METHODS AND APPARATUS FOR CREATING LARGE ENERGY STORAGE MASS THROUGH THE COLLECTION AND USE OF WARMED WATER

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ABSTRACT

A system for heating and supplying electricity to residential, commercial, and industrial buildings using renewable energy that is stored, at little or no incremental cost, in a large mass of warm or hot water. The large thermal mass is sized based on the building. Thermal energy from a number of sources, including, but not limited to renewable energy panels, waste heat, and flue gas, are used to provide heat to the large thermal mass.
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FIELD OF INVENTION

[0001] This invention relates to the field of renewable energy. Specifically, this invention relates to the large-scale creation and storage of water, which is warmer than the ambient environmental conditions, using renewable heat sources.

BACKGROUND OF INVENTION

[0002] Currently, most of the world’s economies are reliant heavily on fossil fuels. Fossil fuels have many drawbacks. Fossil fuels pollute and are largely responsible for deleterious Global Warming, the greenhouse effect. Additionally, pollution from fossil fuels makes air in many major cities, such as Mexico City, Beijing, and Los Angeles, unhealthy to breathe for many people. The procurement of fossil fuels, whether in mining coal or drilling for petroleum, is inherently polluting. Mountaintop removal for coal and fracking for natural gas both contaminate ground water, endangering the life and health of those nearby. Drilling for petroleum is also fraught with hazard; witness the BP drilling catastrophe in the Gulf of Mexico in 2010 or the grounding of the Exxon Valdez in 1989.

[0003] Fossil fuels give undue influence to governments who control large exportable quantities. The majority of exported crude comes from areas of the world with known unstable, unpopular governments, and/or those in tension with the West. For instance, much imported oil America receives comes from the Middle East, Venezuela, Angola and Nigeria—all meeting the above description. Many oil-exporting Middle East regimes are openly hostile to and contemptuous of the United States, notably Iran. Many other autocratic “friendly” regimes such as Saudi Arabia and Kuwait are clearly unstable and vulnerable, in light of the Arab Spring. The U.S. secures additional petroleum from Venezuela, which in recent history has badly strained relations with the U.S. Western Europe procures much of its fossil fuels (natural gas) from Russia, an historic, competitive with the West. Even without these serious national security issues, to the extent that fossil fuels are imported needlessly, a nation exports its wealth, needlessly.

[0004] Fossil fuels are also becoming increasingly scarce, meaning that their price is rising. The United States International Energy Agency estimates that 2006 was the peak year of petroleum production. The global output of petroleum will now slowly decline. Meanwhile, the BRIC countries (Brazil, Russia, India, and China) are rapidly growing, driving demand for petroleum upward. This has led to volatility in the oil markets, with the cost of a barrel of oil peaking at $140 in 2008. Since then, the price for crude oil has varied from a low of $70 per barrel to a high of $110 per barrel; such swings of 50% in a basic commodity are painful all by themselves. All indicators are that the price of a wide variety of fossil fuels will steadily increase, faster than other goods, until they are exhausted.

[0005] In response to these drawbacks of fossil fuels, industry, governments, and academic institutions have been pouring resources into finding renewable energy sources for years. To date, the results are mixed. Current renewable resources all have three drawbacks: cost, environmental impact, and consistency of availability. The cost of a renewable energy source is measured by various metrics: Return on Investment (“ROI”), cost per kilowatt hour (“CPEH”), levelized cost of energy (“LCE”), etc. In order to be competitive, the CPEH must be comparable to that of fossil fuel. Alternatively, the ROI (reciprocal of payback period) must be realistic with a short number of payback years. Currently, no renewable sources are cheaper than fossil fuels over the short-run (3 years or less).

[0006] Many renewable energy sources have a significant environmental impact. Environmental impact means not only pollution, but also a visible, intrusive installation footprint. For example, in order to generate usable quantities of solar energy using photovoltaic cells (“PV”), one needs a sunny location and very large surface area due to their characteristic conversion efficiencies of 20% or less. In order to produce wind energy economically, most developers lay out wind-turbine farms, requiring tens or hundreds of acres. To produce hydro-electric energy, a dam must be built, disturbing the environment far upstream, and potentially disrupting wetlands and delicate eco-systems. In order to produce ethanol, farmers must grow corn on industrial scales, using significant amounts of land, water, petroleum, and pesticides (to date, no ethanol growers are doing so organically).

[0007] Last, many renewable energy installations are severely limited as to the times, during which they can provide power. For example, most types of PV only provide significant power with direct beam sunlight. Yet peak electricity demand is typically in hours around and after dusk, just when PV loses its generating capacity. Wind turbines only provide power when it’s windy. This means that a wind turbine can only add to the grid when there is wind. When the wind dies down or PV arrays have a cloud pass overhead, the electrical grid must suddenly be able to provide power using other more reliable means; severe grid destabilization, threatening regional blackouts, can occur when PV and wind comprise more than 4 to 5% of a region’s generating capacity. Moreover, the grid requires 100% of its former fossil capacity as backup, since PV and wind promise zero baseline stability. The inconsistency of power generation therefore greatly reduces the appeal of these renewable energy resources.

