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**Burke**

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(54) **SYSTEMS AND METHOD FOR TIME USE OPTIMIZATION**

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(51) **Int. Cl.**

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| ***G05B 13/02*** | (2006.01) |
| ***G06Q 50/06*** | (2012.01) |
| ***G05B 15/02*** | (2006.01) |
| ***G05B 19/048*** | (2006.01) |

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(58) **Field of Classification Search**

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See application file for complete search history.

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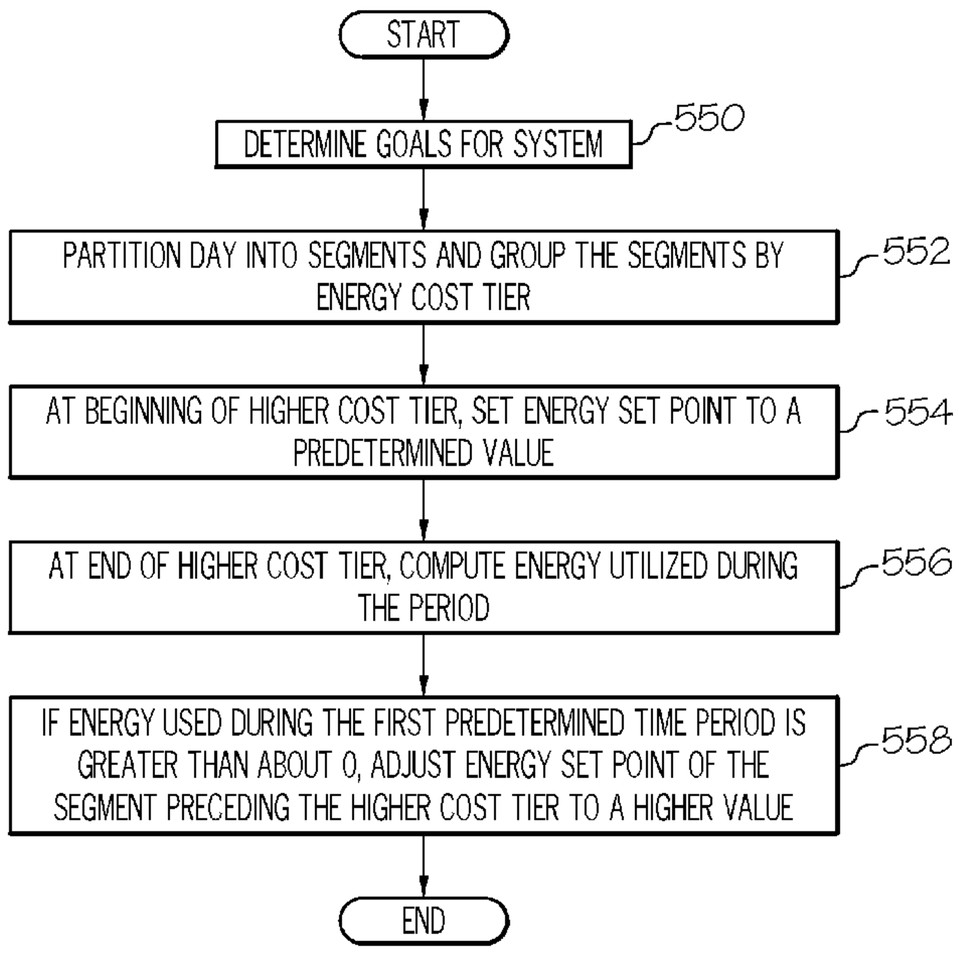
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(57) **ABSTRACT**

Systems and methods for time use optimization are provided. One embodiment of a method includes determining time of use pricing data associated with purchase of energy from an energy provider, partitioning a predetermined amount of time into a plurality of segments, where the plurality of segments corresponds with the higher cost tier and the lower cost tier, and creating an energy set point schedule for setting a set point of a controllable device, where the energy set point schedule sets the set point of the controllable device to a predetermined value for each of the plurality of segments. Some embodiments include determining energy utilized by the controllable device during at least a portion of the energy set point schedule and iteratively altering the energy set point schedule, based on a comparison of the energy utilized and a current status of the energy set point schedule.

