



(19) **United States**

(12) **Patent Application Publication**
Bedros et al.

(10) **Pub. No.: US 2011/0046805 A1**

(43) **Pub. Date: Feb. 24, 2011**

(54) **CONTEXT-AWARE SMART HOME ENERGY MANAGER**

Publication Classification

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(51) **Int. Cl.**
G06F 1/32 (2006.01)

(52) **U.S. Cl.** **700/291**

(57) **ABSTRACT**

A context-aware smart home energy management (CASHEM) system and method is disclosed. CASHEM dynamically schedules household energy use to reduce energy consumption by identifying contextual information within said household, selecting a comfort of service preference, wherein said comfort of service preference is based on different said contextual information, and extracting an appliance use schedule for maximum energy savings based on said contextual information in light of said comfort of service preferences, by executing a program instruction in a data processing apparatus. CASHEM correlates said contextual information with energy consumption levels to dynamically schedule said appliance based on an energy-saving condition and a user's comfort. Comfort of service preferences are gathered by CASHEM by monitoring occupant activity levels and use of said appliance. CASHEM can also recommend potential energy savings for a user to modify comfort of service preferences.

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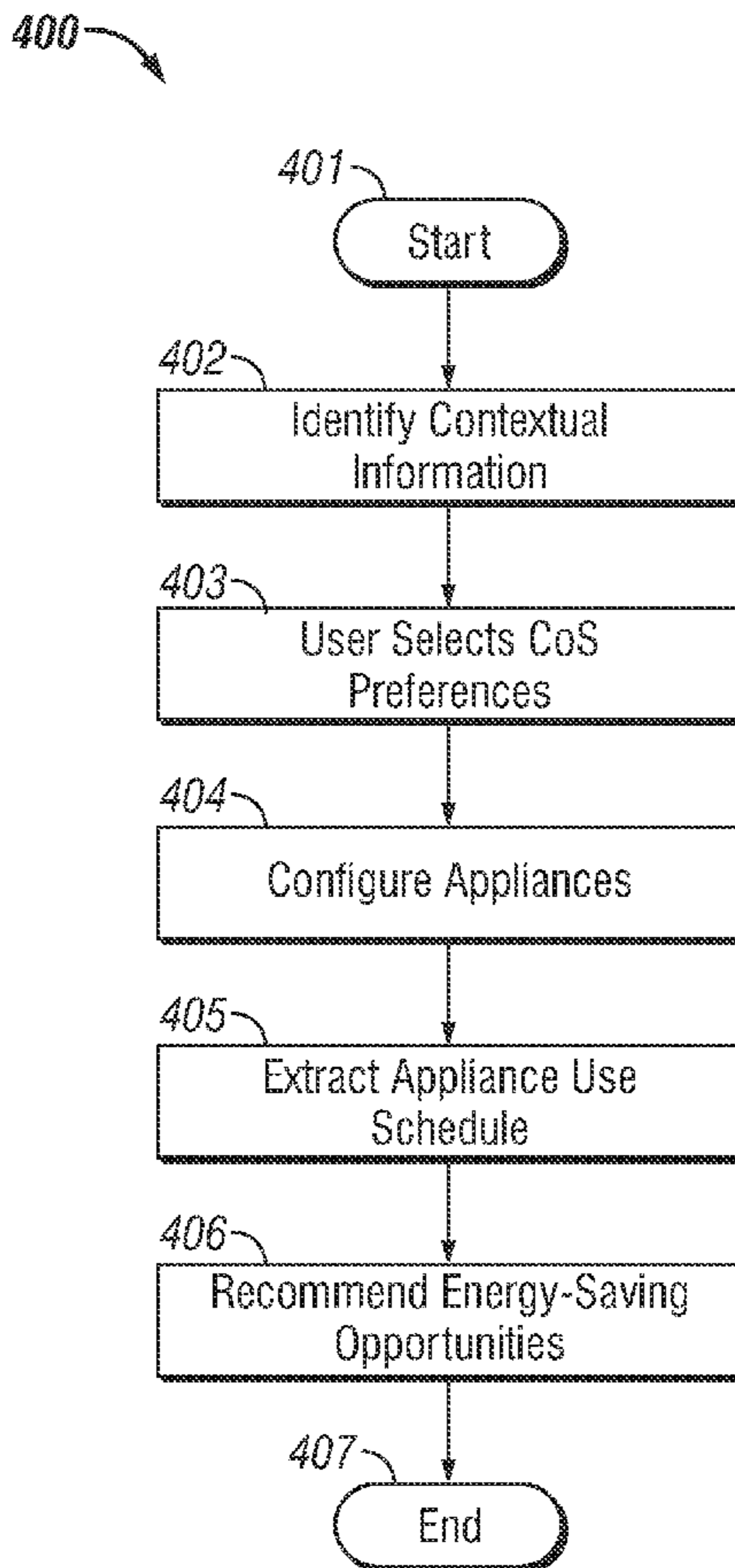
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(21) Appl. No.: **12/852,690**

(22) Filed: **Aug. 9, 2010**

Related U.S. Application Data

(60) Provisional application No. 61/234,947, filed on Aug. 18, 2009.



