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Yoshimoto et al.

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(54) **ENERGY MANAGEMENT SYSTEM AND ENERGY MANAGEMENT METHOD**

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(Continued)

(52) **U.S. Cl.**
CPC .... ***F24F 11/46*** (2018.01); ***F24F 11/52*** (2018.01); ***F24F 11/54*** (2018.01); (Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

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Jongyeon Lim, et al., "Hierarchical Bayesian modeling for predicting ordinal responses of personalized thermal sensation: Application to outdoor thermal sensation data", Building and Environmental 142, 2018, p. 414-426.

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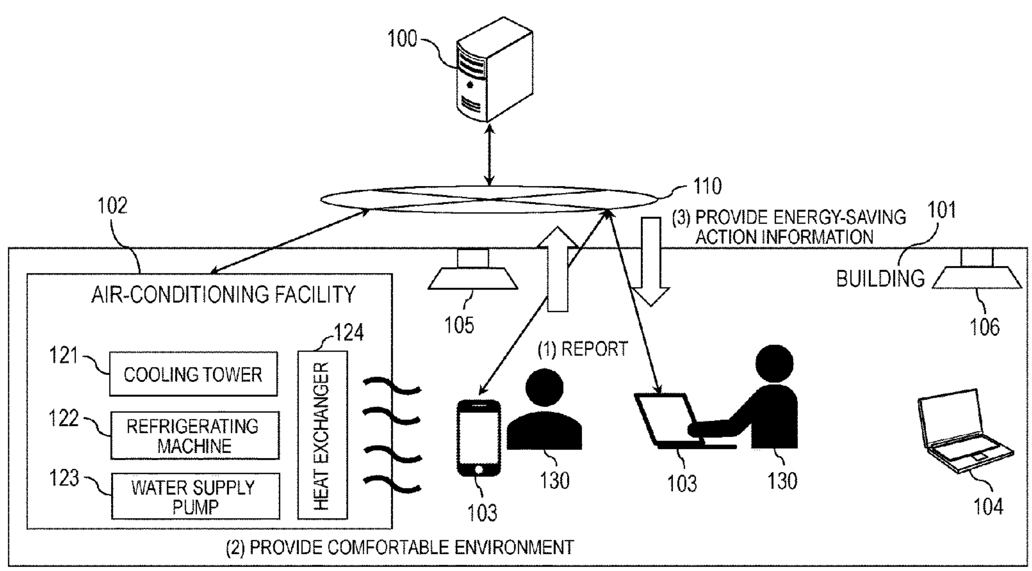
(74) *Attorney, Agent, or Firm* — Mattingly & Malur, PC

(57) **ABSTRACT**

An energy management system is configured to calculate a percentage of satisfied based on the report data for each of the plurality of buildings; create, for each of the plurality of buildings, a plan for operating each of the air-conditioning facilities based on the percentage of satisfied and a predetermined target percentage of satisfied; calculate a first energy consumption amount based on the first piece of data; calculate a second energy consumption amount based on the second piece of data, the third piece of data, and the fourth piece of data, the second energy consumption amount being obtained when the each of the air-conditioning facilities is operated after a lapse of a predetermined time period; and control, when the first energy consumption amount is larger than the second energy consumption amount, the operation of the each of the air-conditioning facilities so as to achieve the second energy consumption amount.

7 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

F24F 11/54	(2018.01)
F24F 120/20	(2018.01)
F24F 140/60	(2018.01)
F24F 110/10	(2018.01)
F24F 110/20	(2018.01)
F24F 110/30	(2018.01)

(52) **U.S. Cl.**
CPC *F24F 2110/10* (2018.01); *F24F 2110/20* (2018.01); *F24F 2110/30* (2018.01); *F24F 2120/20* (2018.01); *F24F 2140/60* (2018.01)

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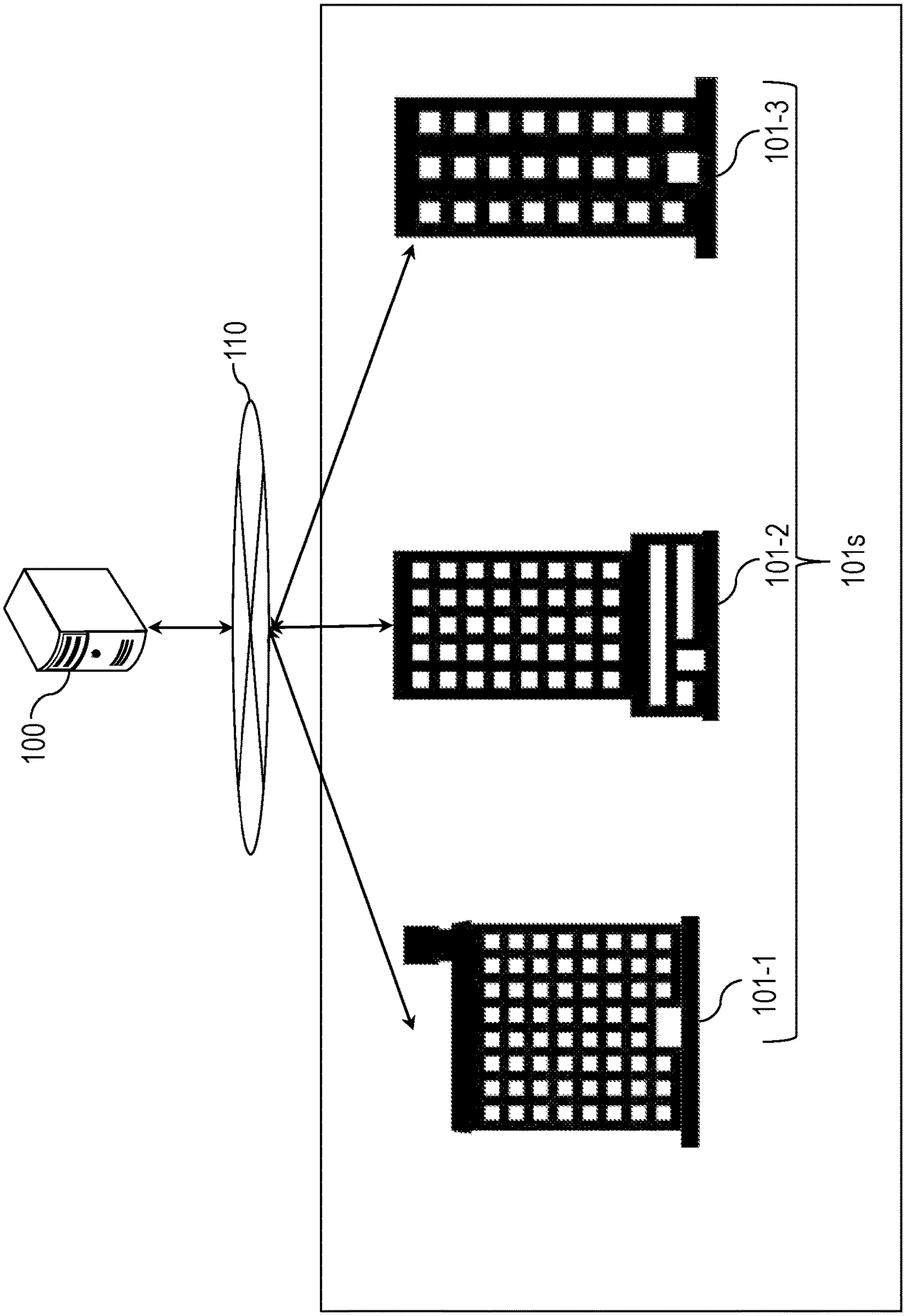