**17 Claims, 5 Drawing Sheets**



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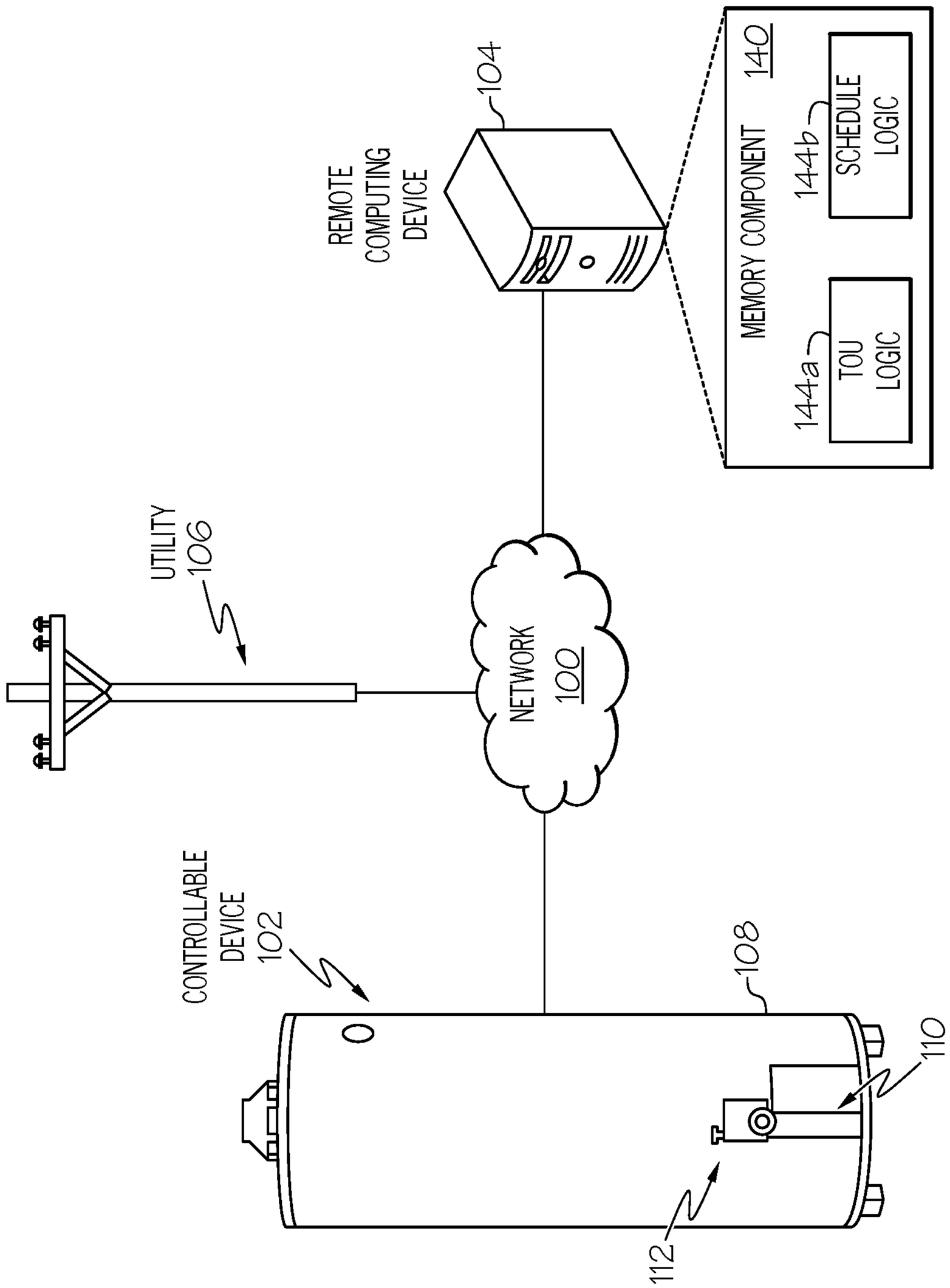

REMOTE COMPUTING DEVICE
104
MEMORY COMPONENT 140
144b
SCHEDULE LOGIC
144a
TOU LOGIC
UTILITY
106
NETWORK
100
CONTROLLABLE DEVICE
102
108
110
112

FIG. 1

| | |
|---|---|
| WEEKENDS 12:00 AM – 5:00 AM | $0.0887/KWh |
| WEEKENDS 5:01 AM – 12:00 PM | $0.0911/KWh |
| WEEKENDS 12:01 PM – 9:00 PM | $0.0924/KWh |
| WEEKENDS 9:01 PM – 11:59 PM | $0.887/KWh |
| WEEKDAYS 12:00 AM – 5:00 AM | $0.0887/KWh |
| WEEKDAYS 5:01 AM – 5:00 PM | $0.0911/KWh |
| WEEKDAYS 5:01 PM – 11:59 PM | $0.0924/KWh |

FIG. 2

| | |
|---|---|
| WEEKDAYS 5:04 AM | 116°F |
| WEEKDAYS 7:38 AM | 122°F |
| WEEKENDS 8:17 AM | 138°F |
| WEEKENDS 11:41 PM | 102°F |
| SUNDAYS 12:19 PM | 131°F |