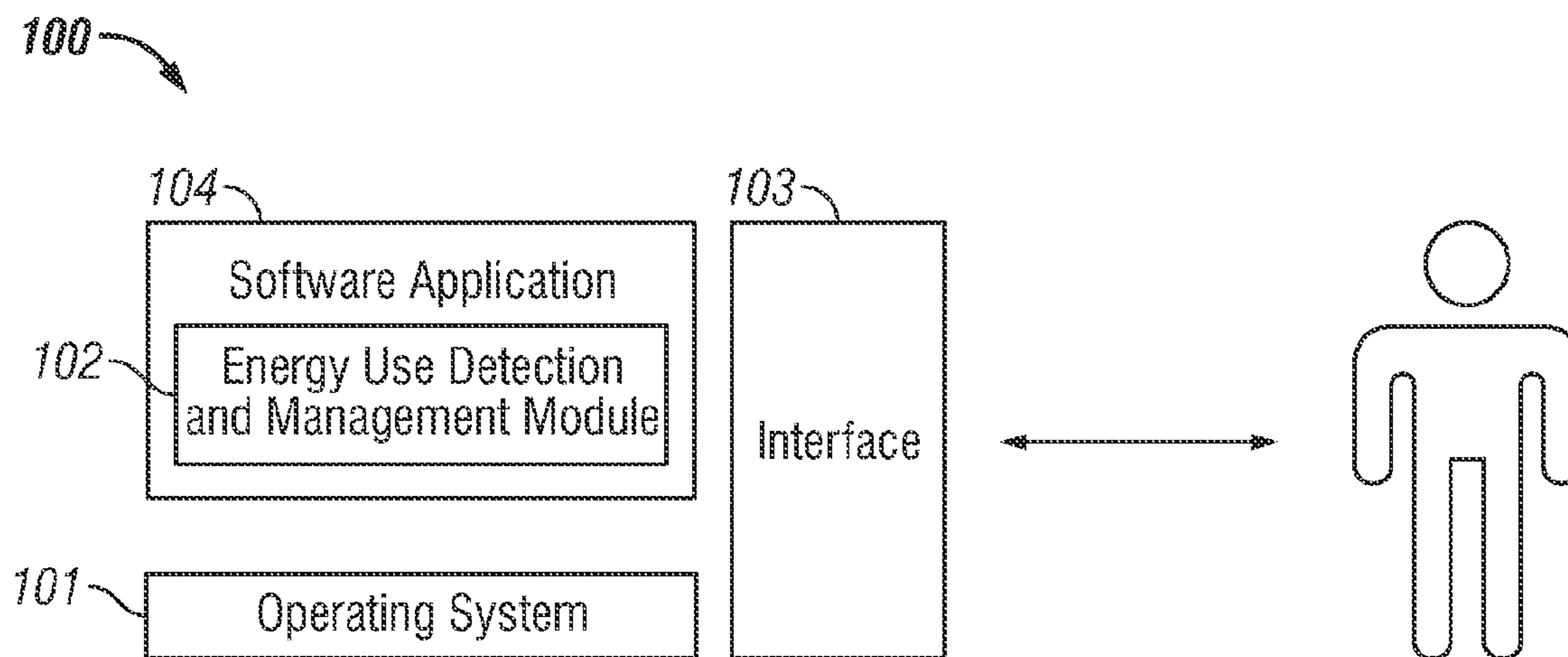


FIG. 1

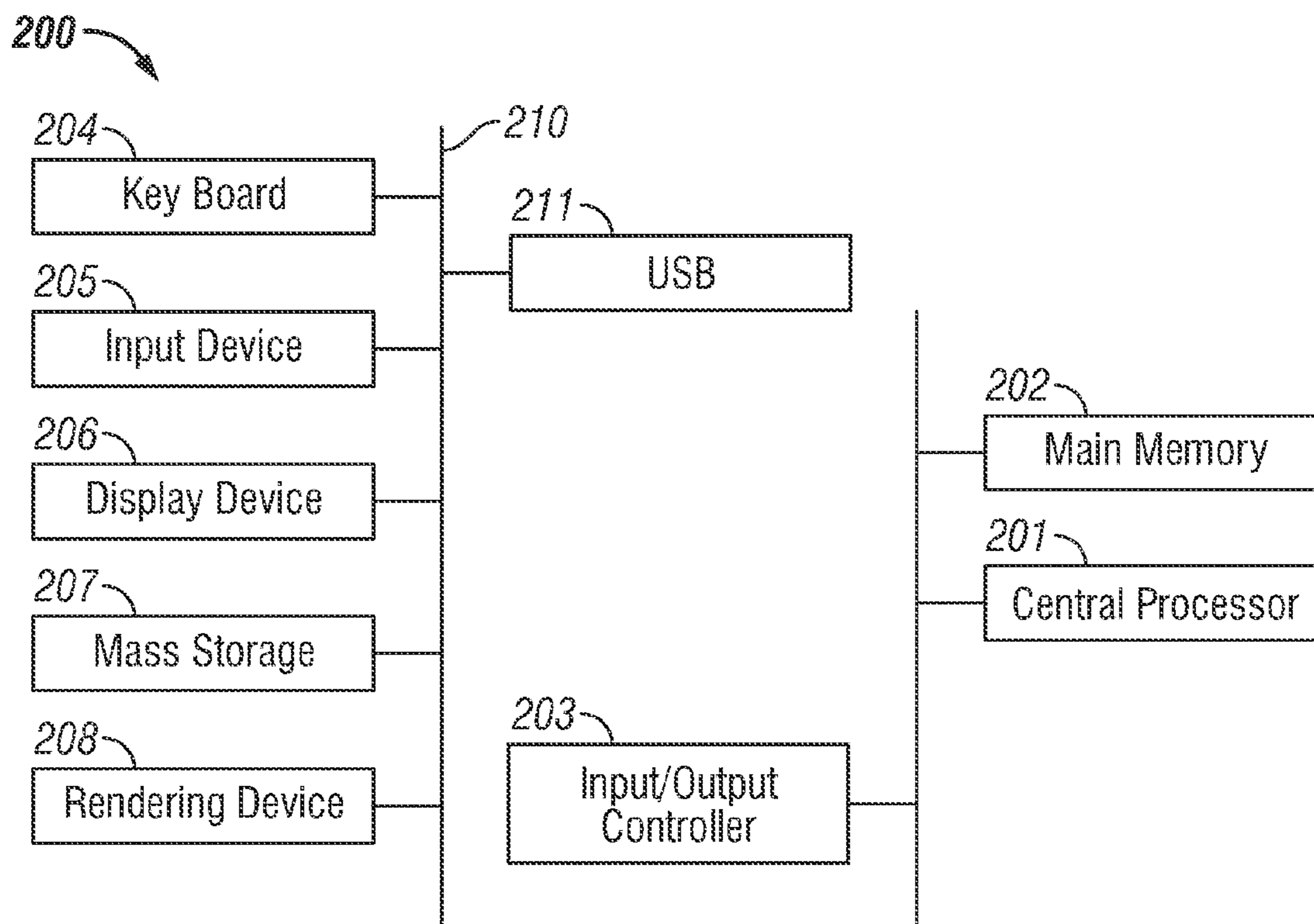


FIG. 2

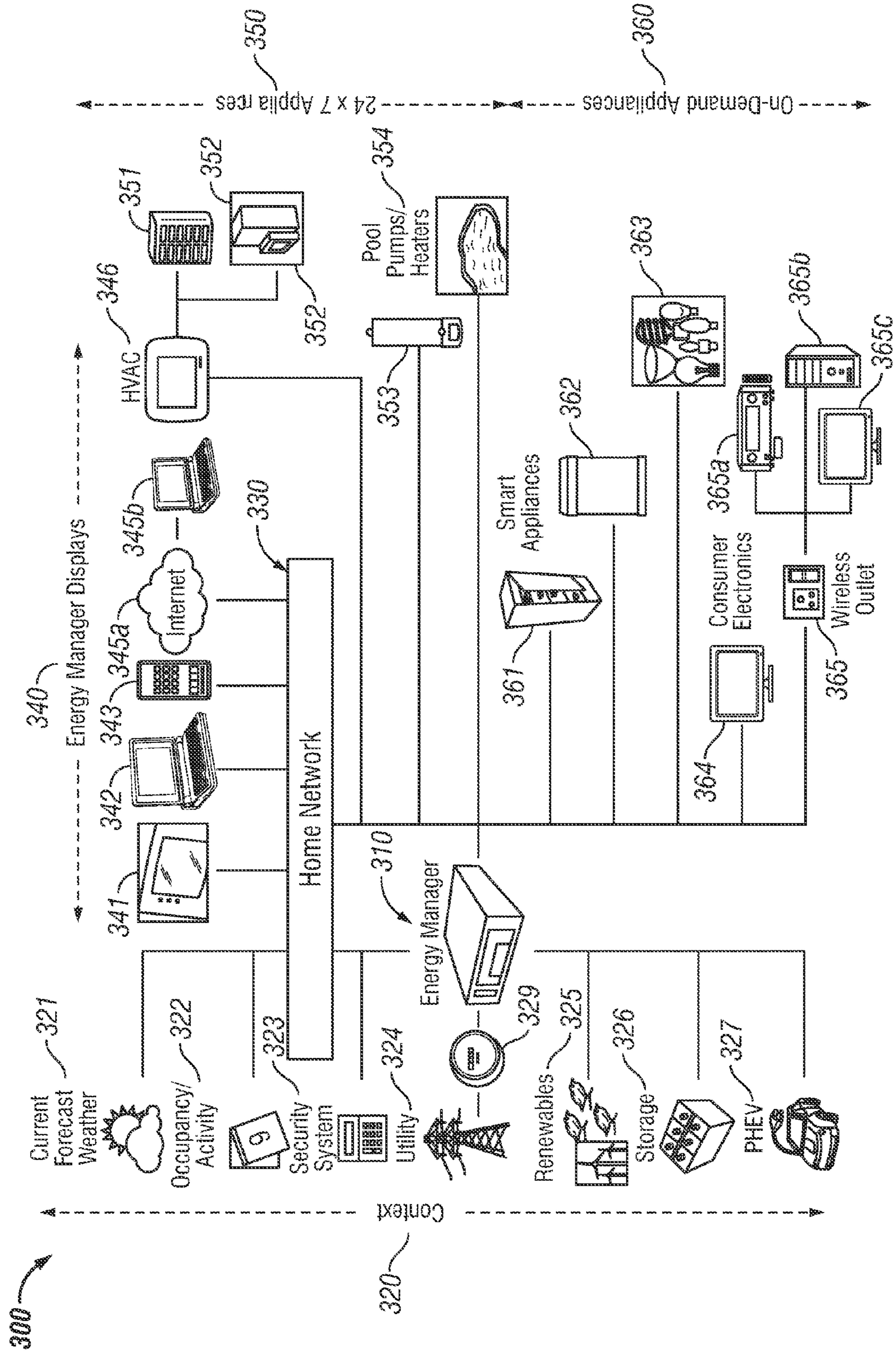


FIG. 3

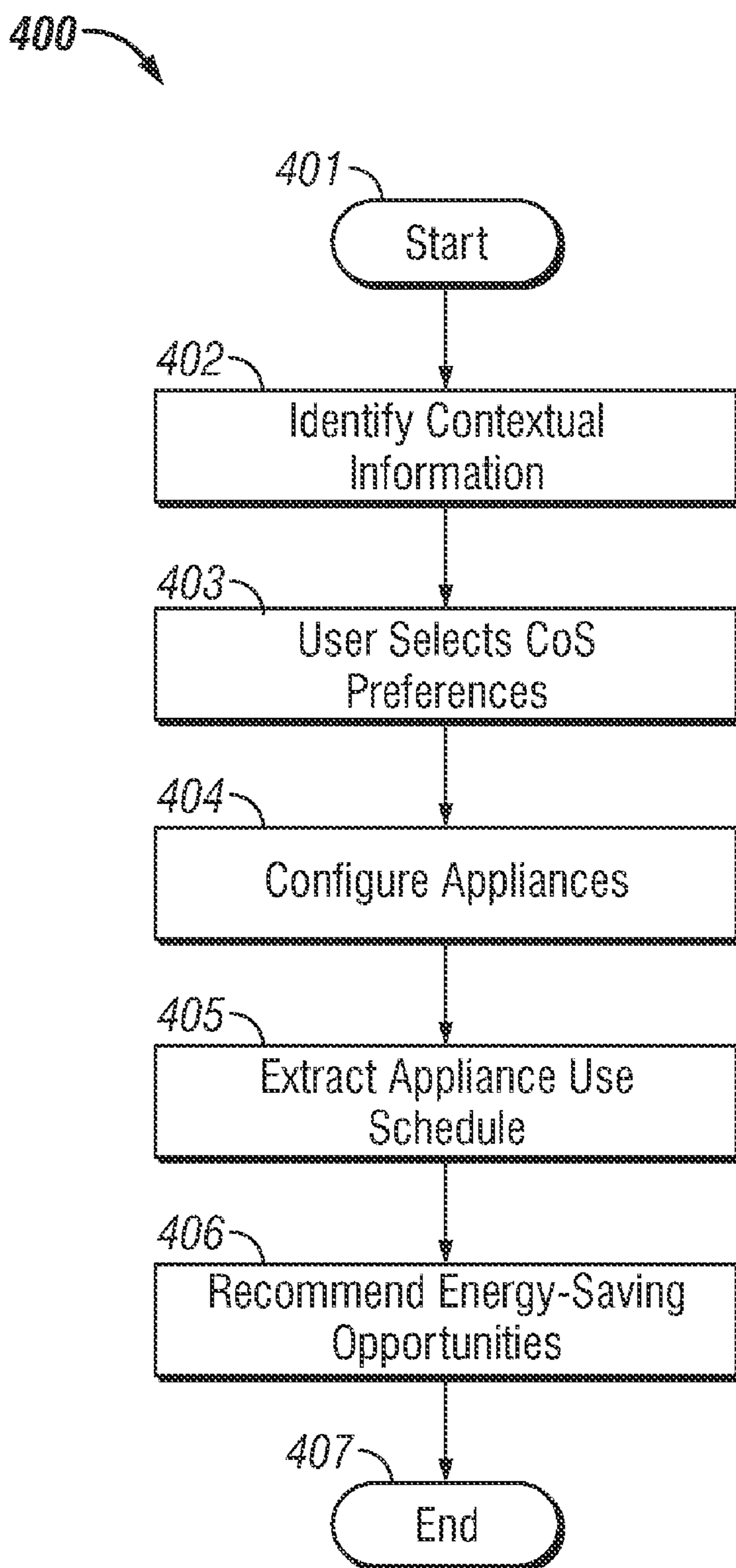


FIG. 4

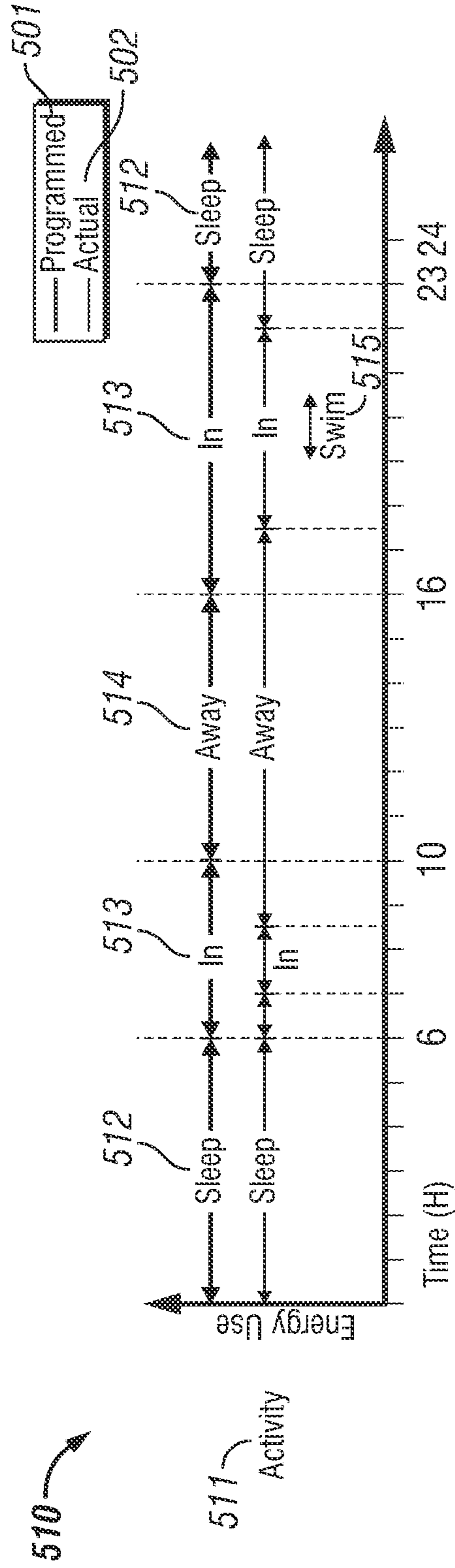


FIG. 5A

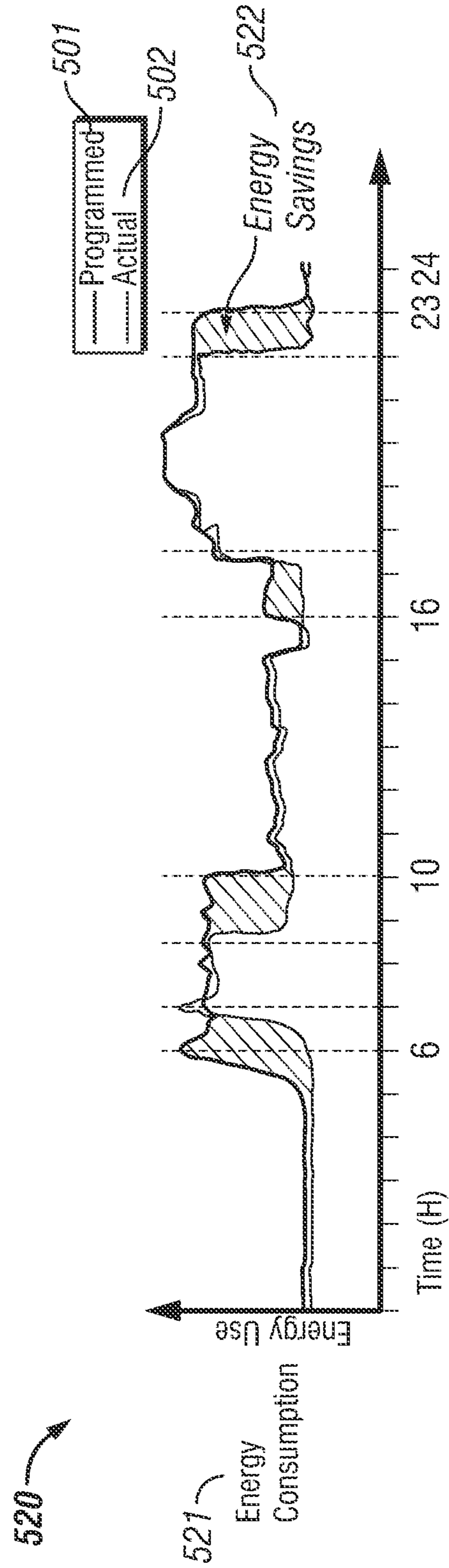


FIG. 5B

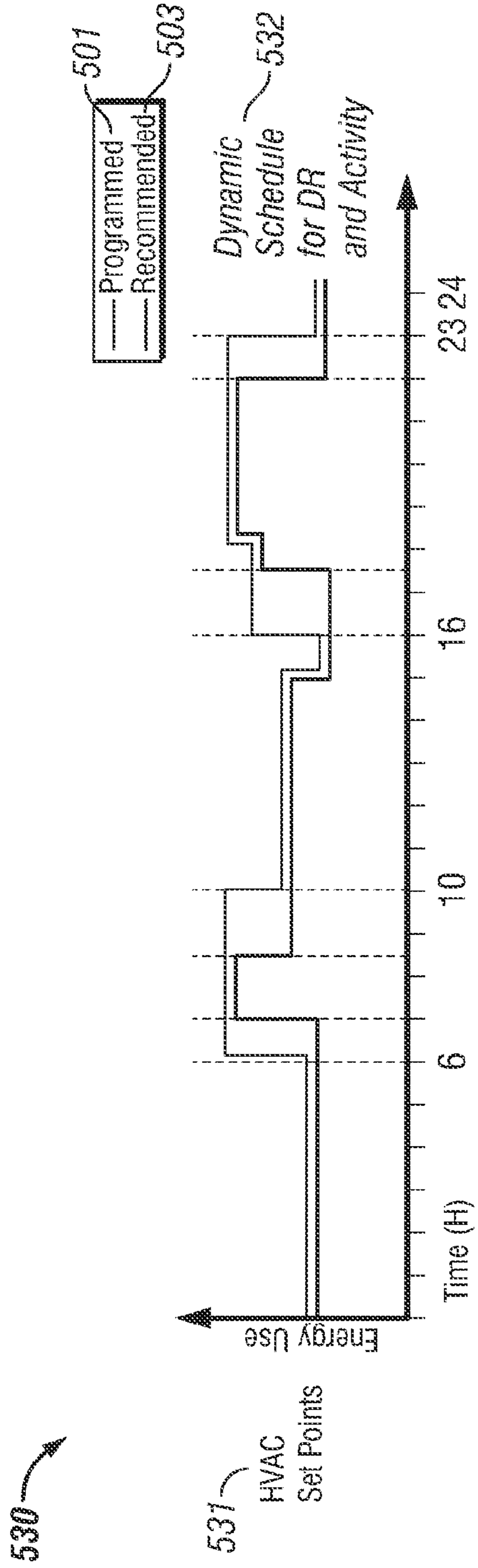


FIG. 5C

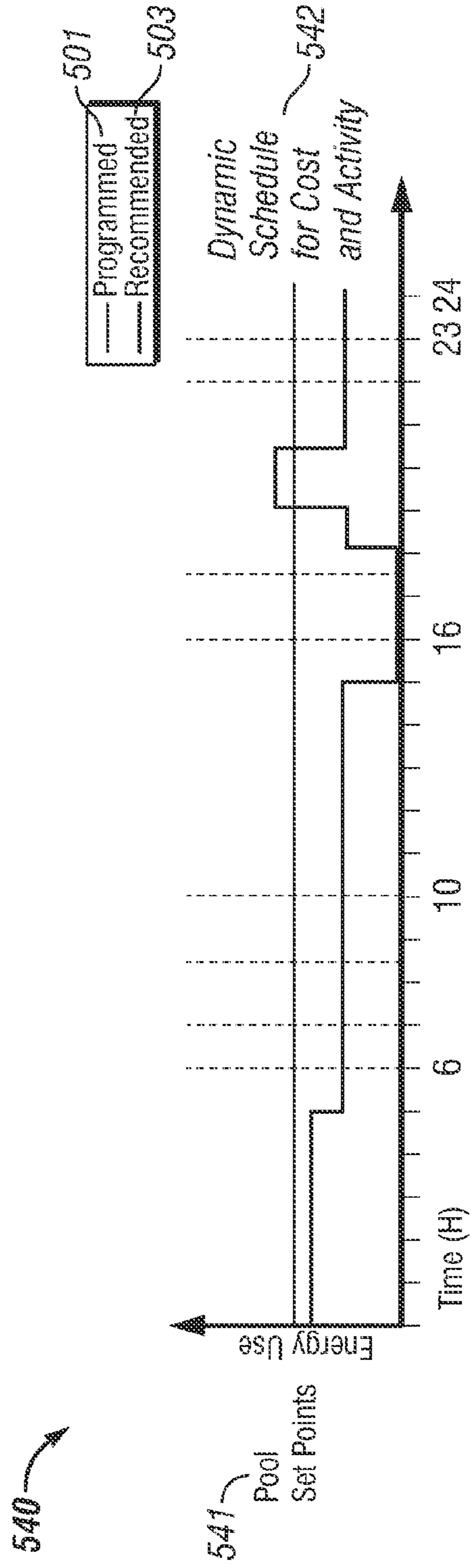


FIG. 5D

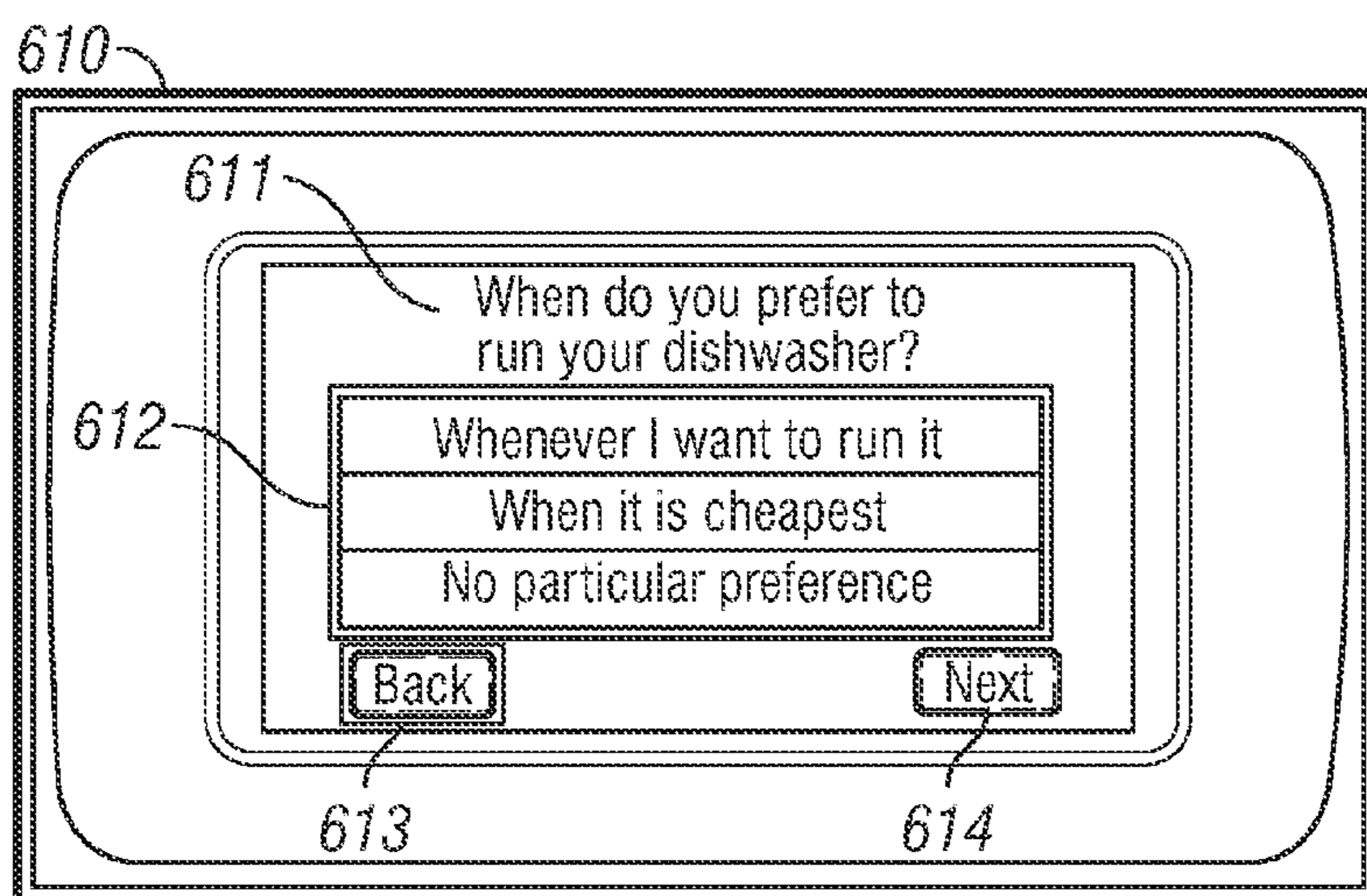


FIG. 6A

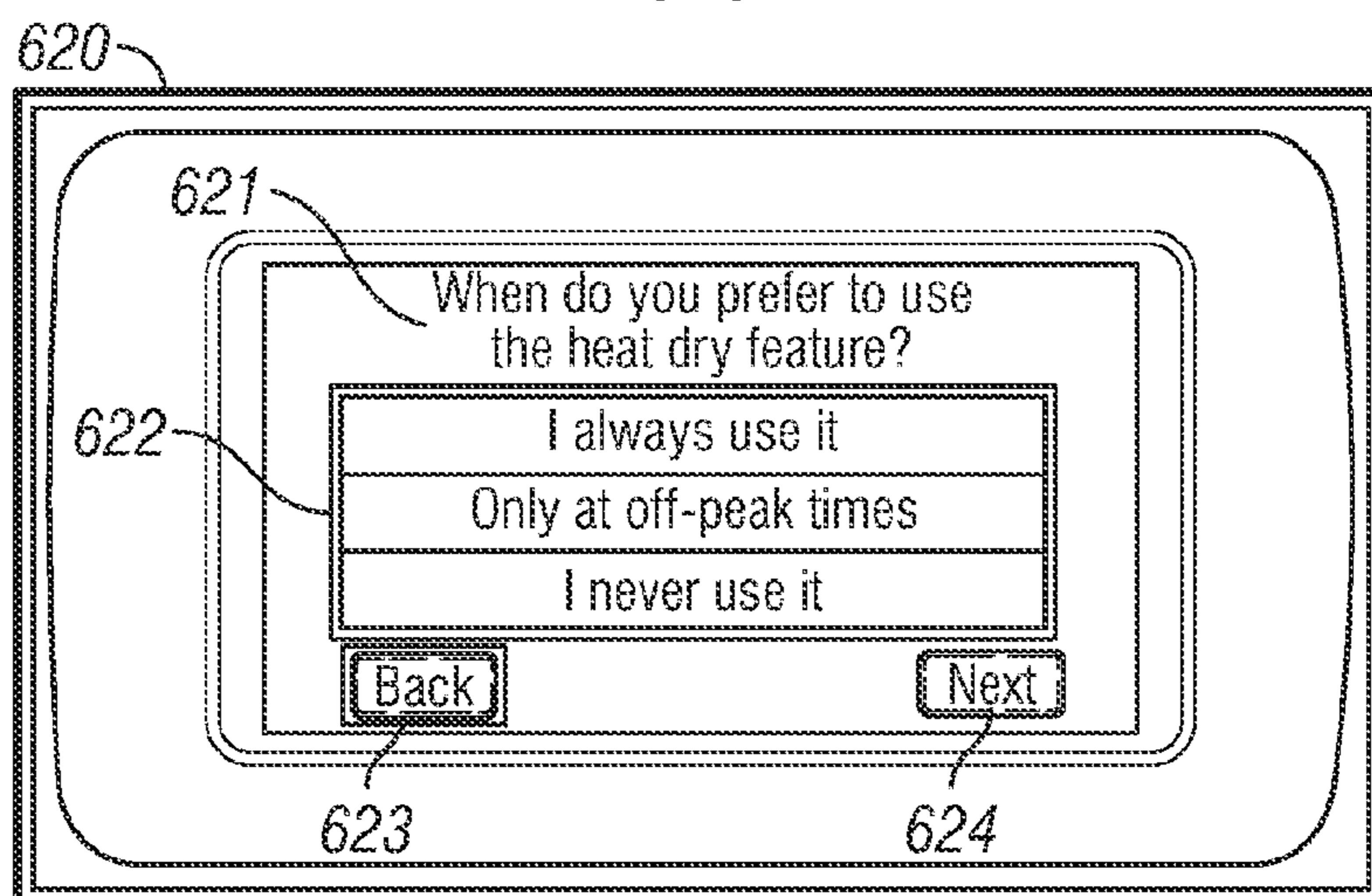


FIG. 6B

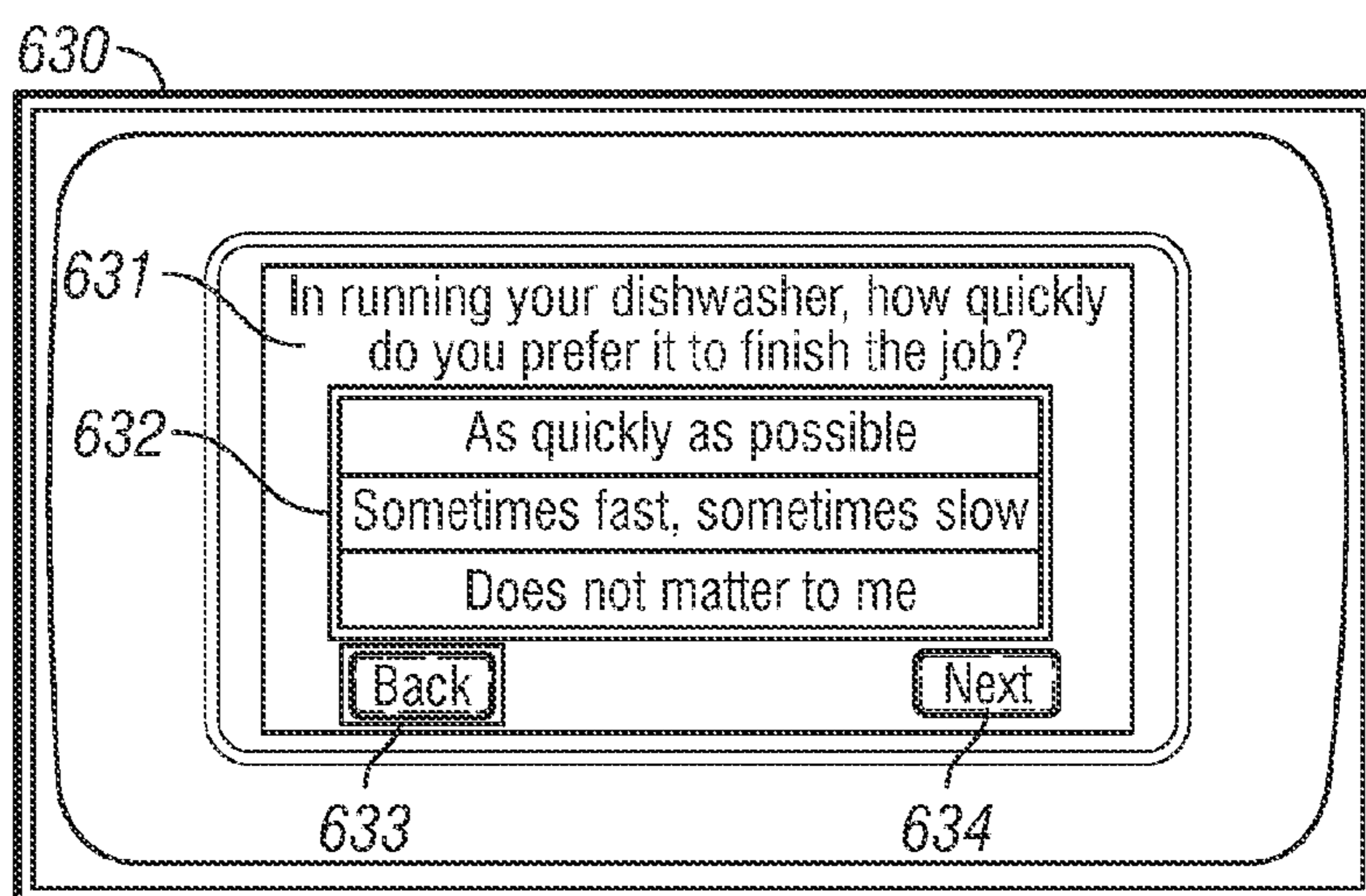


FIG. 6C

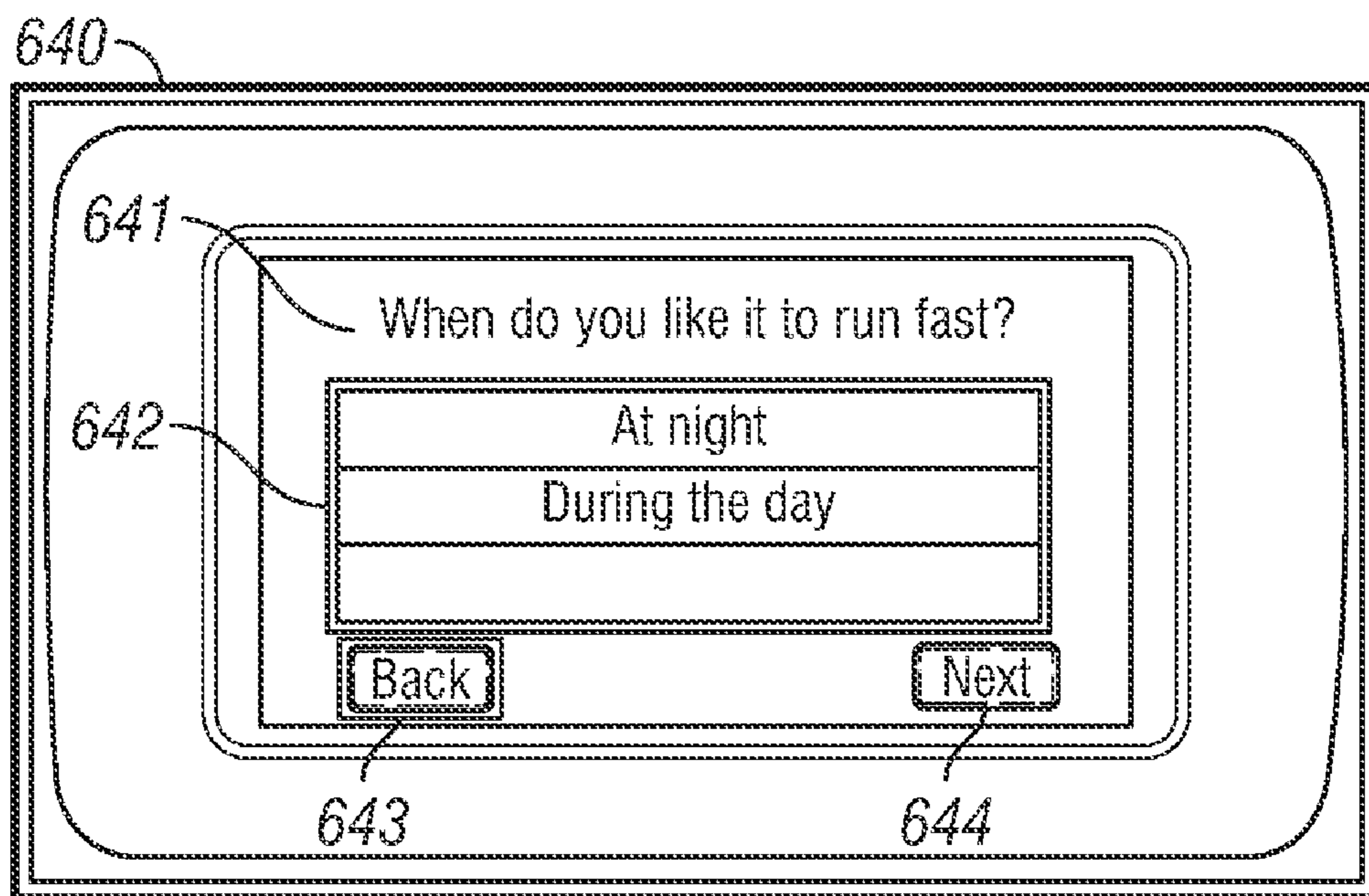


FIG. 6D

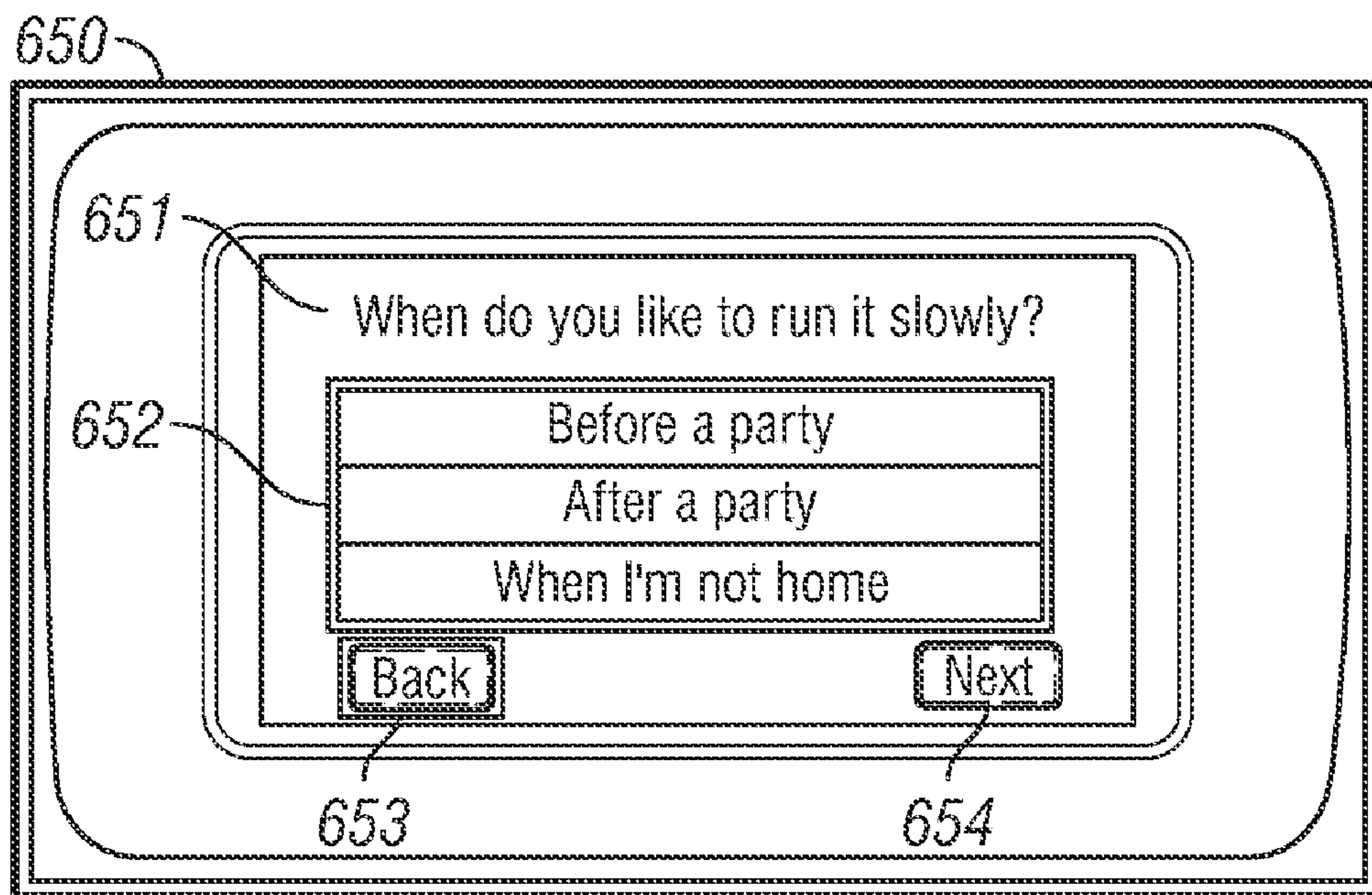


FIG. 6E

CONTEXT-AWARE SMART HOME ENERGY MANAGER

CROSS REFERENCE TO RELATED APPLICATION

[0001] This patent application claims the priority and benefit of U.S. Provisional Patent Application 61/234,947 filed Aug. 18, 2009 entitled “Context-Aware Smart Home Energy Manager” that is herein incorporated by reference.

TECHNICAL FIELD

[0002] Embodiments are generally related to energy management. Embodiments are additionally related to energy management of household consumer appliances. Embodiments are further related to a control interface for energy management of household consumer appliances.

BACKGROUND OF THE INVENTION

[0003] Net zero energy (NZE) homes are structures that combine state-of-the-art, energy-efficient construction techniques and equipment, with renewable energy systems to return as much energy as it uses on an annual basis. To achieve NZE use in a home, a comprehensive energy reduction strategy is required, including the use of efficient appliances, renewable energy resources, and efficient home energy management capable of adapting to the occupant’s lifestyle. Energy management concepts and technologies reduce wasteful energy consumption, reduce peak electricity demand, integrate renewable energy and storage technology, and change the occupant’s behavior for the occupant to learn how to manage and consume less energy.