FIG.1

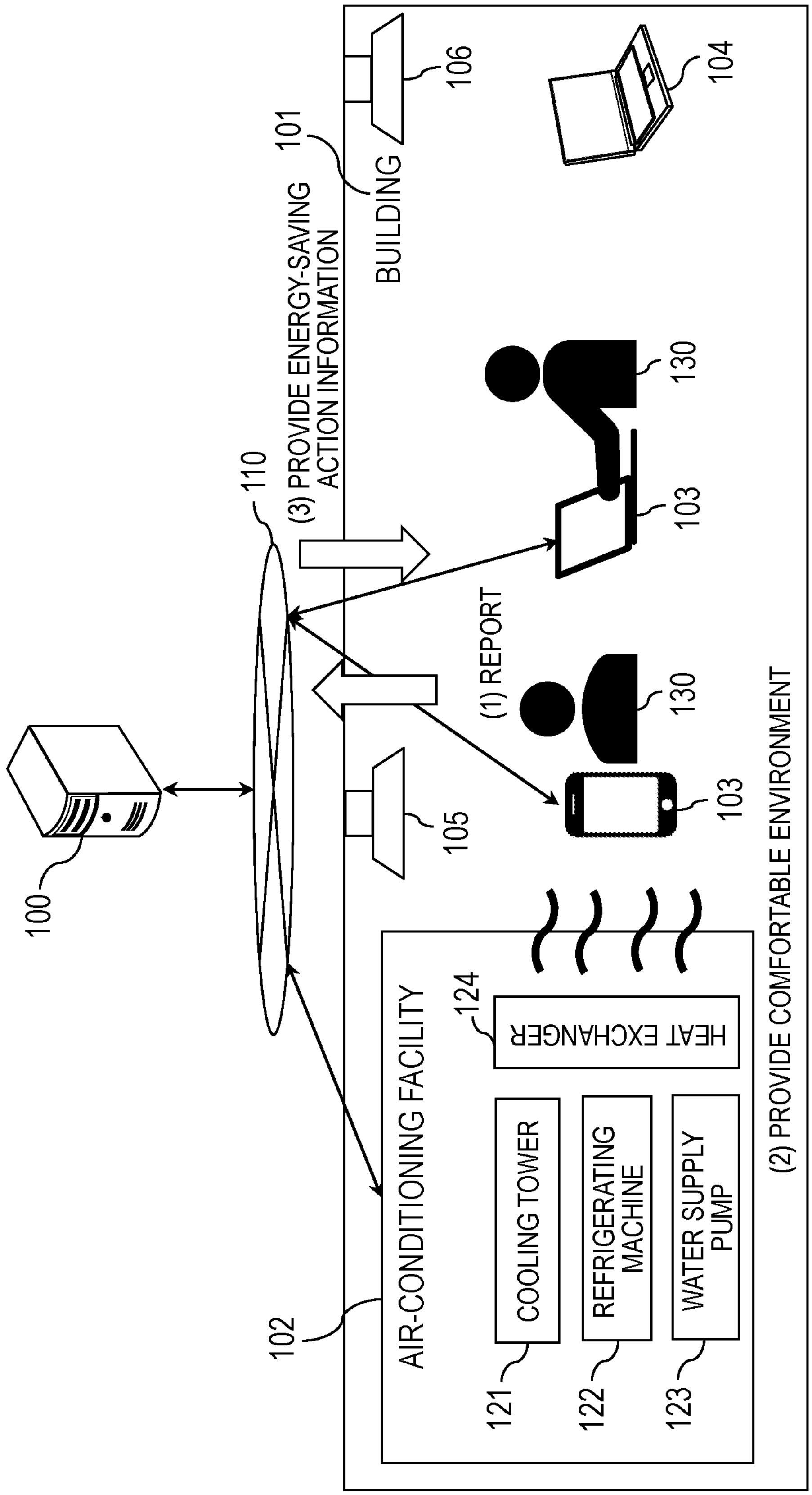
100
110
101
BUILDING
106
104
(3) PROVIDE ENERGY-SAVING ACTION INFORMATION
130
103
(1) REPORT
130
103
105
102
AIR-CONDITIONING FACILITY
124
HEAT EXCHANGER
COOLING TOWER
REFRIGERATING MACHINE
WATER SUPPLY PUMP
121
122
123
(2) PROVIDE COMFORTABLE ENVIRONMENT