FIG. 3

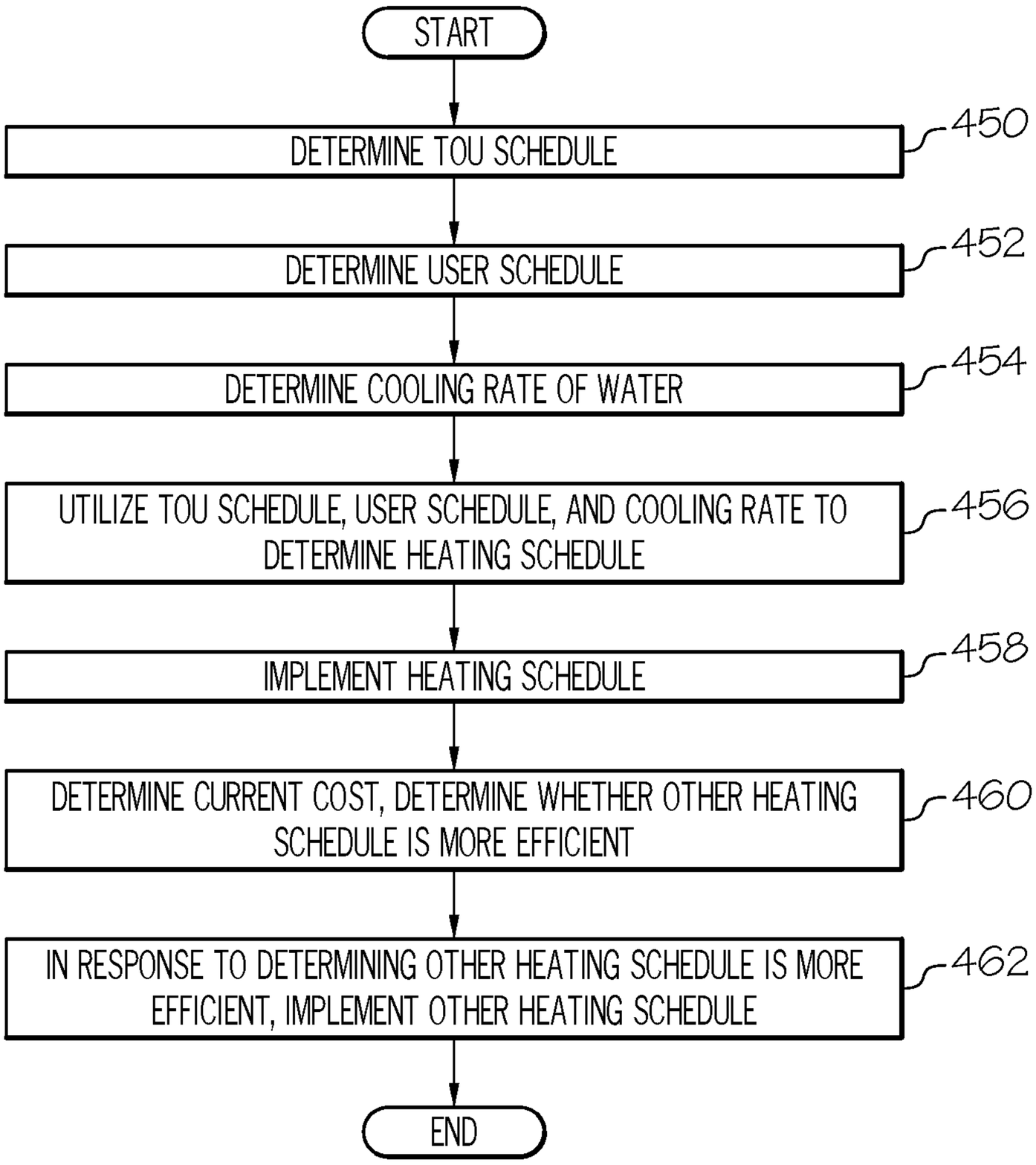

START
DETERMINE TOU SCHEDULE
450
DETERMINE USER SCHEDULE
452
DETERMINE COOLING RATE OF WATER
454
UTILIZE TOU SCHEDULE, USER SCHEDULE, AND COOLING RATE TO DETERMINE HEATING SCHEDULE
456
IMPLEMENT HEATING SCHEDULE
458
DETERMINE CURRENT COST, DETERMINE WHETHER OTHER HEATING SCHEDULE IS MORE EFFICIENT
460
IN RESPONSE TO DETERMINING OTHER HEATING SCHEDULE IS MORE EFFICIENT, IMPLEMENT OTHER HEATING SCHEDULE
462
END