[0004] A home typically uses unmanaged appliances with minimal planning and inefficient scheduling. It is impossible to formulate a home energy plan without a holistic view of home occupancy, usage patterns, demand peaks, or weather effects on home energy usage. Further, without dynamic energy pricing, current NZE strategies fall short as technology focuses on user awareness of energy consumption, basic demand response (DR), and fixed programmable schedules with minimal ability to control and schedule energy consumption. Current DR solutions for energy usage range from simple pager-based solutions to sophisticated appliances, with little homeowner participation or input. Homeowners may try to reduce household energy use by turning off the air conditioning during certain parts of the day or heating the pool to lower temperatures. This approach, however, does not take into account reducing the energy use of all the appliances and consumer electronics, as a collective system, within a home. Other apparatuses and techniques exist to facilitate the efficient operation of the energy consuming devices, including programmable electronic thermostats and various timers for lighting, water heaters, and pool heaters. But these apparatuses, do not communicate with each other through a centralized system to efficiently manage energy use within a home. Such solutions simply shift energy consumption and do not help achieve NZE goals.

[0005] A comprehensive home energy use management system is needed to coordinate efficient and smart appliances, other energy-consuming devices, and renewable energy resources. This home energy use management system also needs to recognize and adjust energy use to varying occupancy levels and conditions within the home. By accommodating to the lifestyle of the occupants, and properly sched-

uling use of appliances, a large percentage of energy can be saved. Therefore, a need exists for a context-aware smart home energy manager (CASHEM) to coordinate and conserve energy use in the home, as will be discussed in greater detail herein.

BRIEF SUMMARY