FIG. 2

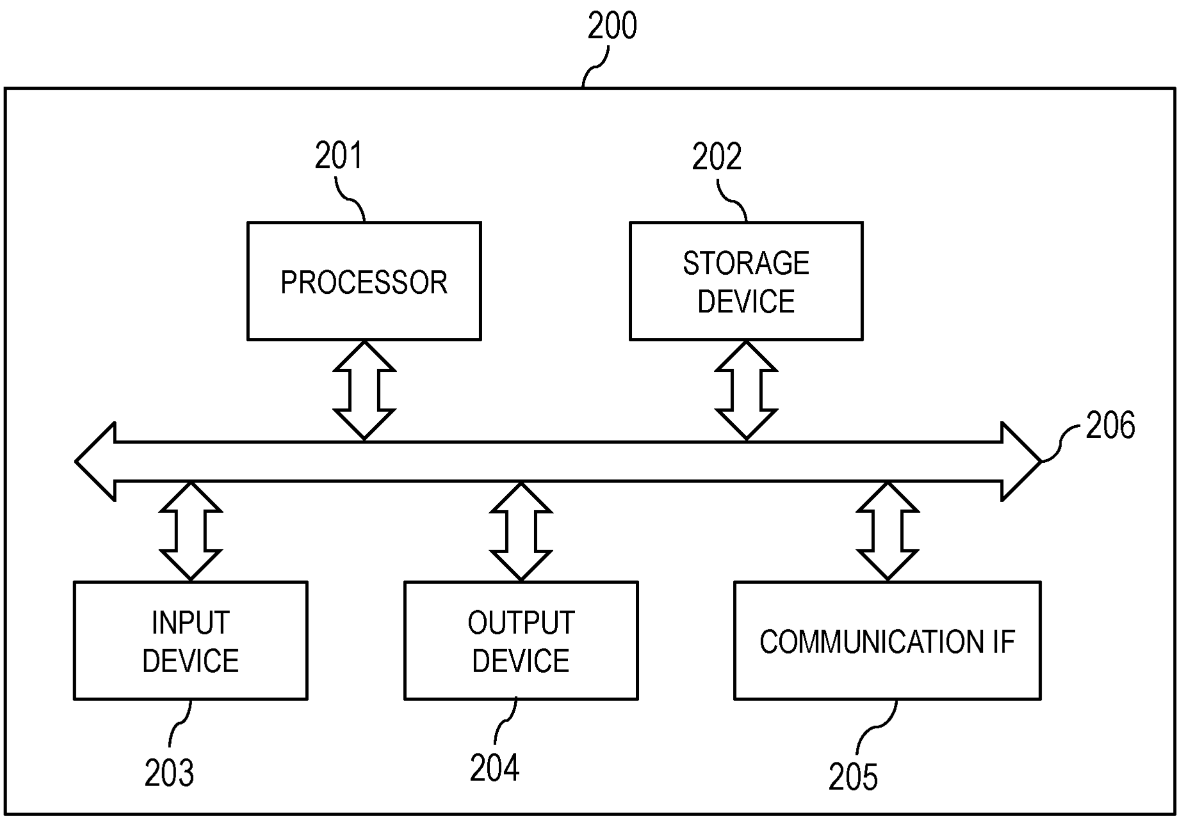
200
201
PROCESSOR
202
STORAGE DEVICE
206
INPUT DEVICE
OUTPUT DEVICE
COMMUNICATION IF
203
204
205

FIG.3

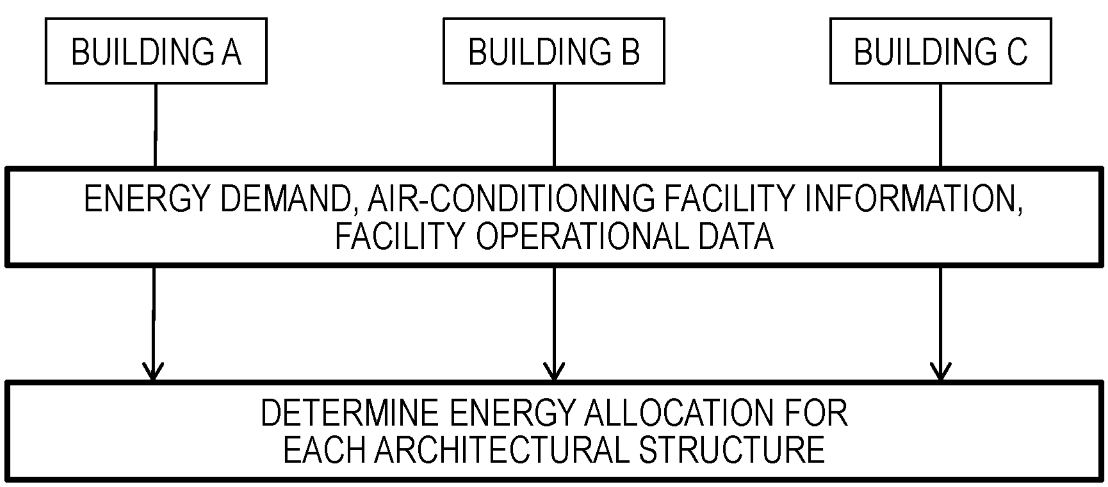
BUILDING A
BUILDING B
BUILDING C
ENERGY DEMAND, AIR-CONDITIONING FACILITY INFORMATION, FACILITY OPERATIONAL DATA
DETERMINE ENERGY ALLOCATION FOR EACH ARCHITECTURAL STRUCTURE