FIG. 4

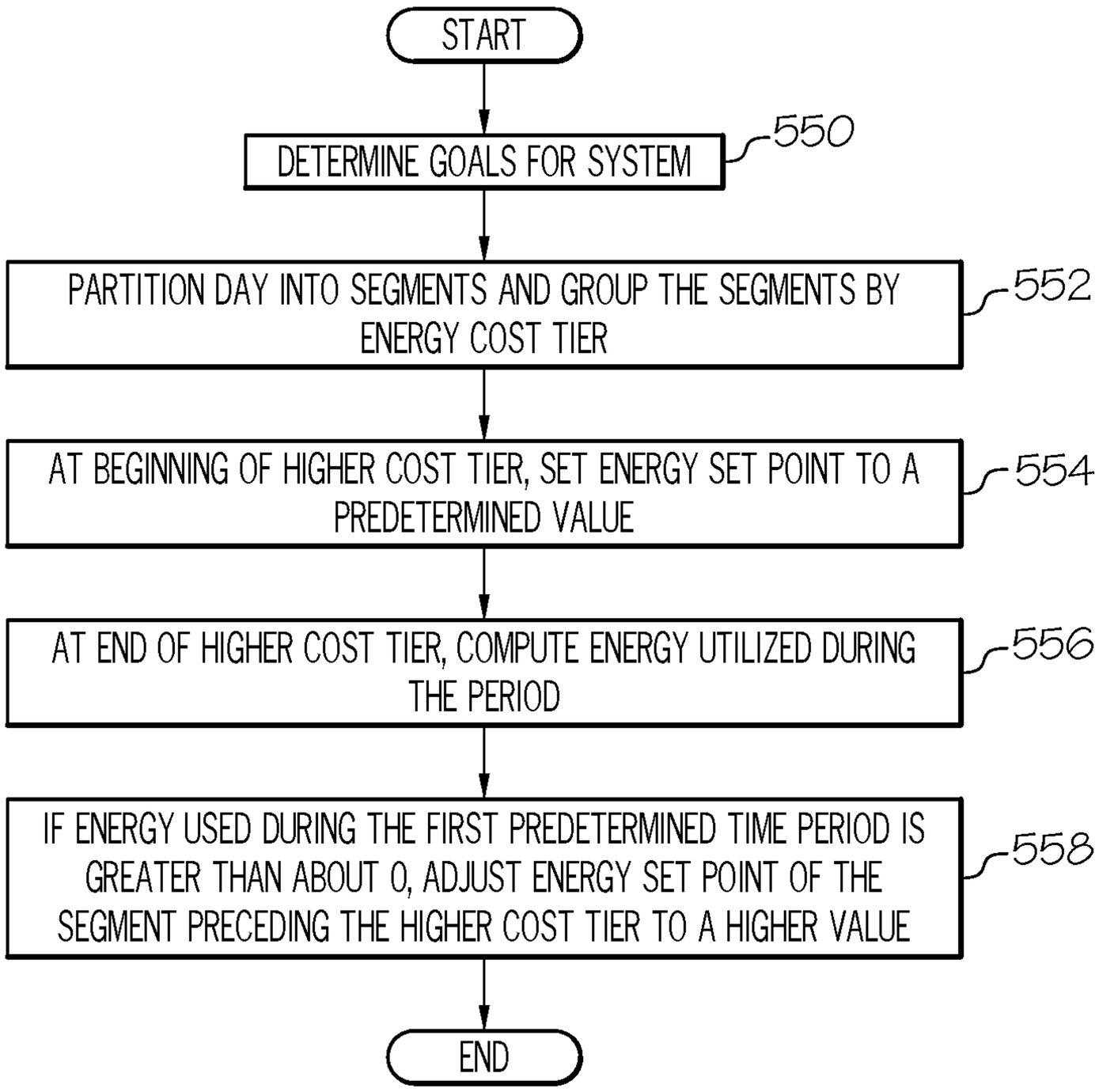

START
DETERMINE GOALS FOR SYSTEM
550
PARTITION DAY INTO SEGMENTS AND GROUP THE SEGMENTS BY ENERGY COST TIER
552
AT BEGINNING OF HIGHER COST TIER, SET ENERGY SET POINT TO A PREDETERMINED VALUE
554
AT END OF HIGHER COST TIER, COMPUTE ENERGY UTILIZED DURING THE PERIOD
556
IF ENERGY USED DURING THE FIRST PREDETERMINED TIME PERIOD IS GREATER THAN ABOUT 0, ADJUST ENERGY SET POINT OF THE SEGMENT PRECEDING THE HIGHER COST TIER TO A HIGHER VALUE
558
END

FIG. 5

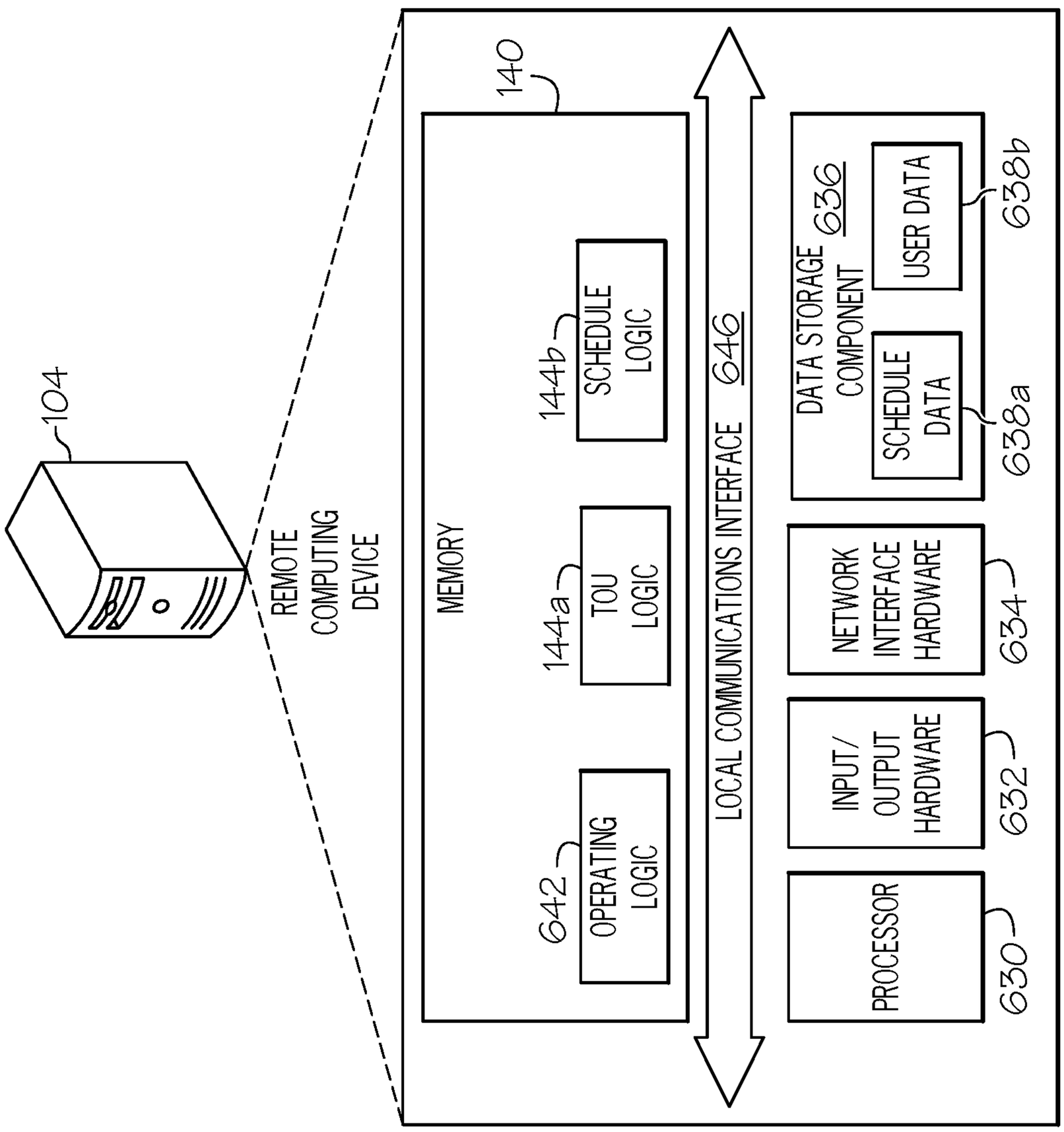

104
REMOTE COMPUTING DEVICE
MEMORY
140
144b
SCHEDULE LOGIC
144a
TOU LOGIC
642
OPERATING LOGIC
LOCAL COMMUNICATIONS INTERFACE 646
DATA STORAGE COMPONENT 636
SCHEDULE DATA
638a
USER DATA
638b
NETWORK INTERFACE HARDWARE
634
INPUT/ OUTPUT HARDWARE
632
PROCESSOR
630

FIG. 6

# SYSTEMS AND METHOD FOR TIME USE OPTIMIZATION

## CROSS REFERENCE

This application claims the benefit of U.S. Provisional Ser. No. 62/427,554, filed Nov. 29, 2016, which is incorporated herein by reference in its entirety.

## TECHNICAL FIELD

Embodiments described herein generally relate to systems and methods for time use optimization and, more specifically, to systems and methods for optimizing use of a water heater or other controllable device.