[0006] The following summary is provided to facilitate an understanding of some of the innovative features unique to the disclosed embodiment and is not intended to be a full description. A full appreciation of the various aspects of the embodiments disclosed herein can be gained by taking into consideration the entire specification, claims, drawings, and abstract as a whole.

[0007] It is, therefore one aspect of the disclosed embodiment to provide for an improved energy management system and method.

[0008] It is another aspect of the disclosed embodiment to provide for an improved energy management system and method for household consumer appliances.

[0009] It is a further aspect of the disclosed embodiment to provide for a control interface for energy management of household consumer appliances.

[0010] The aforementioned aspects and other objectives and advantages can now be achieved as described herein. A context-aware smart home energy management (CASHEM) system and method is disclosed. “Context-awareness” describes the conditions of energy consumption in the house. CASHEM identifies contextual information within said household, selects a comfort of service preference based on previously expressed homeowner preferences, and generates an appliance use schedule for maximum energy savings based on said contextual information in light of said comfort of service preferences. It does this by executing a program instruction in a data processing apparatus. Once running, CASHEM continues to monitor actual appliance use and identifies additional opportunities for energy savings that match up with the homeowner’s evolving energy use behavior. Part and parcel to this is the use various incentives to motivate energy use behavior change in the desired direction. An energy manager display coordinates and gathers said user preferences to formulate a dynamic energy-savings plan for a household.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying figures, in which like reference numerals refer to identical or functionally-similar elements throughout the separate views and which are incorporated in and form a part of the specification, further illustrate the invention and, together with the detailed description of the invention, serve to explain the principles of the disclosed embodiments.

