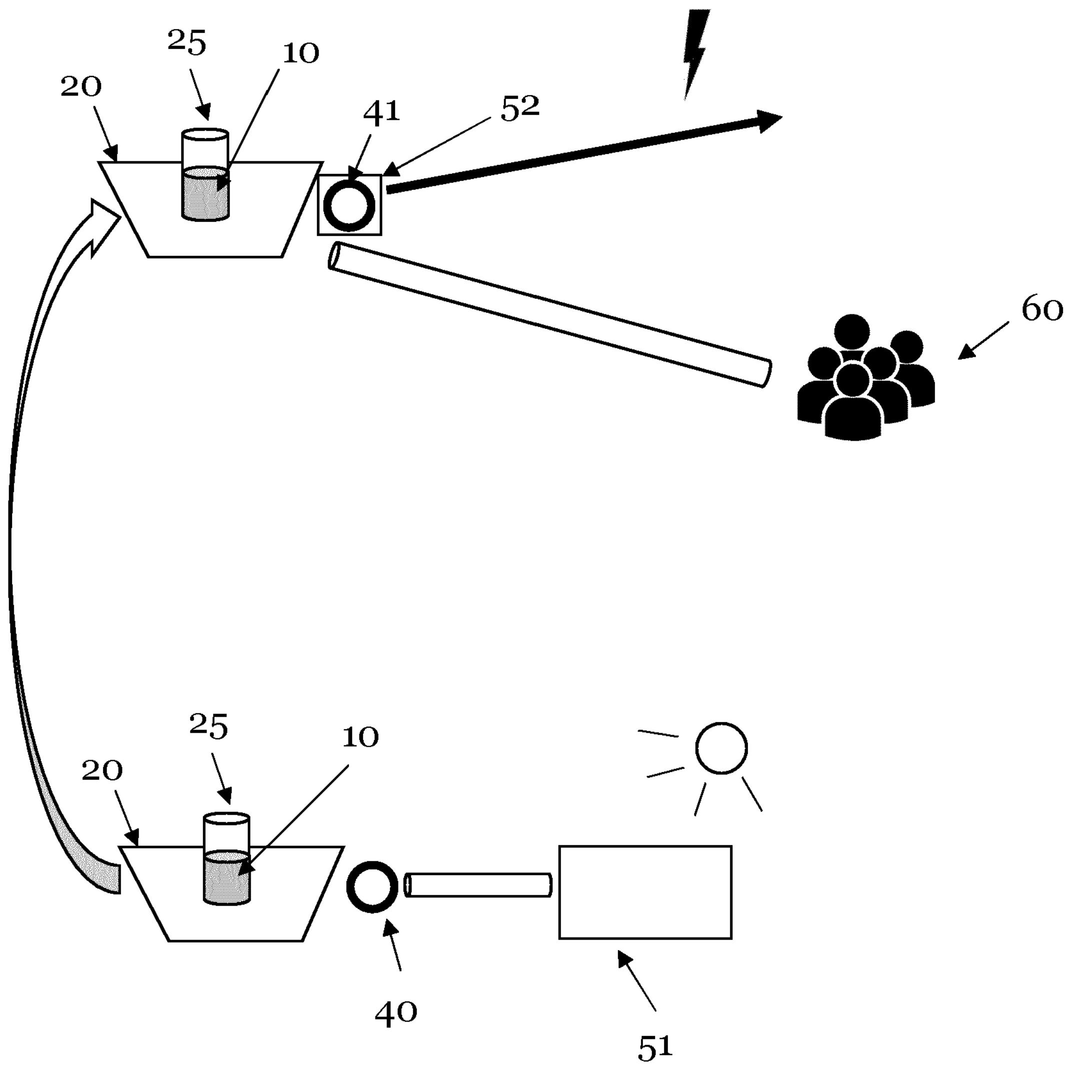

Fig. 1

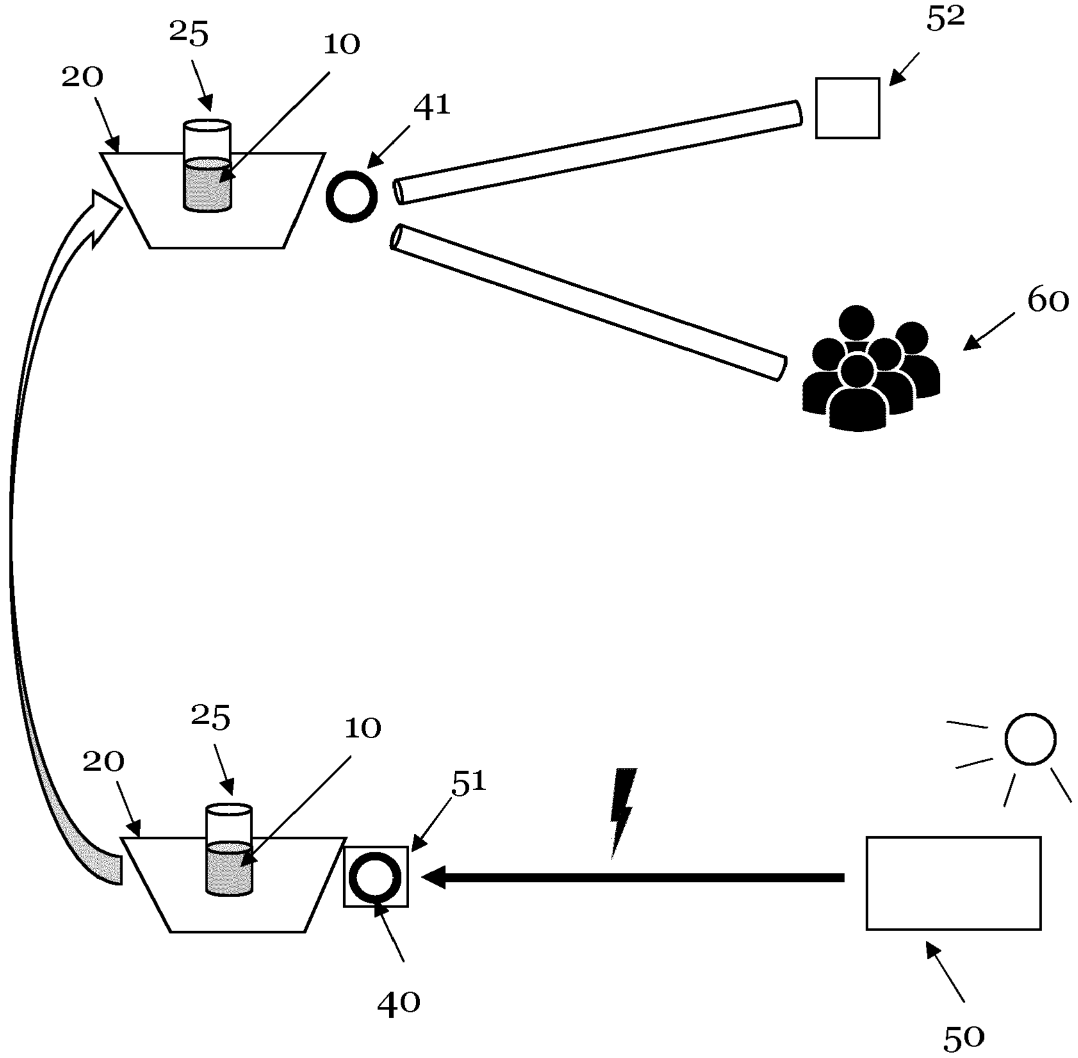

Fig. 2

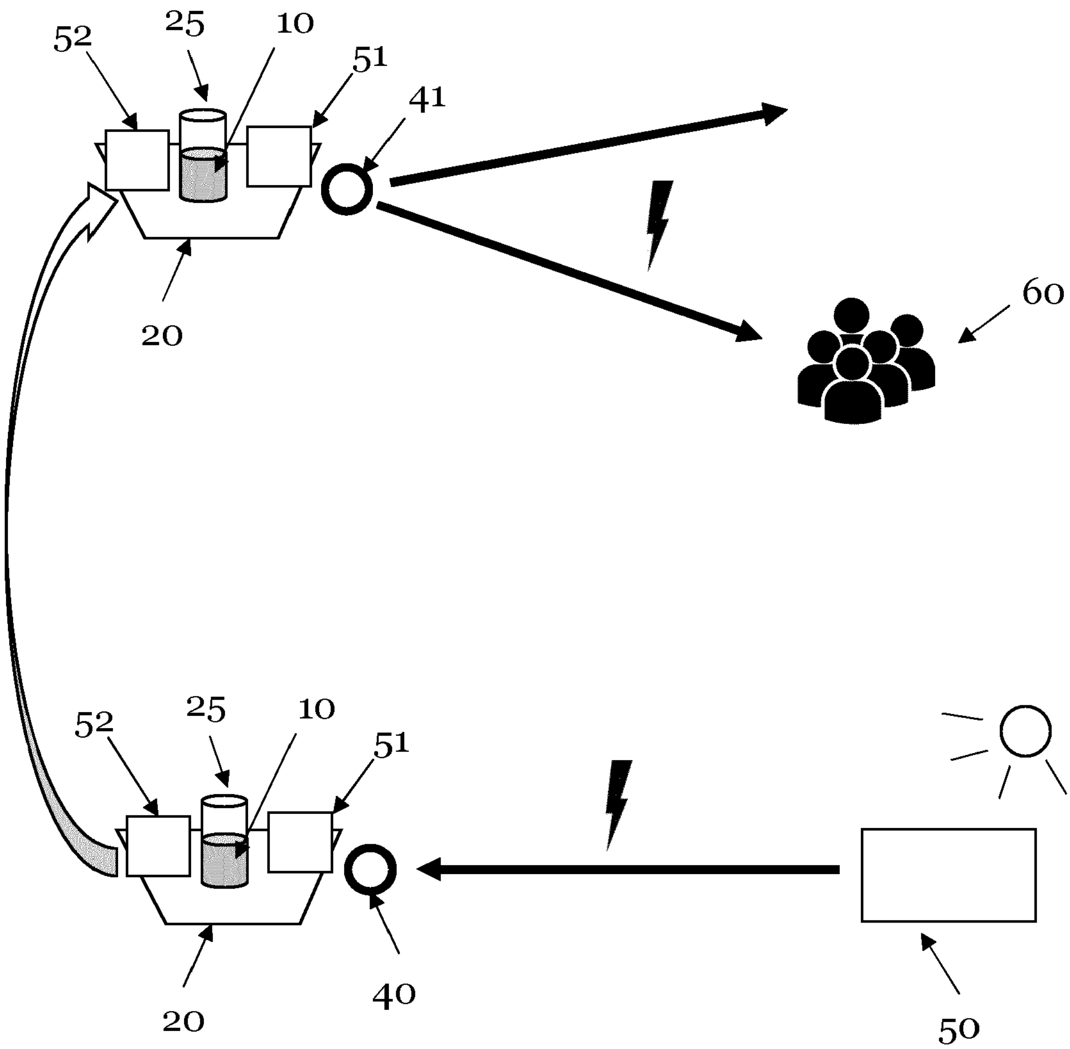

Fig. 3