FIG.4

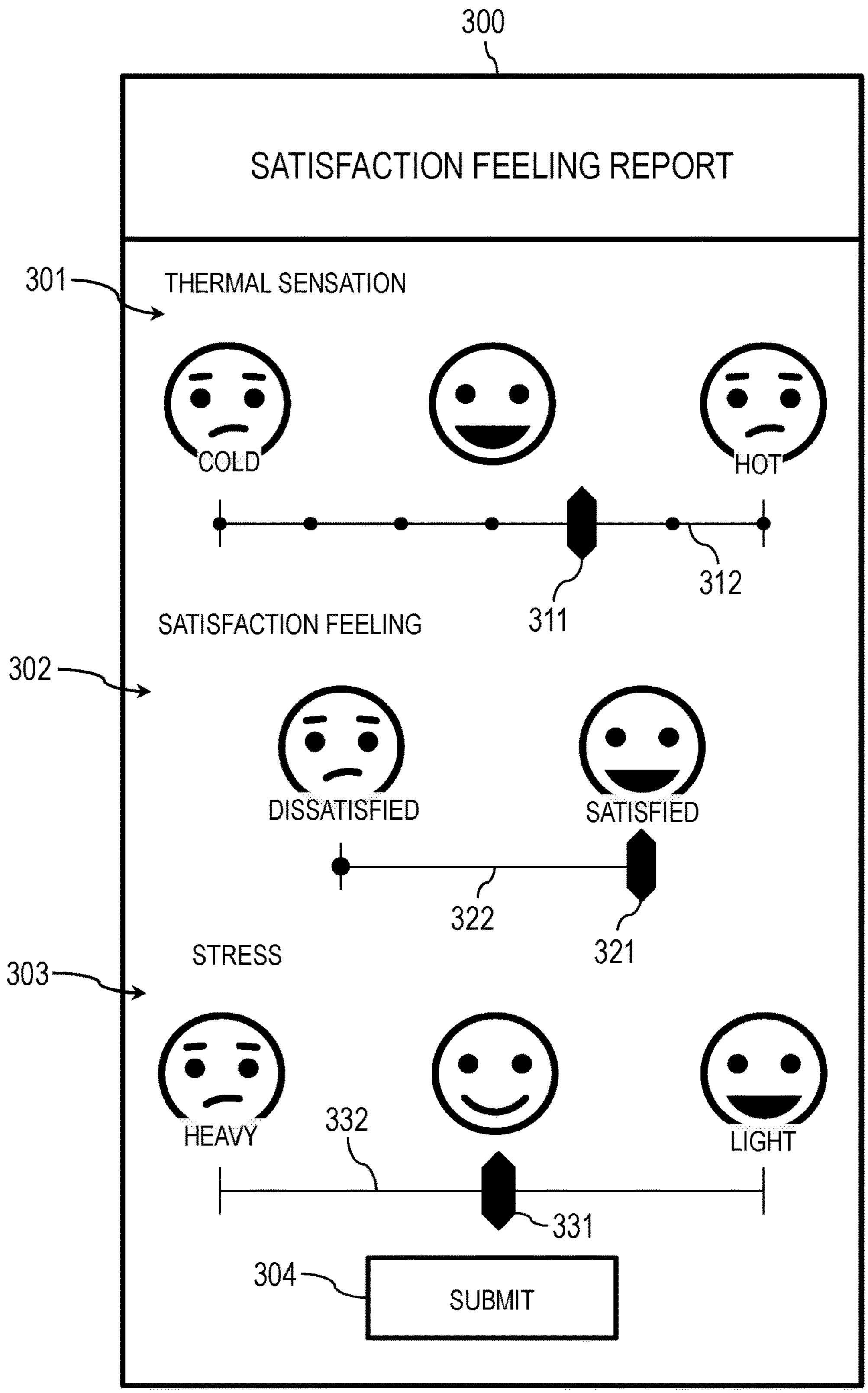
300
SATISFACTION FEELING REPORT
301
THERMAL SENSATION
COLD
HOT
311
312
SATISFACTION FEELING
302
DISSATISFIED
SATISFIED
322
321
STRESS
303
HEAVY
332
LIGHT
331
304
SUBMIT

FIG.5

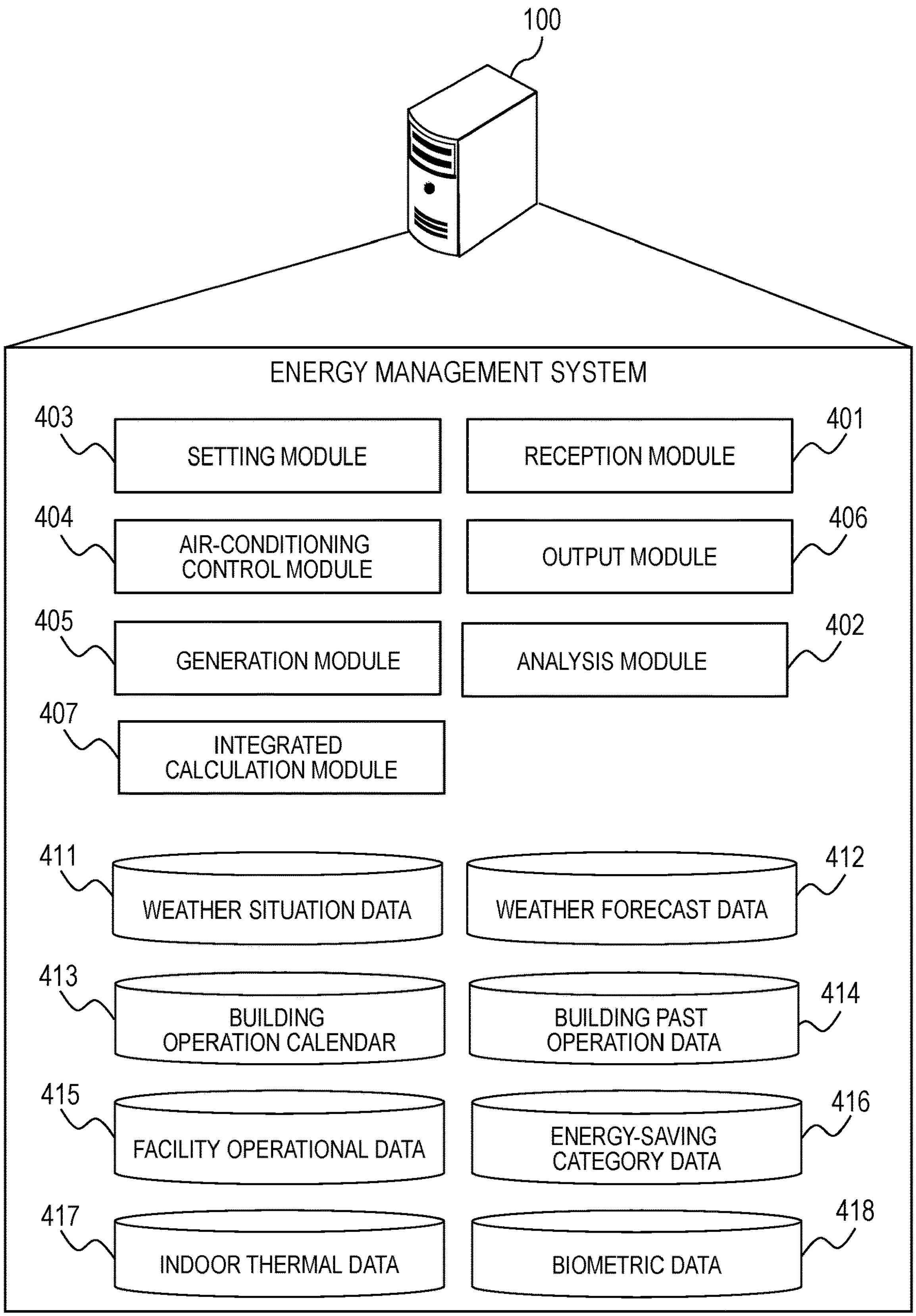
100
ENERGY MANAGEMENT SYSTEM
403
SETTING MODULE
401
RECEPTION MODULE
404
AIR-CONDITIONING CONTROL MODULE
406
OUTPUT MODULE
405
GENERATION MODULE
402
ANALYSIS MODULE
407
INTEGRATED CALCULATION MODULE
411
WEATHER SITUATION DATA
412
WEATHER FORECAST DATA
413
BUILDING OPERATION CALENDAR
414
BUILDING PAST OPERATION DATA
415
FACILITY OPERATIONAL DATA
416
ENERGY-SAVING CATEGORY DATA
417
INDOOR THERMAL DATA
418
BIOMETRIC DATA