## BACKGROUND

Household devices, commercial devices, and other controllable devices may store energy, such as thermal energy, electrical energy, potential energy, etc. As an example, water heaters and heating ventilation, air conditioning (HVAC) systems may store thermal energy. Batteries and capacitors may store electrical energy. Additionally, many energy companies now offer price structures such that incentivize an energy user to consume energy at predetermined periods during a day. As such, those devices that operate consistently throughout the day may not operate as financially efficiently as possible.

As an example, a water heater typically stores energy in the form of hot water for usage at a later time. Because water heaters are often well insulated, it often does not matter when the water is heated, so long as there is sufficient hot water when the user needs to use the water. As a result, oftentimes the water in a water heater could be heated at any time of day.

## SUMMARY

Systems and methods for time use optimization are provided. One embodiment of a method includes determining time of use pricing data associated with purchase of energy from an energy provider, partitioning a predetermined amount of time into a plurality of segments, where the plurality of segments corresponds with the higher cost tier and the lower cost tier, and creating an energy set point schedule for setting a set point of a controllable device, where the energy set point schedule sets the set point of the controllable device to a predetermined value for each of the plurality of segments. Some embodiments include determining energy utilized by the controllable device during at least a portion of the energy set point schedule and iteratively altering the energy set point schedule, based on a comparison of the actual energy usage and a current status of the energy set point schedule.

Embodiments of a system include a controllable device that includes an energy storage component for storing energy and an energy distribution component for distributing the energy to an environment, where the energy is purchased from an energy provider. The system may also include a computing device that includes a processor and a memory component. The memory component may store logic that, when executed by the processor, causes the system to receive time of use pricing data associated with purchase of the energy from the energy provider, where the time of use pricing data includes a higher cost tier associated with a higher cost for the energy during a first predetermined time period and a lower cost tier associated with a lower cost for the energy during a second predetermined time period. The logic may further cause the system to determine a desired energy output for the controllable device and create an energy set point schedule that controls a setting of the controllable device, such that the energy set point schedule causes the computing device to adjust the setting of the controllable device at predetermined segments to maintain a desired energy set point for the controllable device, while factoring the time of use pricing data. The logic may further cause the system to collect data regarding an actual demand for the energy, where the data regarding the actual demand includes an amount of energy actually used, a time of actual use, and a cost of the energy actually used, based on the time of use pricing data and iteratively alter the energy set point schedule based on the data regarding the actual demand for the energy.

Embodiments of a non-transitory computer-readable medium are also provided. Some embodiments include logic that, when executed by a computing device causes the computing device to determine time of use pricing data associated with purchase of energy from an energy provider, where the time of use pricing data includes a higher cost tier associated with a higher cost for the energy during a first predetermined time period and a lower cost tier associated with a lower cost for the energy during a second predetermined time period. The logic may further cause the computing device to partition a predetermined amount of time into a plurality of segments, where the plurality of segments corresponds with the higher cost tier and the lower cost tier and create an energy set point schedule for setting a set point of a controllable device, where the energy set point schedule sets the set point of the controllable device to a predetermined value for each of the plurality of segments. In some embodiments, the logic causes the computing device to, after conclusion of the first predetermined time period, compute energy utilized by the controllable device during a segment associated with the higher cost tier and, in response to a determination that energy used during the first predetermined time period is greater than about zero, adjust an energy set point of a segment that precedes the higher cost tier to a higher value.



## BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments set forth in the drawings are illustrative and exemplary in nature and not intended to limit the disclosure. The following detailed description of the illustrative embodiments can be understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

FIG. **1** depicts a computing environment for time of use optimization, according to embodiments described herein;

FIG. **2** depicts a time of use schedule that may be implemented by a utility, according to embodiments described herein;

FIG. **3** depicts a user heating schedule, according to embodiments described herein;

FIG. **4** depicts a flowchart for time of use optimization, according to embodiments described herein;

FIG. **5** depicts another flowchart for time of use optimization, according to embodiments described herein; and

FIG. **6** depicts a remote computing device for time use optimization, according to embodiments described herein.

## DETAILED DESCRIPTION

Embodiments disclosed herein include systems and methods for time of use optimization. As an example, water

heaters typically include a large tank of water, a heater element, and a control system for regulating the temperature of water in the tank. Some water heaters use electric resistance elements and some also use a heat pump to heat the water. The temperature in the tank decreases in response to two stimuli: conductive losses between the hot water and the outside air and the mixing of incoming cooler water after removal of hot water by the user. The control system attempts to keep the temperature in the tank close to a target (or set point) temperature. Embodiments of other controllable devices are also described herein.

A time of use (TOU) electricity rate is a pricing structure for electricity that changes based on the time of day and day of the week. Typically, the price of energy ($/kilowatt-hour) would be less expensive at night and more expensive during the work-day.

The typical user keeps a fairly predictable schedule, and this predictability can be leveraged to reduce the cost of heating water with time of use rates. Embodiments described herein include an iterative learning algorithm for adjusting the water temperature set point. The learning algorithm may be configured to learn a 7-day set point schedule (or other schedule) to minimize the cost of heating water.

Accordingly, some embodiments may be configured to propose at least one goal and/or objective of the water heater performance (e.g. keep temperature above 100 degrees Fahrenheit and minimize cost). Additionally, embodiments may be configured to partition the day into segments and group segments (periods) by the utility cost. At the start of a high-price period, the set point may be set to a lower threshold temperature. At the end of the high-price period, the electrical energy used during the period may be computed. If energy used is greater 0, the set point temperature of the segment preceding the high-priced period may be adjusted to a higher value. If energy used equals 0, the segment preceding the high-priced period may be adjusted to a lower temperature. In some embodiments, this may be iteratively adjusted until cost and comfort are optimized. The systems and methods for time use optimization incorporating the same will be described in more detail, below.