[0012] FIG. 1 illustrates a schematic view of a software system including an operating system, application software, and a user interface, in accordance with the disclosed embodiments;

[0013] FIG. 2 illustrates a schematic view of a data-processing system, in accordance with the disclosed embodiments;

[0014] FIG. 3 illustrates a graphical representation of a computer-implemented context-aware smart home energy management system (CASHEM), in accordance with the disclosed embodiments;

[0015] FIG. 4 illustrates a flow chart illustrating the logical operation steps of CASHEM's operation, in accordance with the disclosed embodiments;

[0016] FIGS. 5A-5B illustrates graphical representations model of energy savings using CASHEM's dynamic scheduling based on various activities, in accordance with the disclosed embodiments;

[0017] FIGS. 5C-5D illustrates graphical representations model of energy savings when using CASHEM's dynamic scheduling techniques to provide a user with a recommended energy savings usage plan, in accordance with the disclosed embodiments; and

[0018] FIGS. 6A-6E illustrate a graphical user interface (GUI) for interaction with the context-aware smart home energy management system (CASHEM), in accordance with the disclosed embodiments.

DETAILED DESCRIPTION

[0019] The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof.

[0020] FIGS. 1-2 are provided as exemplary diagrams of data-processing environments in which embodiments of the present invention may be implemented. It should be appreciated that FIGS. 1-2 are only exemplary and are not intended to assert or imply any limitation with regard to the environments in which aspects of embodiments of the disclosed embodiments may be implemented. Many modifications to the depicted environments may be made without departing from the spirit and scope of the disclosed embodiments.