FIG.6

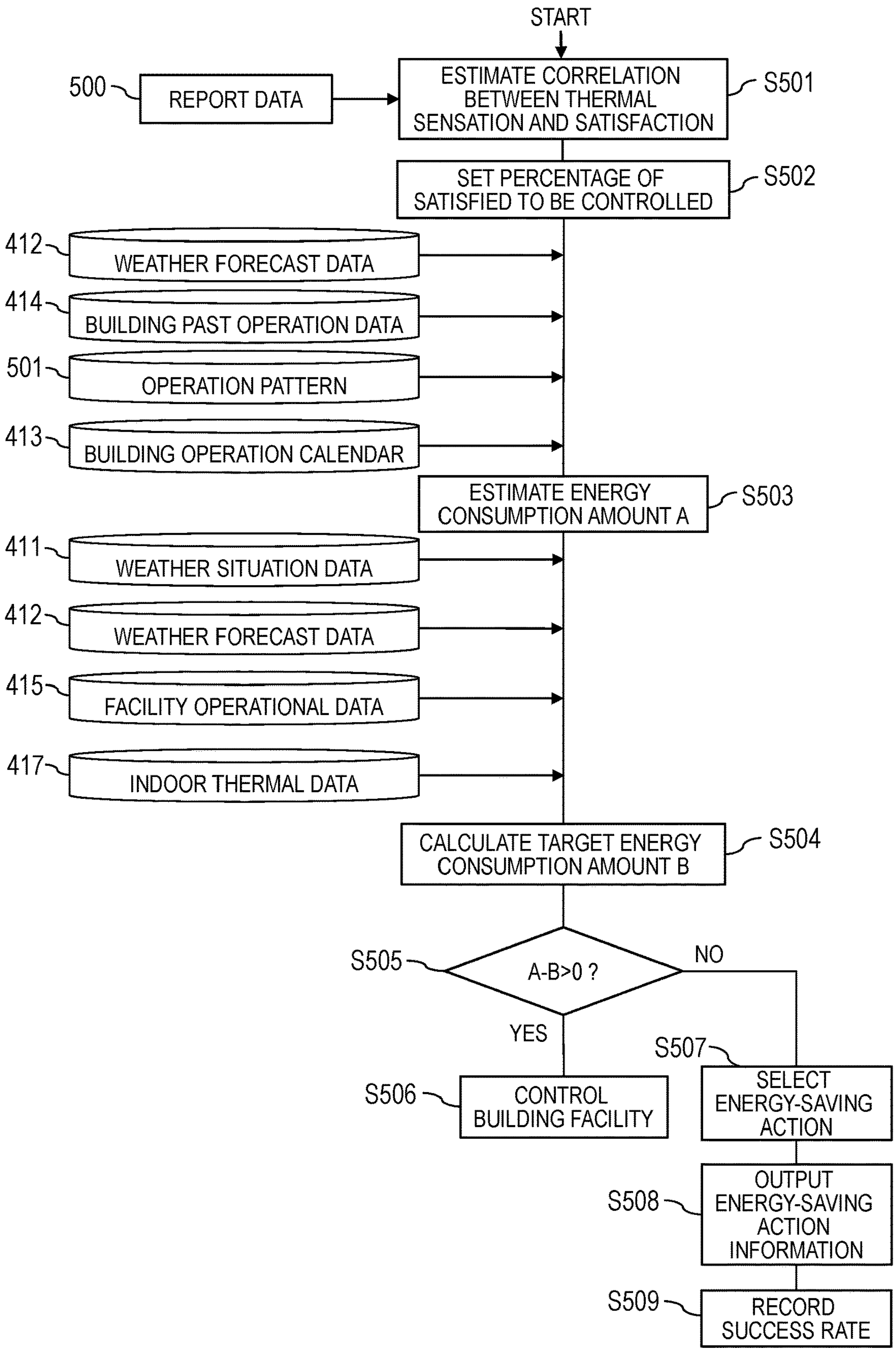
START
ESTIMATE CORRELATION BETWEEN THERMAL SENSATION AND SATISFACTION
S501
500
REPORT DATA
SET PERCENTAGE OF SATISFIED TO BE CONTROLLED
S502
412
WEATHER FORECAST DATA
414
BUILDING PAST OPERATION DATA
501
OPERATION PATTERN
413
BUILDING OPERATION CALENDAR
ESTIMATE ENERGY CONSUMPTION AMOUNT A
S503
411
WEATHER SITUATION DATA
412
WEATHER FORECAST DATA
415
FACILITY OPERATIONAL DATA
417
INDOOR THERMAL DATA
CALCULATE TARGET ENERGY CONSUMPTION AMOUNT B
S504
S505
A-B>0 ?
NO
YES
S506
CONTROL BUILDING FACILITY
S507
SELECT ENERGY-SAVING ACTION
S508
OUTPUT ENERGY-SAVING ACTION INFORMATION
S509
RECORD SUCCESS RATE