[0008] Clearly, the world is searching for a renewable energy resource which is cost-effective, has a low environmental impact, and is consistent in its generating capacity. One potentially under-appreciated component of such a system is water. In most of the temperate part of the world, it is relatively easy to sequester water from the environment, either through precipitation or ground-water. Additionally, the relatively low-cost of water from municipal sources makes large-scale water storage economically feasible.

[0009] Water has both a high thermal capacity and a high latent heat needed to be fuse. A high thermal capacity means that water can absorb significant heat without extreme changes in its temperature. Likewise, water can radiate significant heat without extreme changes in its temperature. Water is also unique in that its heat capacity does not drastically change when it changes phase. The specific heat, or thermal capacity of water, is 1.16 MJ/m³ °C or 0.32 kJ/hr/ m³ °C.

[0010] Because of its thermal capacity, water can store a substantial amount of energy, even at relatively modest temperatures. To put that in perspective, according to a study by U.C. Irvine, the average household consumption of energy in southern California in 2007 was 6 MW-hr. Water, heated to 106 °C above ambient, would hold 3.2 kW-hr/m³, when com-
pared with the ambient environment. Under these conditions, to create a thermal mass that contained the heat equivalent energy of that used by the typical southern California home in a year would require a cube 12.3 m on a side. To create a thermal mass that contained the heat equivalent of that used by the typical southern California home on an average day would be a cube 1.75 m on a side.

[0011] A hot water storage facility is of great utility to a renewable energy system, because it can be scaled for the amount of power needed to be stored, the ambient environment, the available amount of water, and the available amount of storage space. Cubic storage is ideal, because the energy storage capacity is proportional to the volume, and the losses are proportional to the surface area. This means that larger storage masses are inherently more efficient and effective than smaller ones.

[0012] This is all made possible, because, “Heat flow is energy transfer that takes place as a consequence of temperature differences only” [Physics for Scientists and Engineers, R.A. Serway, Saunders College Publishing, 2nd ed., New York, 1982, p. 426]. In other words, when there is a difference in temperatures between two sources, there can be an energy transfer attributable to the heat flow. This can be represented by

$$Q = m c \Delta T.$$  \hspace{1cm} [1]

where Q is heat energy, m is mass, c is the specific heat, and ΔT is the difference in temperature between the mass and the environment. As discussed, above, the specific heat for water is quite high. Eq. 1 is a simplified form assuming that the specific heat is constant over the range of temperatures of interest. Although that is usually not the case, it is a good first approximation, and when needed, can be corrected by an integral form of the equation taking account of the variation of the specific heat

$$Q = m c(T_f - T_i). \hspace{1cm} [2]$$

where $T_i$ is the initial temperature, and $T_f$ is the final temperature.

[0013] Heat transfer can take place via conduction, convection or radiation.

[0014] Heat energy is most efficiently transferred into a thermal mass of water using conduction. The heat and energy transfer of objects, of different temperature, which are in contact. Conduction would take place in a typical liquid-to-liquid, or air-to-liquid heat exchanger, or by using a renewable energy panel, such as a photo-voltaic (“PV”) or solar thermal panel.

SUMMARY OF THE INVENTION

[0015] The present invention is an apparatus and method to store ambient environmental energy in warm or hot water, on a large enough scale, that it becomes practical as part of a renewable energy system for residential, office, and industrial uses. It is a technology that is practical both in areas where there are high temperatures at least part of the year, and in places where there is significant sunshine. In sunny climates, it is possible to use warm water storage in conjunction with renewable energy panels.

[0016] The present system is comprised of a system or method for making and storing a large mass of warm or hot water, a cover and/or other methods of insulating the water, a piping system connecting the storage area to a heat exchanger, either a liquid-to-liquid or a liquid-to-air heat exchanger, a controller that regulates the flow of hot liquid to the heat exchanger, and a device that allows the heat energy to be removed from the storage area. The liquid medium of the heat exchanger can be water, oil, glycol, or other suitable energy transfer media. In systems in which the liquid medium is water, the device that allows for the removal of heat energy from the storage area is either piping, allowing the hot water to be used for residential or business uses; or allows for the removal of hot energy from the storage area through a liquid to liquid heat exchanger.