[0021] FIG. 1 illustrates a computer software system 100 for directing the operation of the data-processing system 200 depicted in FIG. 2. Software application 104, stored in main memory 202 and on mass storage 207 (as described in FIG. 2), generally includes a kernel or operating system 101 and a shell or interface 103. One or more application programs, such as software application 104, may be "loaded" (i.e., transferred from mass storage 207 into the main memory 202) for execution by the data-processing system 200. The data-processing system 200 receives user commands and data through user interface 103; these inputs may then be acted upon by the data-processing system 100 in accordance with instructions from operating system module 101 and/or software application 104.

[0022] As illustrated in FIG. 2, the disclosed embodiments may be implemented in the context of a data-processing system 200 that includes, for example, a central processor 201, a main memory 202, an input/output controller 203, a keyboard 204, an input device 205 (e.g., a pointing device, such as a mouse, track ball, pen device, etc), a display device 206, a mass storage 207 (e.g., a hard disk), and a USB (Universal Serial Bus) peripheral connection 211. Additional input/output devices, such as a rendering device 208 (e.g., printer, scanner, fax machine, etc), for example, may be associated with the data-processing system 200 as desired. As illustrated, the various components of data-processing system 200 can communicate electronically through a system bus 210 or similar architecture. The system bus 210 may be, for example, a subsystem that transfers data between, for example, computer components within data-processing system 200 or to and from other data-processing devices, components, computers, etc.

[0023] The following discussion is intended to provide a brief, general description of suitable computing environments in which the system and method may be implemented. Although not required, the disclosed embodiments will be described in the general context of computer-executable instructions, such as program modules, being executed by a single computer. In most instances, a "module" constitutes a software application.

[0024] Generally, program modules include, but are not limited to routines, subroutines, software applications, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types and instructions. Moreover, those skilled in the art will appreciate that the disclosed method and system may be practiced with other computer system configurations, such as, for example, hand-held devices, multi-processor systems, data networks, microprocessor-based or programmable consumer electronics, networked PCs, minicomputers, mainframe computers, servers, and the like.

[0025] Note that the term module as utilized herein may refer to a collection of routines and data structures that perform a particular task or implements a particular abstract data type. Modules may be composed of two parts: an interface, which lists the constants, data types, variable, and routines that can be accessed by other modules or routines, and an implementation, which is typically private (accessible only to that module) and which includes source code that actually implements the routines in the module. The term module may also simply refer to an application, such as a computer program designed to assist in the performance of a specific task, such as word processing, accounting, inventory management, etc.

[0026] The interface 103 can include, for example, a graphical user interface (GUI) or an interactive speech interface. The interface 103 can serve to display results, whereupon a user may supply additional inputs or terminate a particular session. In some embodiments, operating system 101 and interface 103 can be implemented in the context of a "Windows" system. It can be appreciated, of course, that other types of systems are possible. For example, rather than a traditional "Windows" system, other operation systems, such as, for example, Linux may also be employed with respect to operating system 101 and interface 103. The software application 104 can include, for example, an energy use detection and management module 102 for providing a CASHEM. The energy use detection and management module 102 can include instructions, such as those of method 300 and 400 discussed herein with respect to FIGS. 3-4.

[0027] FIGS. 1-2 are thus intended as an example, and not as an architectural limitation with respect to particular embodiments. Such embodiments, however, are not limited to any particular application or any particular computing or data-processing environment. Instead, those skilled in the art will appreciate that the disclosed system and method may be advantageously applied to a variety of system and application software. Moreover, the present invention may be embodied on a variety of different computing platforms, including Macintosh, UNIX, LINUX, a real time OS/kernel and the like.

[0028] FIG. 3 illustrates a graphical representation of a computer-implemented context-aware smart home energy manager (CASHEM) 310, in accordance with the disclosed embodiments. CASHEM recognizes and adjusts to different conditions around, and within, a house 320, 340, 350, 360 to

minimize total energy consumption. Note that in FIGS. 1-9 identical parts or elements are generally indicated by identical reference numerals. The disclosed embodiments take advantage of dynamically planning, scheduling and programming the different appliances of the house based on these different conditions and the expressed user preferences within the different conditions. The term “appliance” refers to any device in the home that consumes, stores or produces energy. Depending on the varying conditions 320, a home’s appliances 350, 360 can operate at lower or higher energy consumption levels based on the comfort or convenience level demanded by the occupant. Adaptation of the appliance coordination system can be supported based on monitoring and analysis of occupant’s activity and the use of the appliances. The appliance tasks can also be shifted at some time in the future to consume less energy based on the forecasted weather condition 321. CASHEM 310 is designed to work with existing homes and appliances, and grow its capabilities as smart appliances and other components are added to the home. CASHEM 310 can be the hub for communicating with appliances 350, 360 and use information from different operational, environmental, and energy supply type parameters. As context sensors become available, CASHEM 310 can use the sensors for enhanced energy management.

[0029] CASHEM 310 integrates renewable energy sources into the home and reduces overall energy consumption. By increasing the focus on systems design, integration, and control, CASHEM 310 serves as a central point to collect information from all available sources and build the big picture necessary to manage energy consumption. To build the big picture of a home’s energy usage 300, the computer-implemented home network 330 connects a home’s energy-use contexts 320, a home’s energy manager displays 340, and a home’s appliances, including both 24/7-type appliances 350 and on-demand appliances 360. The home energy manager 310 connects to a home’s energy meter 329 to collect electricity use information.

[0030] “Context-awareness” describes the conditions of energy consumption in the house. CASHEM’s 310 objective is to identify the current contextual state 320, 340 350, 360, note the user preference associated with that current state, and then configure a context-driven, appliance-use, convenience, or comfort, of service (CoS) model. The CoS model correlates the different contexts with energy consumption levels, and dynamically schedules the appliances 350, 360 under the stated conditions, based on efficient energy consumption and occupancy comfort. The type and amount of CoS deviation can vary between different homeowners with homeowners submitting CoS preferences at system configuration time. CASHEM 310 reduces energy consumption while keeping the user comfortable by adapting its recommendations to the occupant’s expressed CoS preferences. The system 310 can also monitor and analyze energy consumption, recommend further energy saving actions, and engage/motivate the homeowner to adopt those recommendations.

[0031] Contexts 320 that the system 300 gathers to formulate CoS preferences include, but are not limited to: weather conditions 321, both current and forecasted; occupancy and occupancy activity information 322; security system information 323; utility information 324; renewable energy-use information 325; energy storage information 326; and plug-in hybrid electric vehicle (PHEV) information 327. CASHEM 310 integrates on-site energy generation and renewable energy sources 325. With context-aware characteristics,

CASHEM 310 can coordinate use of wind and solar energy with charging a hybrid electric vehicle to minimize energy consumption and reduce carbon footprints. Combined heat and power is becoming practical in some northern climates, while photovoltaic panels are becoming cost-effective in the southwest. Energy storage, particularly in the form of plug in hybrid electric vehicles, is also making its way into homes.

[0032] CASHEM 310 coordinates energy manager displays 340 when gathering a home’s context information 320 to appropriately adjust energy consumption. Energy manager displays include, but are not limited to: In Home Displays 341; computing device 342, mobile communications devices, such as a Smartphone 343, a computing device 345B connected to the Internet 345A, HVAC controls 346 for cooling 351 and heating devices 352.

[0033] An energy efficient home can have smart appliances capable of one or two-way communication with CASHEM 310. The central communications and data integration allows the home to be treated as a system 300 as opposed to a collection of independent, non-communicating appliances. CASHEM 310 can coordinate different types of appliances, including both 24/7-type appliances 350 and on-demand appliances. 24/7-type appliances include those appliances used nearly twenty-four hours of a day, for seven days a week. These include cooling 351 and heating 352 units, water heaters 353, pool pumps and heaters 354, refrigerators and freezers 361. On-demand appliances 360 include those appliances used less frequently than 24/7-type appliances 350. On-demand appliances include, but are not limited to: dishwashers 362, lighting 363, consumer electronics, such as entertainment devices 364, appliances that run off of wireless controlled outlets 365, including stereos 365A, computing devices 365B, and televisions 365C. CASHEM can integrate other similar sensors and systems when additional appliances are used in the home, such as security systems, smoke detectors, HVAC, structured wiring, energy management, and video, to provide one integrated system.

[0034] CASHEM 310 alerts users to pending problems through the home’s IP network 330. Condition-based monitoring (CBM) techniques can be scaled down and integrated in CASHEM 310. Alerts to the homeowner through various energy manager displays 340 can be as simple as, for example, “The furnace has run 265 hours since the filter was changed.” CASHEM can use abnormal vibration detection to identify potential problems in HVAC systems. CASHEM enables two-way communication with the electrical grid 324 to obtain real-time pricing and demand response events via an open automated demand response (OpenADR) server or other mechanism that complies with National Institute of Standards and Technology standards.

[0035] By adjusting to the occupant’s preferences and behaviors under different activity or occupancy conditions of the house, appliance energy consumption is reduced while keeping the occupants satisfied with a desirable CoS for each appliance under the different conditions. The capabilities of the system 300 shown in FIG. 3 are best described through a series of non-limiting CASHEM 310 use cases, as follows:

Example 1

[0036] Sleep mode activation: The homeowner goes to bed early 322. CASHEM 310 is notified by the security system 323, which triggers the HVAC system 346 to go into “Sleep” mode. CASHEM 310 also enables the dishwasher 362 and dryer to complete their pending cycles. The water heater’s

353 settings are changed to reflect reduced energy consumption **329**. The entertainment devices **364** and lighting **363** are scheduled turn off to reduce or eliminate energy consumption **329**.

Example 2

[0037] Vacation scheduling: Before leaving on vacation **322**, the homeowner notifies CASHEM **310**. The online calendar indicates that the homeowner can be away for a week **322**. CASHEM **310** transmits requests to all appliances **350**, **360** to either shutdown or switch to vacation mode. Other appliances **350**, **360** may be shut down or switched to vacation mode including: managing the HVAC system **346**, setting the water heater **353** and refrigerator **361** to power saving modes, turning the entertainment system **364** off, lowering the set point on the pool heater and pump **354** and turning off lighting **363**, as appropriate. Later in the week, CASHEM **310** is notified of the Homeowner's impending return **322** through an SMS text message on a Smartphone **343**, or an e-mail or Tweet™ on a computer device connected to the internet **345b**. In response, CASHEM **310** prepares the home for a homeowner's arrival.

Example 3

[0038] Convenience of Service: CASHEM **310** is aware of the homeowner's CoS requirements. The homeowner prioritized on the side of energy conservation. During the cooling season **321**, CASHEM **310** looks for opportunities to bring in outside air **325** whenever feasible instead of running the air conditioner **351** even though this can affect humidity levels in the home.

Example 4

[0039] Adaptation of Schedule for 24/7 Appliances **350**: CASHEM **310** noted that the homeowner's schedule has changed **322** due to seasonal factors. CASHEM **310** determines a new energy-usage schedule that better reflects the energy usage of the home **322** and presents it to the homeowner. With the homeowner's concurrence, the new schedule is put into trial service. Later the new schedule is accepted as a permanent energy usage schedule.