FIG. 7

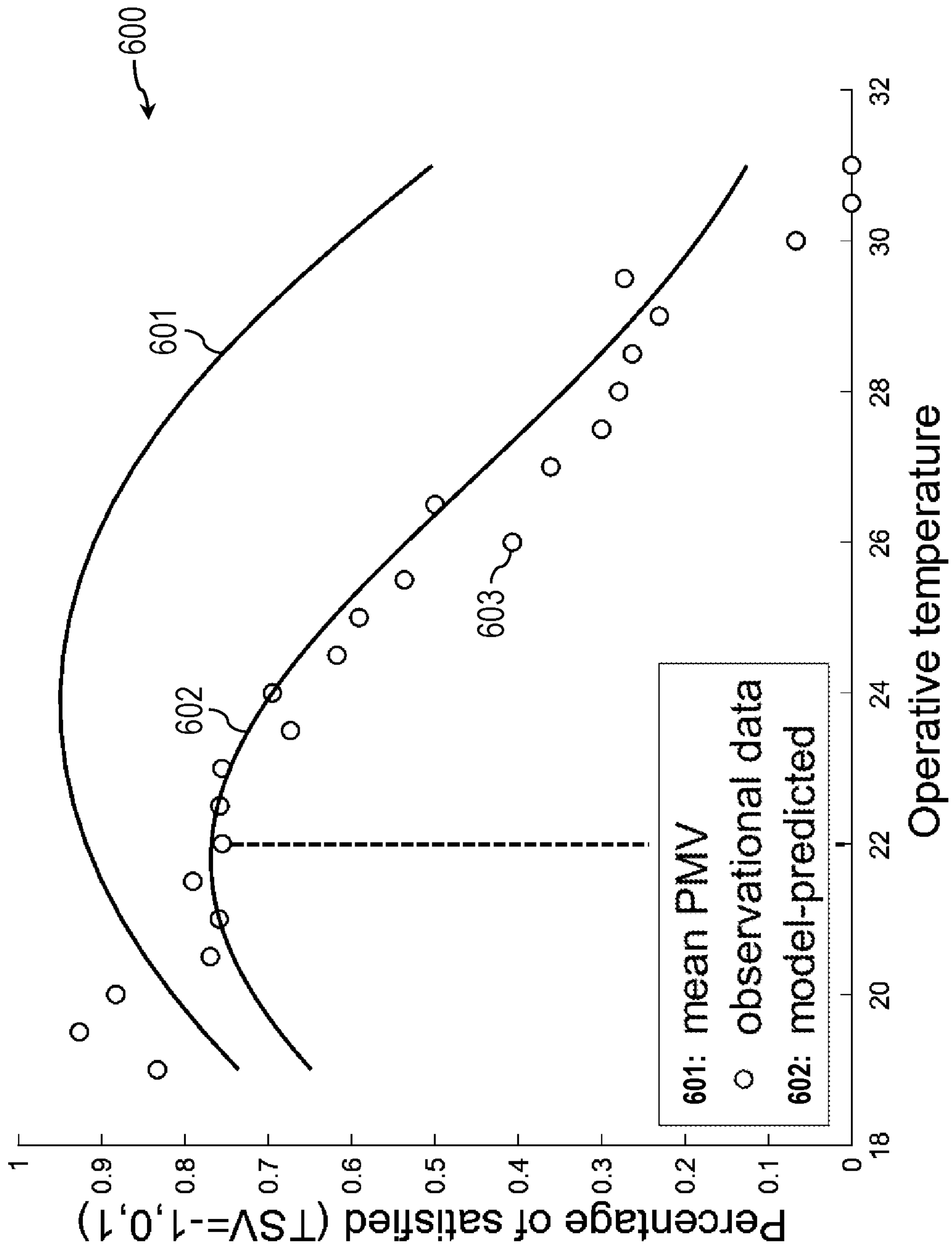
600
601
602
603
601: mean PMV
○ observational data
602: model-predicted
Percentage of satisfied (TSV=-1,0,1)
Operative temperature
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
18
20
22
24
26
28
30
32