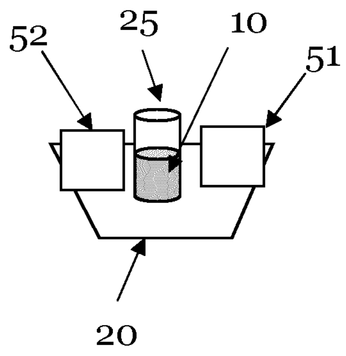

Fig. 4

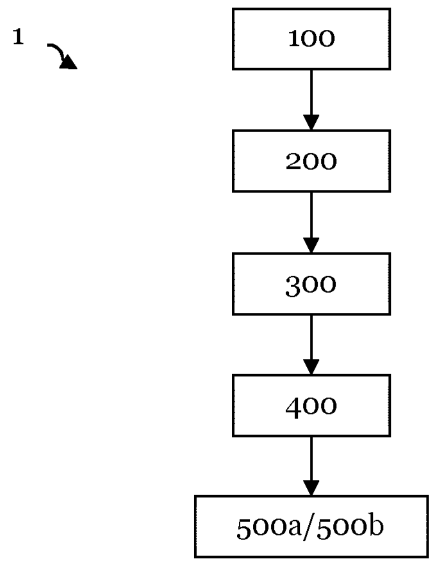

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 9252

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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	13 September 2022	Mellado Ramirez, J

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