Additionally, other embodiments of controllable devices may utilize similar processes to utilize time of use incentives advantageously. As an example, an electric battery may be configured to pull electrical energy from a utility, based on a balance of cost and anticipated demand. Determinations may also be made regarding wither the capacity of the controllable device is sufficient to fully optimize the time of use price structure and energy demand. If not, embodiments may provide a recommendations for upgrade.

Referring now to the drawings, FIG. **1** depicts a computing environment for time of use optimization, according to embodiments described herein. As illustrated, a network **100** may facilitate communication between of energy from a utility **106** and/or data among a controllable device **102**, a remote computing device **104**, and a utility **106**. As such, the network **100** may include an electricity network to provide electrical power to homes and businesses, a gas line network to provide natural gas to homes and businesses, a wide area network, such as the internet, a local network, etc. Additionally, the controllable device **102** is depicted as a tank water heater, but may include any device that is subject to time of use scheduling and is controllable according to a predetermined schedule, such as a battery, a home ventilation air condition (HVAC) system, and/or other device.

As illustrated, the controllable device **102** may include a tank **108** (or cell, depending on the embodiment), a local computing device **110**, and a heating element **112**. The tank **108** may be configured for receiving water for heating. The heating element **112** may be configured for electrical and/or gas heating, depending on the embodiment, and may include a thermometer and/or thermostat to measure and regulate the temperature of the water. The local computing device **110** may be configured to receive and/or determine a schedule for time of use, user schedule and/or heating, and communicate with the thermostat to regulate the temperature, as described herein.

The remote computing device **104** may be coupled to the utility **106** and/or the controllable device **102** and may include a memory component **140** that stores time of use logic **144***a* and schedule logic **144***b*. The time of use logic **144***a* may be configured to cause the remote computing device **104** to receive and/or determine a time of use schedule that is implemented by the utility **106**. The time of use logic **144***a* may additionally cause the remote computing device **104** to determine a user schedule associated with the controllable device **102**. The schedule logic **144***b* may cause the remote computing device **104** to determine a schedule for activating the heating element **112** to maximize efficiency and reduce cost, while still maintaining a user-defined level of service by the controllable device **102**.

It should be understood that while the remote computing device **104**, the time of use logic **144***a*, and the schedule logic **144***b* are depicted as being remote from the controllable device **102**, this is merely an example. Some embodiments are configured such that at least a portion of this functionality is provided by the local computing device **110**.

FIG. **2** depicts a time of use schedule that may be implemented by a utility **106**, according to embodiments described herein. As illustrated, a time of use schedule may be communicated to the remote computing device **104** by the utility **106**.

FIG. **3** depicts a user heating schedule, according to embodiments described herein. Depending on the particular embodiment, the remote computing device **104** and/or the local computing device **110** may monitor usage of the controllable device **102** to determine the schedule in FIG. **3**. In some embodiments, the remote computing device **104** may provide a user interface for the user to specifically input a desired schedule and/or edit an existing schedule. Regardless, based on the information in the user heating schedule and the time of use schedule of FIG. **2**, a calculation may be performed to determine when the heating element **112** should be active to heat the water, such that the controllable device **102** can provide water at a predetermined temperature at the determined user heating schedule. As such, some embodiments of the remote computing device **104** may provide the user with a user interface to specify a desired temperature during times of usage. Depending on the embodiment, this option may be provided on the controllable device **102**. The remote computing device **104** may also monitor the water temperature to determine a rate of temperature drop in the controllable device **102**.

As an example, if the user specifies that the desired water temperature from the controllable device **102** should be 100 degrees Fahrenheit, the remote computing device **104** may determine how long the heating element **112** should heat the water to achieve the set point temperature during the times of high usage. Additionally, the remote computing device **104** may also consider the time of usage schedule to select the most cost effective heating schedule to achieve both the set point and the cost efficiency.

FIG. **4** depicts a flowchart for time of use optimization, according to embodiments described herein. As illustrated in

block **450**, a time of use schedule may be determined. In block **452**, a user heating schedule may be determined. In block **454**, a cooling rate of the water may be determined. In block **456**, the time of use schedule, the user heating schedule, and the cooling rate may be utilized to determine a heating schedule that meets a predetermined set point, as well as meets the desired cost efficiency. In block **458**, the heating schedule may be implemented. In block **460**, the current cost may be determined, as well as whether another heating schedule can achieve the same level of service, with a lower cost. In block **462**, in response to determining that the other heating schedule is more efficient, the other heating schedule may be implemented.

FIG. **5** depicts another flowchart for time of use optimization, according to embodiments described herein. As illustrated in block **550**, goals for the system may be determined. Depending on the embodiment, the goal is utilized to determine a characteristic of the energy set point schedule. In block **552**, a day may be partitioned into segments and the segments may be grouped by energy cost tier. In block **554**, at the beginning of a higher cost tier, the energy set point may be set to a first predetermined value. In block **556**, at the end of the higher cost tier, energy utilized during the period may be computed. As will be understood, reference to energy being utilized may include external energy added to the system, energy removed from the system from basic losses, energy removed from the system by usage, e.g. people using hot water, a difference in energy from the desired setting and the current setting at the end of the time period. In a water heater example, this could be the difference in temperature from the set point and the current temperature. This may represent excess or deficient system energy.

In block **558**, if the energy used during the first predetermined time period is greater than about 0, the energy set point of the segment preceding the higher cost tier ay be adjusted to a higher value. Additionally, in response to a determination that energy used during the first predetermined time period is greater than about zero, the energy set point schedule may be altered at the first predetermined time period to a lower value. In response to a determination that energy used during the first predetermined time period is less than about zero, the energy set point of a segment that precedes the higher cost tier may be adjusted to a lower value.