FIG.8

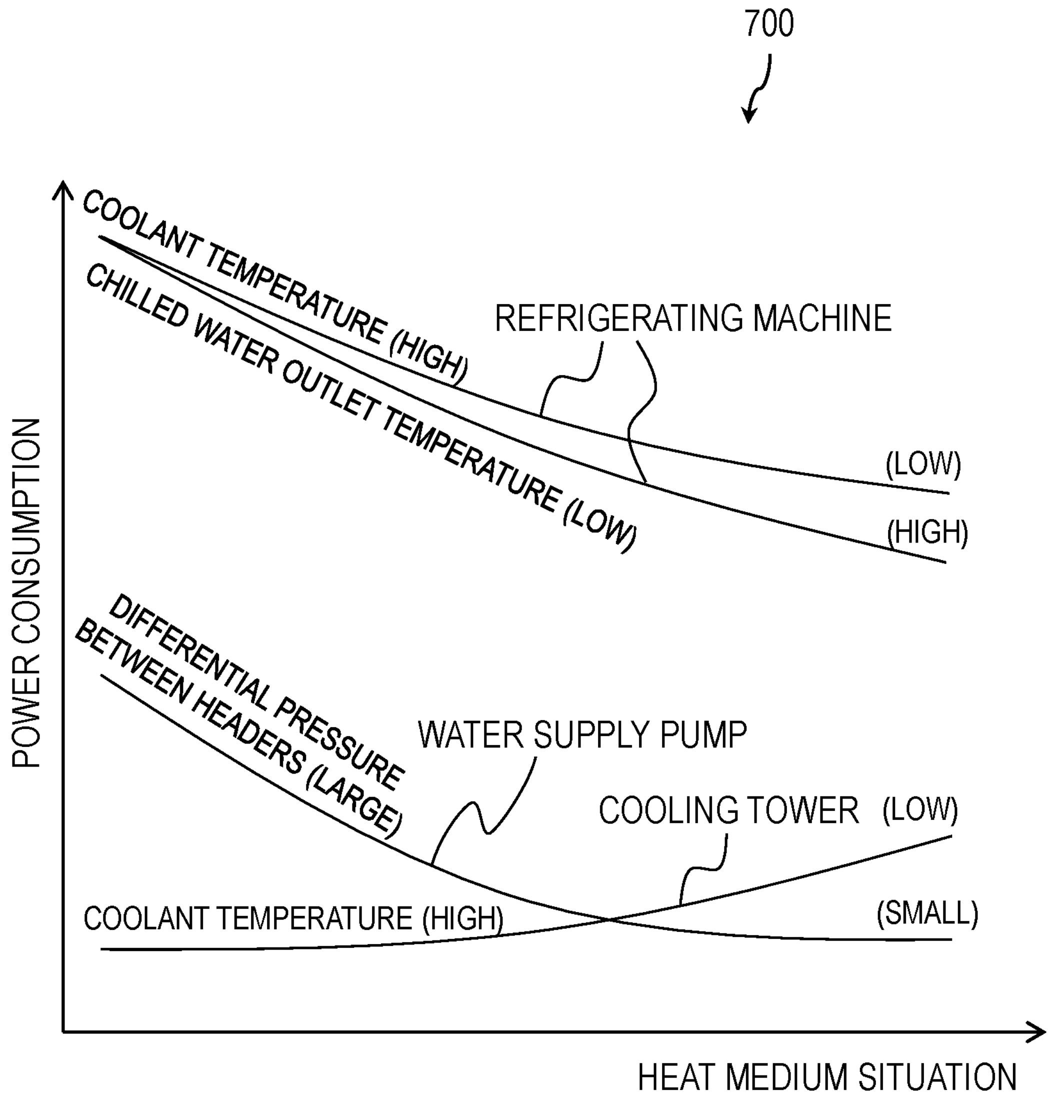
700
POWER CONSUMPTION
COOLANT TEMPERATURE (HIGH)
CHILLED WATER OUTLET TEMPERATURE (LOW)
REFRIGERATING MACHINE
(LOW)
(HIGH)
DIFFERENTIAL PRESSURE BETWEEN HEADERS (LARGE)
WATER SUPPLY PUMP
COOLING TOWER
(LOW)
COOLANT TEMPERATURE (HIGH)
(SMALL)
HEAT MEDIUM SITUATION

FIG.9

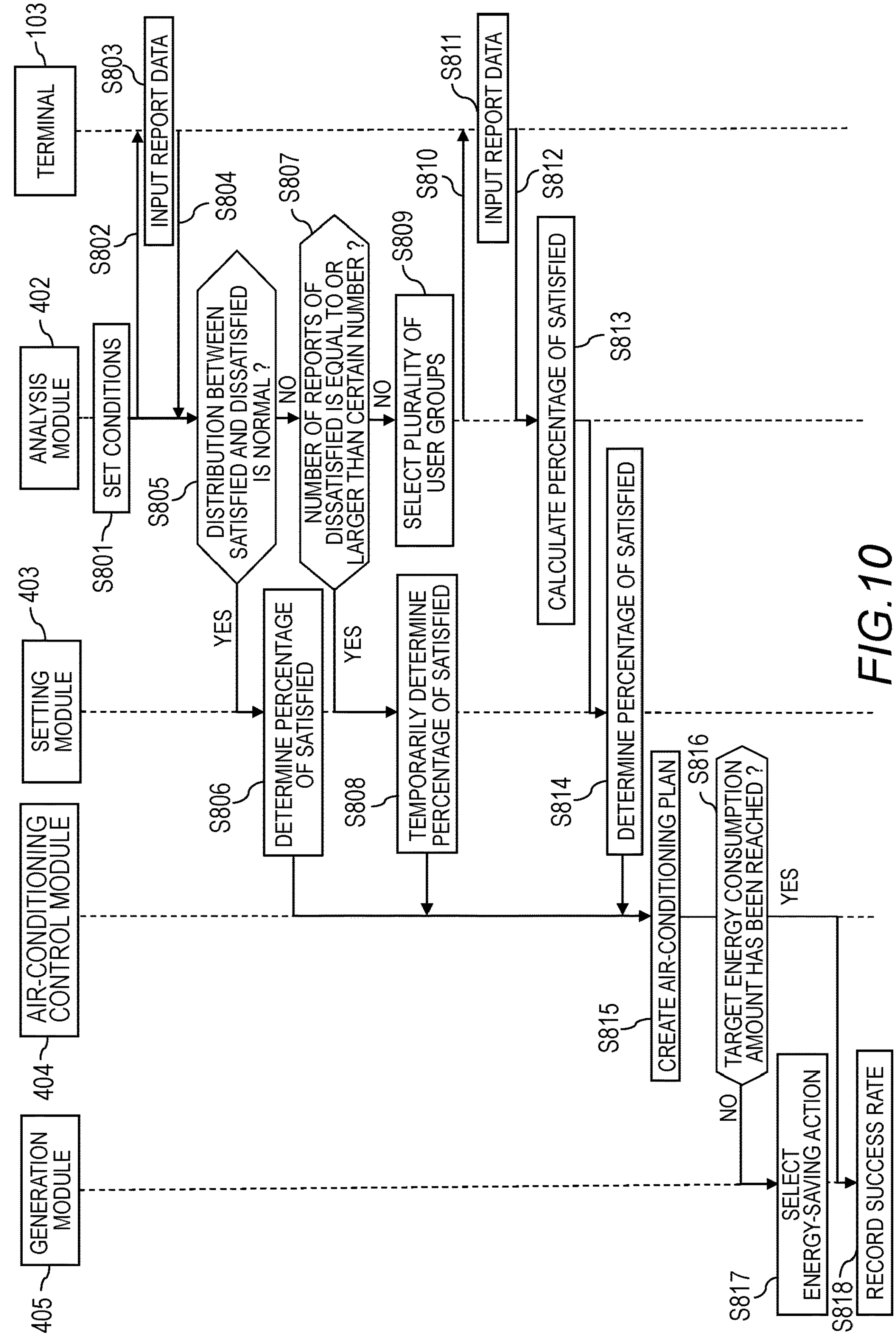
TERMINAL
103
ANALYSIS MODULE
402
SETTING MODULE
403
AIR-CONDITIONING CONTROL MODULE
404
GENERATION MODULE
405
S801
SET CONDITIONS
S802
S803
INPUT REPORT DATA
S804
S805
DISTRIBUTION BETWEEN SATISFIED AND DISSATISFIED IS NORMAL ?
YES
NO
S806
DETERMINE PERCENTAGE OF SATISFIED
S807
NUMBER OF REPORTS OF DISSATISFIED IS EQUAL TO OR LARGER THAN CERTAIN NUMBER ?
YES
NO
S808
TEMPORARILY DETERMINE PERCENTAGE OF SATISFIED
S809
SELECT PLURALITY OF USER GROUPS
S810
S811
INPUT REPORT DATA
S812
S813
CALCULATE PERCENTAGE OF SATISFIED
S814
DETERMINE PERCENTAGE OF SATISFIED
S815
CREATE AIR-CONDITIONING PLAN
S816
TARGET ENERGY CONSUMPTION AMOUNT HAS BEEN REACHED ?
YES
NO
S817
SELECT ENERGY-SAVING ACTION
S818
RECORD SUCCESS RATE