Example 5

[0040] Adaptation for On-Demand Appliances **360**: CASHEM **310** has identified that the dishwasher **362** is generally run after dinner **322** with high CoS settings. Given time-of-use pricing and the desire of the Homeowner to conserve energy **329**, CASHEM **310** recommends using the dishwasher's **362** delay feature to start washing after the lower prices set in. It also suggests using air drying mode, since the clean dishes are not needed until the morning.

Example 6

[0041] Predictive Load Management: It is Friday and the weather **321** is expected to be unusually hot. The utilities **324** issued a peak pricing alert for the afternoon, but the homeowner generally works from home **322** on Fridays. CASHEM **310** anticipates cooling needs and pre-cools **351** the house

during the morning hours on Friday to reduce the load during peak hours, and raises the set point of the HVAC system **346**.

Example 7

[0042] Demand response and dynamic pricing: CASHEM **310** is notified that peak pricing can be in effect and responds by taking actions pre-approved by the homeowner to reduce demand on the utilities **324**. Typical responses might include reducing set points of HVAC **346**, water heater **353**, pool pump and heater **354**, and delaying the start of energy consuming appliances **350**, **360** such as dishwashers **362** and dryers. Depending on the criticality of the pricing request and the CoS settings, more conservative actions can be taken.

Example 8

[0043] Renewable energy management: The home is equipped with a small wind turbine **325** and battery storage **326**. During the cooling season, the wind forecast **321** indicates significant generation potential overnight. Knowing the off-peak utility pricing and the health and capacity of the battery **326**, CASHEM **310** decides to first charge the battery **326** then uses the excess energy to pre-cool in anticipation of a hot summer day.

[0044] Illustrated in FIG. 4 is a flow chart illustrating the logical operation steps of CASHEM's **310** operation, in accordance with the disclosed embodiments. As illustrated in block **401**, the CASHEM process is initiated. CASHEM **310** first identifies contextual information that affects the CoS of home appliances, as illustrated in block **402**. As illustrated in block **403**, the user selects CoS preferences on the computer-human graphical user interface **103** (GUI), as shown in FIG. 1. The GUI is provided to display and capture the occupant's appliance operation preferences and convenience constraints. Next, the appliances are configured for the different home conditions using a selected CoS preference, as illustrated in block **404**. CASHEM **310** then extracts an appliance use schedule to run the appliances at an efficient rate to guide the occupant to either test or comply with further energy saving opportunities, as illustrated in block **405**. Through data monitoring, the system can analyze energy consumption under different conditions and recommend to the user further energy saving opportunities, as illustrated in block **406**. The CASHEM controller continues to process and identify contextual information and configure appliances, even when the user has not provided new CoS preferences, as illustrated in block **407**.

[0045] CASHEM **310** first identifies contextual information that affects the CoS of home appliances, as illustrated in block **402**. Context describes a setting or a situation that impacts the energy consumption of an appliance. Awareness of the context with respect to the occupant or the home environment is used to significantly reduce energy consumption without compromising the occupant's comfort and convenience. Recognizing different types of contexts can dictate development of efficient modes of operations for home appliances. Three main types of context information exist as a function of time that potentially affect energy consumption, as follows:

[0046] Operational conditions: These are mainly driven by the user's occupancy and can be summarized by short and long term schedule. According to the user schedule, different

user modes can be identified as a function of time. For example, these user modes include In, Vacation, At the Office, Sleeping, Party, etc.

[0047] Environmental conditions: This context type is typically related to the current and predicted weather conditions around the house. If the current and forecasted weather are known, some appliance systems, such as HVAC, can potentially utilize efficient operational strategies. Also, weather information such as sunny or windy conditions can affect the renewable energy supply use in the home.

[0048] Energy supply type and/or cost conditions: This information is important for the integration and management of renewable sources. It is related to the reliability of the current and predicted energy supply from the available sources of energy. It also includes the different utility signals including at least one of the following signals: demand response (DR), real-time-pricing (RTP) information, time-of-use (TOU) tariff.

[0049] As illustrated in block 403, the user selects CoS preferences. The primary objective of CASHEM is to reduce the total energy consumption around the house by providing an integrated and optimal schedule that reflects the CoS for each appliance at different times of the day. The gathered context information helps develop a specific CoS level for a particular home. The CoS settings are driven by the variations in context types. Based on the homeowner preferences and convenience constraints under different conditions or context information of the house, CASHEM knows and recommends the best way of operating the home appliances and renewable resources while meeting the requested convenience constraint.

[0050] A CoS for renewable resources can also be defined according to the estimated supply and related uncertainty level of the supplied energy. A CoS metric is then applied to the different appliances. The CoS level is related to the time it takes to finish a job, or the thermal comfort in an environment. The CoS is typically correlated to the amount of energy consumed. Based on the condition driven by the context, the user can configure the CoS of an appliance for that particular condition. The CoS can also provide a range base control versus set point control to provide the occupant with a choice between comfort vs. energy conservation. For example, when the occupant is "IN", the CoS is 76+/-2 degrees F.; when the occupant is "ON VACATION", the CoS is 62+/-4 degrees F.; and, when the occupant is in the office, the CoS is 70+/-4 degrees F. The temperature range points are mapped to a CoS metric. The user can change these CoS values under different supply type modes, such as DR mode from utilities, solar supply, or wind supply.

[0051] Once a CoS level is developed, a home's appliances are configured, as illustrated in block 404. The initial operational context extraction related to homeowner activity or schedule can be implemented using programmable thermostats. Two approaches are typically used to assess context information: direct sensing measurements and indirect, inferred by integrating information from multiple sensors. The static schedule can be enhanced by making use of more accurate context extraction that is related to the user's activity. Home appliances are first categorized under two distinct categories, either as on-demand or 24/7 appliances, before developing a CoS level, as follows:

[0052] On demand (OD) appliances are activated randomly, or scheduled by external trigger. OD appliances include clothes washers and dryers, dishwashers, televisions,

lighting, etc. These systems generally have discrete modes of operation. For on-demand appliances, the task is to correlate the convenience constraints, typically time range of use, to the energy consumption for the discrete modes of operation. In general, the goal for the OD appliances is to move to a lower CoS for the given condition, or move the task to a different time of the day. For example, CASHEM can recommend washing dishes in three hours instead of two when the user is IN, or move the task to "SLEEP" time and wash the dishes in 5 hours.

[0053] For 24/7 appliances, the energy savings can be achieved by recommending a lower CoS for a given condition or reducing the time of the highest quality conditions. For example, a user could either lower the heating set point from 72 to 68 deg F. for "IN" or shrink the "IN" time to 7 hours instead of 8 hours based on occupancy data. 24/7 appliances generally have continuous modes of operation, such as controlling to a set point. These appliances also have transitional modes of operations that move from one set point to another, such as pre-heating or pre-cooling modes. 24/7 appliances include equipments such as HVAC systems, water heaters, pool heaters and pool pumps. The task for the 24/7 appliances can be similar to the on-demand appliances. Weather conditions, however, can affect the relationship and need to be included in the assignment of a CoS analysis. For example, to maintain 76 degrees F. for cooling conditions, ventilation can be provided if the outdoor temperature is low. An example of CoS for heating and cooling is a comfort index that can be calculated based on temperature or more broadly based on a predicted mean vote (PMV) (**) index that is based on actual temperature, humidity, wind velocity, user activity and clothing. Some of these parameters can be configured or estimated seasonally. The user can indicate his or her tolerance of comfort range based on activity, weather, and energy supply type.

[0054] As illustrated in block 405, CASHEM then extracts an appliance use schedule. Under a given CoS, CASHEM can then select the best mode for a particular appliance in each category and estimate the energy consumed under a given CoS. A static schedule is developed first. Typically, the static schedule during the initial setup results in adherence to CoS preferences and lower energy savings. CASHEM can also evaluate the cost of energy and recommend a more efficient schedule based on energy cost while maintaining homeowner satisfaction. In other cases, the schedule can deviate enough that the unhappy user can turn off the scheduling mode. CASHEM can reduce peaks using a combination of range base control and load shifting via predicted scheduling. When a demand peak is signaled, CASHEM can automatically shed loads based on information from the homeowner. CASHEM can supervise and properly schedule all the appliances during demand response by multiple set point strategy for example, delaying running the dehumidifier until well after the peak load. For additional energy savings, CASHEM can respond to non-scheduled events requested by the user.

[0055] As illustrated in block 406, CASHEM provides the user with recommended energy-saving opportunities based on the data collected and user-inputted CoS preferences. CASHEM provides recommendation to the user to educate the user on current energy savings and future modifications to CoS preferences to further increase energy savings. The process ends, as illustrated in block 407.

[0056] FIGS. 5A-5B illustrate graphical representations of energy savings using CASHEM's dynamic scheduling based on various activities 511. For example, FIG. 5A illustrates

energy savings when using CASHEM 510 based on user's activity levels 511. CoS preferences for different activity levels 511 are used to program 501 the energy-use levels of various appliances over a twenty-four hour period. A user programs 501 energy use levels for "Sleep" modes 512, "In" modes 513, an "Away" mode 514, and a "Swim" mode 515, for example. CASHEM dynamically schedules actual energy use 502 based on these CoS preferences for particular activities 511, but also incorporates energy saving techniques discussed herein. Therefore, CASHEM lowers actual energy use 502 for all scheduled modes 512-515, as illustrated in FIG. 5B. During sleep modes 512, energy use is lower than energy use during "In" 513 and "Swim" 515 modes. CASHEM's dynamical scheduling for lower energy use results in energy savings 522 especially during modes of higher energy use.

[0057] FIGS. 5C-5D illustrate graphical representations of energy savings when using CASHEM's dynamic scheduling techniques to provide a user with a recommended 503 energy savings usage plan. For example, in FIG. 5B, CASHEM 520 uses HVAC set points 521 to dynamically schedule for DR and activity 522. CASHEM's recommended 503 energy use levels are lower than programmed energy use levels 501. Similarly in FIG. 5C, CASHEM 530 uses pool set points 531 to dynamically schedule for cost and activity 532. CASHEM's recommended 503 energy use levels are lower than programmed energy levels 501, as well.

[0058] CoS preferences and CASHEM options are programmed using a graphical user interface (GUI), as illustrated in FIGS. 6A-6E. FIG. 6A illustrates a GUI 610-650 for display of CASHEM options, in accordance with the disclosed embodiments. Note that the GUI 610, 620, 630, 640, and/or 650 can be implemented utilizing a GUI such as, for example, the interface 103 depicted in FIG. 1 herein, and may be provided by a module, such as, for example, module 102 (i.e., a software application). GUI 610, 620, 630, 640, and/or 650 can be displayed via a display device such as a monitor 206 depicted in FIG. 2. In the illustrated figures herein, the depicted GUI can be implemented in the context of a GUI "window". Note that in computing, a GUI window is generally a visual area containing some type of user interface (e.g., GUI 103). Such a "window" usually (but not always) possesses a rectangular shape, and displays the output of and may allow input to one or more processes. Such windows are primarily associated with graphical displays, where they can be manipulated with a mouse cursor, such as, for example, the pointing device 205 depicted in FIG. 2. The user may use a mouse, joystick, light pen, roller-ball, keyboard, finger or other peripheral devices for manipulating the pointing device 205 over the GUI 610. For example, CASHEM options directly on the GUI 610. A GUI using windows as one of its main "metaphors" is often referred to as a windowing system.