Depending on the particular embodiment, the energy set point schedule may be altered based on the following: $T_i(k+1)=T_i(k)-\rho\gamma E_i(k)$; $T_{i-1}(k+1)=T_{i-1}(k)+\varepsilon\gamma E_i(k)$ when $P_{i-1}<P_i$; $T_i(k+1)=T_i(k)$; $T_{i-1}(k+1)=T_{i-1}(k)$ when $P_{i-1}>=P_i$; where k is a current iteration, $T_1$ is a scheduled state variable at a time segment i, $E_1$ is a change in energy over the time segment i, $\rho>0$ and $\varepsilon>0$ are learning constants, and $\gamma$ is a conversion from energy to state variable. Other formulations for determining the energy set point schedule may also be utilized.

FIG. **6** depicts a remote computing device **104** for time use optimization, according to embodiments described herein. As illustrated, the remote computing device **104** includes a processor **630**, input/output hardware **632**, the network interface hardware **634**, a data storage component **636** (which stores schedule data **638***a*, user data **638***b*, and/or other data), and the memory component **140**. The memory component **140** may be configured as volatile and/or non-volatile memory and as such, may include random access memory (including SRAM, DRAM, and/or other types of RAM), flash memory, secure digital (SD) memory, registers, compact discs (CD), digital versatile discs (DVD), and/or other types of non-transitory computer-readable mediums. Depending on the particular embodiment, these non-transitory computer-readable mediums may reside within the remote computing device **104** and/or external to the remote computing device **104**.

The memory component **140** may store operating logic **642**, the time of use logic **144***a*, and the schedule logic **144***b*. The time of use logic **144***a* and the schedule logic **144***b* may each include a plurality of different pieces of logic, each of which may be embodied as a computer program, firmware, and/or hardware, as an example. A local interface **646** is also included in FIG. **6** and may be implemented as a bus or other communication interface to facilitate communication among the components of the remote computing device **104**.

The processor **630** may include any processing component operable to receive and execute instructions (such as from a data storage component **636** and/or the memory component **140**). The input/output hardware **632** may include and/or be configured to interface with microphones, speakers, a display, and/or other hardware.

The network interface hardware **634** may include and/or be configured for communicating with any wired or wireless networking hardware, including an antenna, a modem, LAN port, wireless fidelity (Wi-Fi) card, WiMax card, ZigBee card, Bluetooth chip, USB card, mobile communications hardware, and/or other hardware for communicating with other networks and/or devices. From this connection, communication may be facilitated between the remote computing device **104** and other computing devices, such as the controllable device **102**.

The operating logic **642** may include an operating system and/or other software for managing components of the remote computing device **104**. As also discussed above, time of use logic **144***a* and the schedule logic **144***b* may reside in the memory component **140** and may be configured to perform the functionality, as described herein.

It should be understood that while the components in FIG. **6** are illustrated as residing within the remote computing device **104**, this is merely an example. In some embodiments, one or more of the components may reside external to the remote computing device **104**. It should also be understood that, while the remote computing device **104** is illustrated as a single device, this is also merely an example. In some embodiments, the time of use logic **144***a* and the schedule logic **144***b* may reside on different computing devices. As an example, one or more of the functionalities and/or components described herein may be provided by a remote computing device **104** and/or local computing device **110**, which may be coupled to the remote computing device **104** via the network **100**.

Additionally, while the remote computing device **104** is illustrated with the time of use logic **144***a* and the schedule logic **144***b* as separate logical components, this is also an example. In some embodiments, a single piece of logic (and/or or several linked modules) may cause the remote computing device **104** to provide the described functionality.

As illustrated above, various embodiments time of use optimization are disclosed. These embodiments may cause the user to experience consistent performance of a controllable device at a lower cost, based on time of use scheduling.

While particular embodiments and aspects of the present disclosure have been illustrated and described herein, various other changes and modifications can be made without departing from the spirit and scope of the disclosure. Moreover, although various aspects have been described herein, such aspects need not be utilized in combination. Accordingly, it is therefore intended that the appended claims cover

all such changes and modifications that are within the scope of the embodiments shown and described herein.

It should now be understood that embodiments disclosed herein includes systems, methods, and non-transitory computer-readable mediums for time of use optimization. It should also be understood that these embodiments are merely exemplary and are not intended to limit the scope of this disclosure.

What is claimed is:

**1**. A method for time of use optimization comprising:

determining time of use pricing data associated with purchase of energy from an energy provider, wherein the time of use pricing data includes a higher cost tier associated with a higher cost for the energy during a first predetermined time period and a lower cost tier associated with a lower cost for the energy during a second predetermined time period;

partitioning a predetermined amount of time into a plurality of segments, wherein the plurality of segments corresponds with the higher cost tier and the lower cost tier;

creating an energy set point schedule for setting a set point of a controllable device, wherein the energy set point schedule sets the set point of the controllable device to a predetermined value for each of the plurality of segments while maintaining operation and control of the controllable device through all of the set point schedule, wherein the energy set point schedule is altered based on the following:

$$T_i(k+1)=T_i(k)-\rho\gamma E_i(k);T_{i-1}(k+1)=T_{i-1}(k)+\varepsilon\gamma E_i(k) \text{ when } P_{i-1}<P_i$$

$$T_i(k+1)=T_i(k);T_{i-1}(k+1)=T_{i-1}(k) \text{ when } P_{i-1}>=P_i$$

wherein k is a current iteration, $T_i$ is a scheduled state variable at a time segment i, $E_i$ is a change in energy over a time segment i, $\rho>0$ and $\varepsilon>0$ are learning constants, $P_i$ is the price of energy at time segment i, and $\gamma$ is a conversion from energy to state variable, and wherein k is a current iteration, $T_i$ is a scheduled state variable at a time segment i, $E_i$ is a change in energy over a time segment i, $\rho>0$ and $\varepsilon>0$ are learning constants, $P_i$ is the price of energy at time segment i, and $\gamma$ is a conversion from energy to state variable;

determining whether energy utilized by the controllable device during the higher cost tier is greater than about zero; and

iteratively altering an energy set point temperature of a segment that precedes the higher cost tier to a higher value.