[0017] Such storage is scalable from 200 gallons up to 20 Million gallons. The low end of this range provides days to weeks of thermal energy. The mid and higher volumes, starting from about 1200 cu. ft. (9,000) and higher, permit months and even an entire year of thermal storage. Scalable annual cycle or seasonal thermal storage permits every BTU collectible from a solar thermal panel, PV panel, or other source to be stored for eventual use, with little waste. The stored thermal energy can be used to provide space heat, hot water, or, through thermoelectric generators of various types, electricity.

[0018] The invention allows for the affordable capture and storage of heat energy provided by a variety of systems or methods. The systems or methods for making and storing large scales of warm or hot can vary, depending on the application, the terrain, local zoning ordinances, access to natural or man-made bodies of water, the cost of installation, and other building factors that are evident to those skilled in the trade. The systems or methods for making and storing large scales of warm or hot water can include, but is not limited to, fossil fuel burners, solar thermal, photo-voltaic, cellulosic, flue-gas capture, and other continuous or intermittent heat sources. The systems and methods for making and storing large scales of hot water listed in this patent application are meant to be illustrative in nature, and do not limit the breadth or scope of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 shows a side view of a warm water storage tank connected to a renewable energy system.

[0020] FIG. 2 shows a side view of a hot water storage tank with renewable energy panels mounted to the top.

[0021] FIG. 3 shows a perspective view of an alternative embodiment of the hot water storage tank with renewable energy panels mounted to the top.

[0022] FIG. 4 shows a perspective view of another alternative embodiment of the hot water storage tank with renewable energy panels, on a rotating turn-table, mounted to the top.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] The detailed description is intended to illustrate the present invention, without, in any way, limiting its scope.

[0024] The invention is a component for use in a renewable energy system, applicable to residential, commercial and industrial buildings. The system uses, as one of its components, a large-scale energy storage system. The system is a large-scale energy storage in a warm or hot water thermal mass, and is designed with due consideration of the climate, terrain, zoning, property size, and installation cost.

[0025] FIG. 1 shows a method and system for storing warm thermal. The large thermal mass 202 is a liquid medium. In the preferred embodiment, the large thermal mass 202 is
water. The large thermal mass 202 is contained within a storage container 201. The storage container 201 is characteristically built in an advantageous method. For example, the storage container 201 can have an outer structural wall of steel, concrete or rammed earth; a plurality of intermediate insulating layers; and an inner liner. The large thermal mass 202 is fed heat energy from an ambient collection system, such as a solar thermal panel 203. The solar thermal panel 203 is directly connected to the large thermal mass 202 with variable level insulated input/supply pipes 205. In embodiments using renewable energy panels, combustion sources, flue gas heat capture, or waste flows of energy, a heat exchanger 215, either liquid-to-liquid or liquid-to-air, can be used to maximize energy capture. The system has an automatic controller 204, which optimizes variables including, but not limited to, differential thermostats functions regulating flows sent between the ambient collection system and the large thermal mass 202; demand-sensing for peak-period load shedding; and demand-sensing for utility feed-in tariff revenue maximization.

The system includes several embodiments, mechanisms, and options to maximize total thermal energy usage. In order to minimize waste of thermal energy, the system uses variable-level, ultra-lightweight flexible return lines 206. The weight and diameter of the flexible return lines 206 are designed to allow return fluid to seek its own temperature gradient, without contaminating the stratus above and below. In order to maximize the use of thermal energy, the system uses a stratification barrier film 207, which prevents slush contamination of established thermal gradients during various on and off surges of pumped flows inside the vessel. In order to prevent evaporation, the storage vessel 201 has a floatation-type anti-evaporation barrier resting on the upper surface of the liquid.

The heat from the system can be used to supply either heat or heat-energy for a variety of residential or commercial uses. Supply and return lines 209 connect the large thermal mass 202 to any heat-demanding appliances 210. In appropriate embodiments, the system can have an in-vessel heat-exchanger 211 for either passive or active pumped, preheated water, for residential, business, pool, or spa use. Energy from the heated large thermal mass 202 can be routed to a thermo-electric generator 212 of any type, including, but not limited to solid state TEG chips set into fluidway heat exchangers; shape memory alloy wire pulleys connected to generators; Rankine cycle engines; or Stirling engines. The thermo-electric generator 212 is fed cold water 213, either from a separate cold storage tank, a city water feed, a well, or the cooled return water from a renewable energy system. The electricity 214 could be used on-site or fed to the grid, depending on the needs of the facility. The electricity 214 would also be used to power any controllers 204 or pumps needed in the system.

To improve the insulation, the storage container 201 and large thermal mass 202 would be placed below grade 216. The spoils and backfill 217 would be feathered against the storage container 201.