[0059] The GUI 610-650 may include one or more active windows or panes. In one implementation, four primary panes may be provided, including a CASHEM query pane 601, a query response selection pane 602, a "Back" pane 603 to skip back to the previous GUI display window, and a "Next" pane 604 to move forward to the next GUI display window. These will be discussed in more detail below. Other windows and panes may similarly be provided. Various mechanisms for minimizing, maximizing, moving, and/or changing the dimensions or the individual panes, may be provided as typically found in a windows environment.

[0060] The disclosed GUI 610-650 uses a simple question and answer paradigm to account for wide variations in occu-

pants' perception, definitions, and tolerance of different comfort levels. Therefore, one of the keys to acceptance and compliance with CASHEM's energy-saving recommendations is to tailor the energy tradeoffs to individual homeowners. CASHEM initially extracts schedules for every appliance and the related CoS range from the homeowner in a series of interview questions presented on the GUI 610-650. Thus, the homeowner does not need to be a programmer to implement an energy-savings plan. With the success of the system riding on the computer-human interaction, a homeowner interface to CASHEM engages individual homeowners to indicate their own personal constraints for comfort and convenience, provides a simple paradigm for homeowners to review and understand energy management recommendations made by the system, and communicates the value of these recommendations, thereby motivating the homeowner to comply. Improper use of programmable GUI's can reduce or completely eliminate energy savings, so occupants need easy to use, innovative GUI designs for programmable thermostats, for example, to ensure energy savings.

[0061] CASHEM poses queries 611-651 to users and considers all query responses 612-652 to formulate energy use schedules and recommendations for every appliance. For example, in FIG. 6A, GUI 610 displays a query 611 asking the user, "When do you prefer to run your dishwasher?" The user can select a query response 612 indicating the preferred time, or select the "Back" pane 613 to skip back to the previous query. When the user makes a selection from the query response pane 612, or selects the "Next" pane 614 to skip this pane, the GUI 620 display appears as illustrated in FIG. 6B. The next query 621 displayed in GUI 620 asks the user, "When do you prefer to use the heat dry feature?" The user can select a query response 622 indicating the preferred time, or select the "Back" pane 623 to skip back to the previous query. When the user makes a selection from the query response pane 622, or selects the "Next" pane 624, the GUI 630 display appears as illustrated in FIG. 6C. The next query 631 displayed in GUI 630 asks the user, "In running your dishwasher, how quickly do you prefer to finish the job?" The user can select a query response 632 indicating the preferred selection, or select the "Back" pane 633 to skip back to the previous query. When the user makes a selection from the query response pane 632, or selects the "Next" pane 634, the GUI 640 display appears as illustrated in FIG. 6D. The next query 641 displayed in GUI 640 asks the user, "When do you like to run it fast?" The user can select a query response 642 indicating the preferred selection, or select the "Back" pane 643 to skip back to the previous query. When the user makes a selection from the query response pane 642, or selects the "Next" pane 644, the GUI 650 display appears as illustrated in FIG. 6E. The next query 651 displayed in GUI 650 asks the user, "When do you like to run it slowly?" The user can either select a query response 652 indicating the preferred selection, select the "Back" pane 653 to skip back to the previous query, or select the "Next" pane 654, for any further queries related to this appliance. This question and answer process continues for CASHEM to gather enough CoS preferences and context information to formulate a comprehensive energy-savings schedule for all appliances within a home.

[0062] It will be appreciated that variations of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also that various presently unforeseen or unanticipated alternatives, modifications, variations

or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What is claimed is:

1. A method for dynamically scheduling household energy use that reduces wasteful energy consumption, reduces peak electricity demand, integrates renewable energy and storage technology, and changes a user's behavior to manage and consume less energy, said method comprising:

identifying contextual information within said household, by executing a program instruction in a data processing apparatus;

identifying a user preference for comfort and service within said household, by executing a program that allows said user to indicate said user preference;

selecting a comfort of service preference, wherein said comfort of service preference is based on different said contextual information and said user preference, by executing a program instruction in a data processing apparatus; and

extracting an appliance use schedule for maximum energy savings based on said contextual information, said user preference, and said comfort of service preference, by executing a program instruction in a data processing apparatus.

2. The method of claim 1 further comprising extracting a schedule for using renewable energy sources and storage batteries within said household, wherein said extracted schedule reflects said contextual information about demand response, by executing a program instruction in a data processing apparatus.

3. The method of claim 1 further comprising:

monitoring ongoing appliance use to infer compliance with said appliance use schedule, by executing a program instruction in a data processing apparatus; and

dynamically modifying said appliance use schedule according to monitored contextual information and said user's evolving energy use behavior, by executing a program instruction in a data processing apparatus.

4. The method of claim 1 further comprising correlating said contextual information with energy consumption levels to dynamically schedule said appliance based on an energy-saving condition and a user's comfort, by executing a program instruction in a data processing apparatus.

5. The method of claim 1 further comprising coordinating an energy manager to perform at least one of the following operations:

gathering contextual information related to environmental conditions;

gathering energy supply type conditions;

gathering cost conditions;

selecting a comfort of service preference; and

configuring an appliance use schedule.

6. The method of claim 5 wherein said energy manager comprises a graphical user interface and data processing apparatus, wherein said graphical user interface is configured for at least one of the following operations:

gathering said contextual information related to user activity and a daily schedule;

gathering information about user comfort and service preferences;

displaying energy use feedback to said user;

displaying energy saving opportunities in compliance with said user's evolving behavior;

recommending use of renewable energy source and stored energy within said household; and

displaying incentive or motivational information to said user based on observed energy use behavior and adaptive to said user's energy use pattern.

7. The method of claim 1 further comprising monitoring said household's occupant activity levels and use of said appliance for configuring said appliance use schedule, by executing a program instruction in a data processing apparatus.

8. The method of claim 1 wherein said contextual information either entered by said user or via a networked device includes at least one of the following:

current weather information;

forecast weather information;

security system information;

utility information;

renewable energy-use information;

energy storage information;

energy supply type; and

utility signals including at least one of the following types of signals: demand response (DR), real-time-pricing (RTP) information, time-of-use (TOU) tariff.

9. The method of claim 1 further comprising operating said appliance according to said appliance use schedule at a recommended level equal to a comfort of service preference for maximum energy savings, by executing a program instruction in a data processing apparatus.

10. A system for dynamically scheduling household energy use that reduces wasteful energy consumption, reduces peak electricity demand, integrates renewable energy and storage technology, and changes a user's behavior to manage and consume less energy, said system comprising:

a data-processing apparatus;

a module executed by said data-processing apparatus, said module and said data-processing apparatus being operable in combination with one another to:

identifying contextual information within said household, by executing a program instruction in a data processing apparatus;

identifying a user preference for comfort and service within said household, by executing a program that allows said user to indicate said user preference;

selecting a comfort of service preference, wherein said comfort of service preference is based on different said contextual information and said user preference, by executing a program instruction in a data processing apparatus; and

extracting an appliance use schedule for maximum energy savings based on said contextual information, said user preference, and said comfort of service preference, by executing a program instruction in a data processing apparatus.

11. The system of claim 10 wherein said module and said data-processing apparatus are further operable in combination with one another to extract a schedule for using renewable energy sources and storage batteries in said household, wherein said extracted schedule reflects said contextual information about demand response, by executing a program instruction in a data processing apparatus.

12. The system of claim 10 wherein said module and said data-processing apparatus are further operable in combination with one another to:

monitor ongoing appliance use to infer compliance with said appliance use schedule, by executing a program instruction in a data processing apparatus; and dynamically modify said appliance use schedule according to monitored contextual information and said user's evolving energy use behavior, by executing a program instruction in a data processing apparatus.

13. The system of claim **10** wherein said module and said data-processing apparatus are further operable in combination with one another to correlate said contextual information with energy consumption levels to dynamically schedule said appliance based on an energy-saving condition and a user's comfort, by executing a program instruction in a data processing apparatus.

14. The system of claim **10** wherein said module and said data-processing apparatus are further operable in combination with one another to coordinate an energy manager to perform at least one of the following operations:

- gather contextual information related to environmental conditions;
- gather energy supply type conditions;
- gather cost conditions;
- select a comfort of service preference; and
- configure an appliance use schedule.

15. The system of claim **14** wherein said energy manager comprises a graphical user interface and data processing apparatus, wherein said module, said data-processing apparatus, and said graphical user interface are further operable in combination with one another to:

- collect said contextual information related to user activity and a daily schedule;
- collect information about user comfort and service preferences;
- display energy use feedback to said user;
- display energy saving opportunities in compliance with said user's evolving behavior;
- recommend use of renewable energy source and stored energy within said household; and
- display incentive or motivational information to said user based on observed energy use behavior and adaptive to said user's energy use pattern.

16. The system of claim **12** wherein said module and said data-processing apparatus are further operable in combination with one another to monitor said household's occupant activity levels and use of said appliance to configure said appliance use schedule, by executing a program instruction in a data processing apparatus.

17. The system of claim **12** wherein said contextual information either entered by said user or via a networked device includes at least one of the following:

- current weather information;
- forecast weather information;

- security system information;
- utility information;
- renewable energy-use information;
- energy storage information;
- energy supply type; and
- utility signals including at least one of the following types of signals: demand response (DR), real-time-pricing (RTP) information, time-of-use (TOU) tariff.

18. The system of claim **12** wherein said module and said data-processing apparatus are further operable in combination with one another to operate said appliance according to said appliance use schedule at a recommended level equal to a comfort of service preference for maximum energy savings, by executing a program instruction in a data processing apparatus.

19. An apparatus comprising one or more processor readable storage devices having processor readable code on said processor readable storage devices, said processor readable code for programming one or more processor to perform a method for dynamically scheduling household energy use that reduces wasteful energy consumption, reduces peak electricity demand, integrates renewable energy and storage technology, and changes homeowner behavior to manage and consume less energy, comprising:

- identifying contextual information within said household, by executing a program instruction in a data processing apparatus;
- identifying a user preference for comfort and service within said household, by executing a program that allows said user to indicate said user preference;
- selecting a comfort of service preference, wherein said comfort of service preference is based on different said contextual information and said user preference, by executing a program instruction in a data processing apparatus; and
- extracting an appliance use schedule for maximum energy savings based on said contextual information, said user preference, and said comfort of service preference, by executing a program instruction in a data processing apparatus.

20. The apparatus of claim **19** further comprising:

- a sensor to detect contextual information;
- a network; and
- an energy manager coupled to said network comprising said sensor for detecting context information, a display, said data processing apparatus, and a set of instructions for dynamically scheduling household energy use that reduces wasteful energy consumption, reduces peak electricity demand, integrates renewable energy and storage technology, and changes homeowner behavior to manage and consume less energy.

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