**2**. The method of claim **1**, wherein the controllable device includes at least one of the following: a water heater, a home ventilation and air condition (HVAC) system, or a battery.

**3**. The method of claim **1**, further comprising altering the energy set point schedule to maintain a desired energy output while minimizing cost incurred for the energy.

**4**. The method of claim **1**, wherein the energy set point schedule includes segments for each day of a week.

**5**. The method of claim **1**, further comprising receiving a goal for the energy set point schedule, wherein the goal is utilized to determine a characteristic of the energy set point schedule.

**6**. A system for time of use optimization comprising:

a controllable device that includes an energy storage component for storing energy and an energy distribution component for distributing the energy to an environment, wherein the energy is purchased from an energy provider; and

a computing device that includes a processor and a memory component, wherein the memory component stores logic that, when executed by the processor, causes the system to perform at least the following:

receive time of use pricing data associated with purchase of the energy from the energy provider, wherein the time of use pricing data includes a higher cost tier associated with a higher cost for the energy during a first predetermined time period and a lower cost tier associated with a lower cost for the energy during a second predetermined time period;

determine a desired energy output for the controllable device;

create an energy set point schedule that controls a setting of the controllable device, such that the energy set point schedule causes the computing device to adjust the setting of the controllable device at predetermined segments to maintain a desired energy set point for the controllable device, while maintaining operation and control of the controllable device through all of the set point schedule, and while factoring the time of use pricing data, wherein the energy set point schedule is altered based on the following:

$$T_i(k+1)=T_i(k)-\rho\gamma E_i(k);T_{i-1}(k+1)=T_{i-1}(k)+\varepsilon\gamma E_i(k) \text{ when } P_{i-1}<P_i$$

$$T_i(k+1)=T_i(k);T_{i-1}(k+1)=T_{i-1}(k) \text{ when } P_{i-1}>=P_i$$

wherein k is a current iteration, $T_i$ is a scheduled state variable at a time segment i, $E_i$ is a change in energy over a time segment i, $\rho>0$ and $\varepsilon>0$ are learning constants, $P_i$ is the price of energy at time segment i, and $\gamma$ is a conversion from energy to state variable;

collect data regarding an actual demand for the energy, wherein the data regarding the actual demand includes an amount of energy actually used, a time of actual use, and a cost of the energy actually used, based on the time of use pricing data; and

in response to a determination that energy used during the first predetermined time period is greater than about zero, iteratively alter a temperature of the energy set point schedule based on the data regarding the actual demand for the energy.

**7**. The system of claim **6**, wherein the controllable device includes at least one of the following: a water heater, a home ventilation and air condition (HVAC) system, or a battery.

**8**. The system of claim **6**, wherein the logic further causes the system to alter the energy set point schedule to maintain the desired energy output while minimizing cost incurred for the energy.

**9**. The system of claim **6**, wherein in response to a determination that energy used during the first predetermined time period is greater than about zero, the logic causes the system to alter the energy set point schedule at the first predetermined time period to a lower value.

**10**. The system of claim **6**, wherein in response to a determination that energy used during the first predetermined time period is greater than about zero, the logic causes the system to adjust an energy set point of a segment that precedes the higher cost tier to a higher value.

**11**. The system of claim **6**, wherein in response to a determination that energy used during the first predetermined time period is less than about zero, adjust an energy set point of a segment that precedes the higher cost tier to a lower value.

12. A non-transitory computer-readable medium that stores logic that, when executed by a computing device causes the computing device to perform at least the following:

determine time of use pricing data associated with purchase of energy from an energy provider, wherein the time of use pricing data includes a higher cost tier associated with a higher cost for the energy during a first predetermined time period and a lower cost tier associated with a lower cost for the energy during a second predetermined time period;

partition a predetermined amount of time into a plurality of segments, wherein the plurality of segments corresponds with the higher cost tier and the lower cost tier;

create an energy set point schedule for setting a set point of a controllable device, wherein the energy set point schedule sets the set point of the controllable device to a predetermined value for each of the plurality of segments, while maintaining operation and control of the controllable device through all of the set point schedule, wherein the energy set point schedule is created based on the following:

$$T_i(k+1)=T_i(k)-\rho\gamma E_i(k);T_{i-1}(k+1)=T_{i-1}(k)+\varepsilon\gamma E_i(k) \text{ when } P_{i-1}<P_i$$

$$T_i(k+1)=T_i(k);T_{i-1}(k+1)=T_{i-1}(k) \text{ when } P_{i-1}>=P_i$$

wherein k is a current iteration, $T_i$ is a scheduled state variable at a time segment i, $E_i$ is a change in energy over a time segment i, $\rho>0$ and $\varepsilon>0$ are learning constants, $P_i$ is the price of energy at time segment i, and $\gamma$ is a conversion from energy to state variable;

after conclusion of the first predetermined time period, compute energy utilized by the controllable device during a segment associated with the higher cost tier; and

in response to a determination that energy used during the first predetermined time period is greater than about zero, adjust an energy set point of a segment that precedes the higher cost tier to a higher value.

13. The non-transitory computer-readable medium of claim 12, wherein the controllable device includes at least one of the following: a water heater, a home ventilation and air condition (HVAC) system, or a battery.

14. The non-transitory computer-readable medium of claim 12, wherein the logic causes the computing device to alter the energy set point schedule to maintain a desired energy output while minimizing cost incurred for the energy.

15. The non-transitory computer-readable medium of claim 12, wherein the energy set point schedule includes segments for each day of a week.

16. The non-transitory computer-readable medium of claim 12, wherein the logic further causes the computing device to group the plurality of segments according to the higher cost tier and the lower cost tier.

17. The non-transitory computer-readable medium of claim 12, wherein the energy set point schedule is iteratively adjusted, based on an actual energy usage.

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