To further improve the overall system efficiency, there are additional options/embodiments which can be implemented with the system. Phase-change material can be stored in a sack 224. The phase change material can be eutectic salts and/or paraffin waxes. The sack 224 can be insulated, so that the higher temperature liquid can be fed to the thermo-electric generator 212. The sack 224 can be uninsulated, so that the phase change material can supplement the energy storage capability of the large thermal mass 202. The sack 224 can be manipulated or massaged by a mechanism 225, such as rollers.

In a round storage container 201, the lid can be put on bearings 226. This would allow the lid to rotate. By directionally feeding return water 228 the controller 204 could rotate the lid on top of the bearings 226, keeping the solar thermal panel 203 maximally aligned with the sun.

FIG. 2 shows an embodiment in which the Renewable energy panels 203 are placed on a saw-toothed lid, so that they are properly angled towards the sun in a latitude-dependent fashion. The lid can track the sun either with bearings, rollers, or by adding additional water to the large thermal mass 202.

The warm, large thermal mass 202 can be used in an integrated fashion with adjacent structures. For example, a solaria or greenhouse 219, 221, built from lightweight, high transmissivity plastics or glass can be attached to the storage container 201. Air vents 220 set above the fluid line in the storage container allow warm air to be brought into the adjoining structure 219, 221. A spa or hot-tub 222 can be heated via thermosyphon from the large thermal mass 202.

FIG. 3 shows another alternative embodiment. The thermal mass is contained by a hot fluid storage vessel 101. Solar thermal or other panels 102 can be placed in an array on saw-toothed mounts, on the lid 103. The lid 103 floats on fluids or rides on circumferential ball bearings, wheels or rollers or sets on a turntable. This allows the lid 103 to rotate with the sun, so that the solar thermal or other panels 102 are optimally aimed at the sun.

The system can optionally employ a thermo-electric system of the torque-to-generator type 104. The system would be ganged together on a common cam system 105, employing a common drive-shaft 106. The system would crank a generator 107. The system would have a cold-water feed 108 for the thermo-electric generators 104.

FIG. 4 shows another alternative embodiment. The solar panel array is mounted on a turntable 121, which rotates on ball bearings; rotates on a wheel or roller system; or floats on top of water. The storage container 122 contains a large thermal mass.

We claim:
1. An energy storage system comprised of a system or method for creating and storing a very large thermal mass of warm or hot water, an insulated storage container for the large thermal mass; at least one heat exchanger, a control-box to regulate the heat exchanger; and a system of piping between the stored large thermal mass and the heat exchanger.
2. The invention described in 1, wherein the storage container is a natural or man-made swale in the land containing a pond liner or other impermeable liner.
3. The invention described in 1, wherein the storage container is at least partially below grade.
4. The invention described in 1, wherein the water is originally captured as environmental precipitation and is purified on-site.
5. The invention described in 1, wherein the large thermal mass is at least 50,000 gallons.
6. The invention described in 1, wherein the large thermal mass is at least 500,000 gallons.
7. The invention described in 1, wherein at least one of the heat exchangers is a liquid-to-liquid heat exchanger.
8. The invention described in 1, wherein at least one of the heat exchangers is a liquid-to-air heat exchanger.

9. The invention described in 1, wherein the large thermal mass is warmed directly by a solar thermal panel and associated piping.

10. The invention described in 1, wherein the large thermal mass is warmed via a heat exchanger, from a solar thermal panel, a photovoltaic panel, or other solar-type panel.

11. The invention described in 1, wherein the large thermal mass is warmed, at least partially, from waste-heat from fossil fuel combustion or flue gas.

12. The invention described in 1, wherein lightweight, large-diameter return pipe, containing water from which heat has been removed, is made to float at the temperature strata roughly equal to that of the return water.

13. The invention described in 1, wherein sacks of eutectic salts and/or paraffin waxes are suspended in the large thermal mass.

14. The invention described in 13, wherein the sacks are insulated.

15. The invention described in 13, wherein the sacks are not insulated.

16. The invention described in 13, wherein a mechanism attached to the sacks can massage or squeeze the sacks, in order to optimize the phase change characteristic of the material in the sacks.

17. The invention described in 1, wherein a lightweight barrier is suspended within the tank in order to separate the temperature strata.

18. The invention described in 1, wherein the large thermal mass supplies one side of a thermoelectric generator or a shaped metal alloy heat-engine.

19. The invention described in 18, wherein insulated sacks of eutectic salts and/or paraffin are suspended within the large thermal mass, the thermal heat from which are used to supply the thermoelectric generator or shaped metal alloy heat-engine.

20. The invention described in 1, wherein the lid of the storage container can rotate, either because the lid floats on the large thermal mass of water, or because the lid rests on bearings.

21. The invention described in 20, wherein a controller and plurality of pumps and pipes can rotate the lid, in order to track the sun.

22. The invention described in 22, wherein a plurality of renewable energy panels, such as PV panels or thermal solar panels, are mounted on saw-toothed mounts.

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