FIG. 10

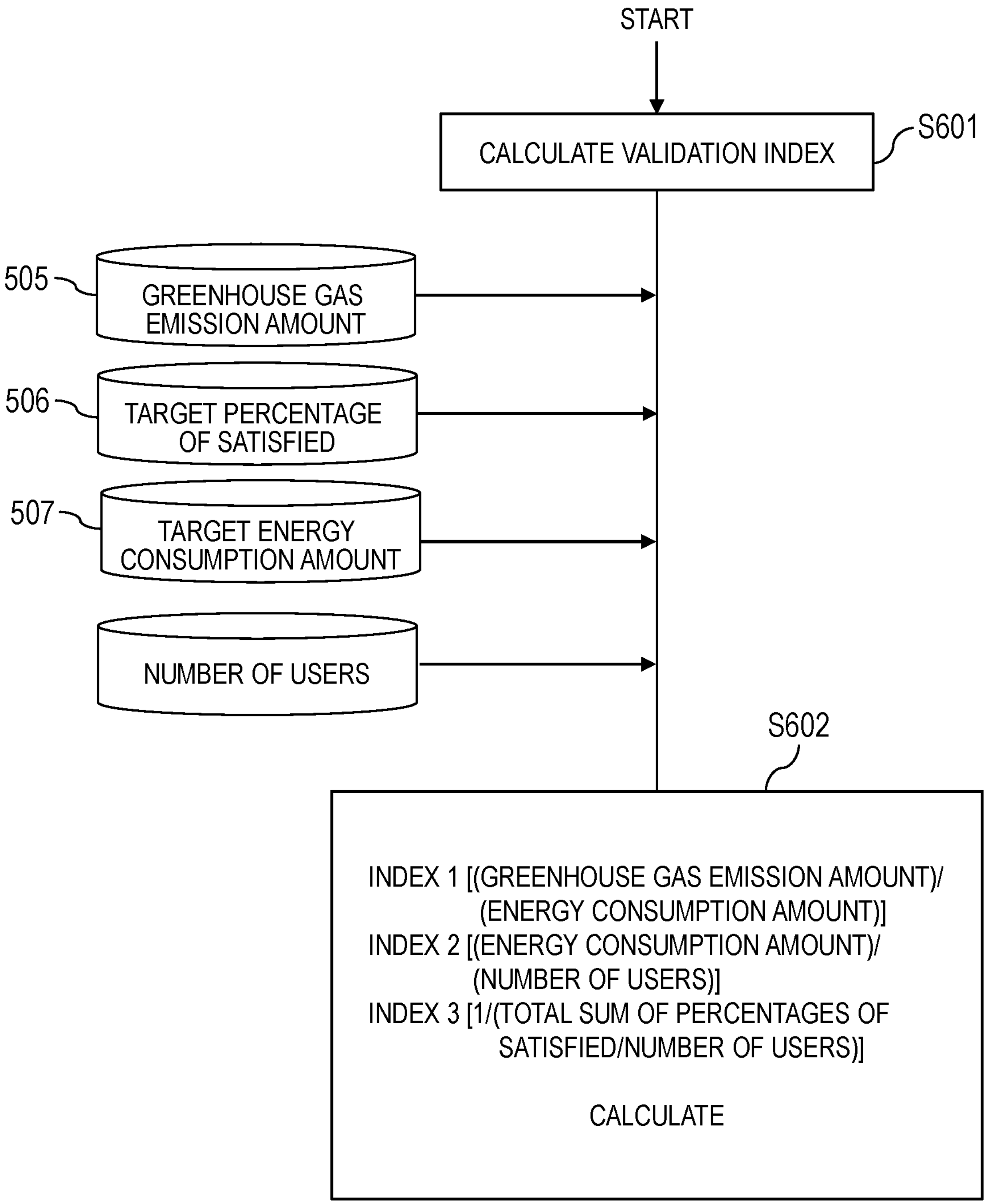
START
CALCULATE VALIDATION INDEX
S601
505
GREENHOUSE GAS EMISSION AMOUNT
506
TARGET PERCENTAGE OF SATISFIED
507
TARGET ENERGY CONSUMPTION AMOUNT
NUMBER OF USERS
S602
INDEX 1 [(GREENHOUSE GAS EMISSION AMOUNT)/ (ENERGY CONSUMPTION AMOUNT)]
INDEX 2 [(ENERGY CONSUMPTION AMOUNT)/ (NUMBER OF USERS)]
INDEX 3 [1/(TOTAL SUM OF PERCENTAGES OF SATISFIED/NUMBER OF USERS)]
CALCULATE

FIG.11

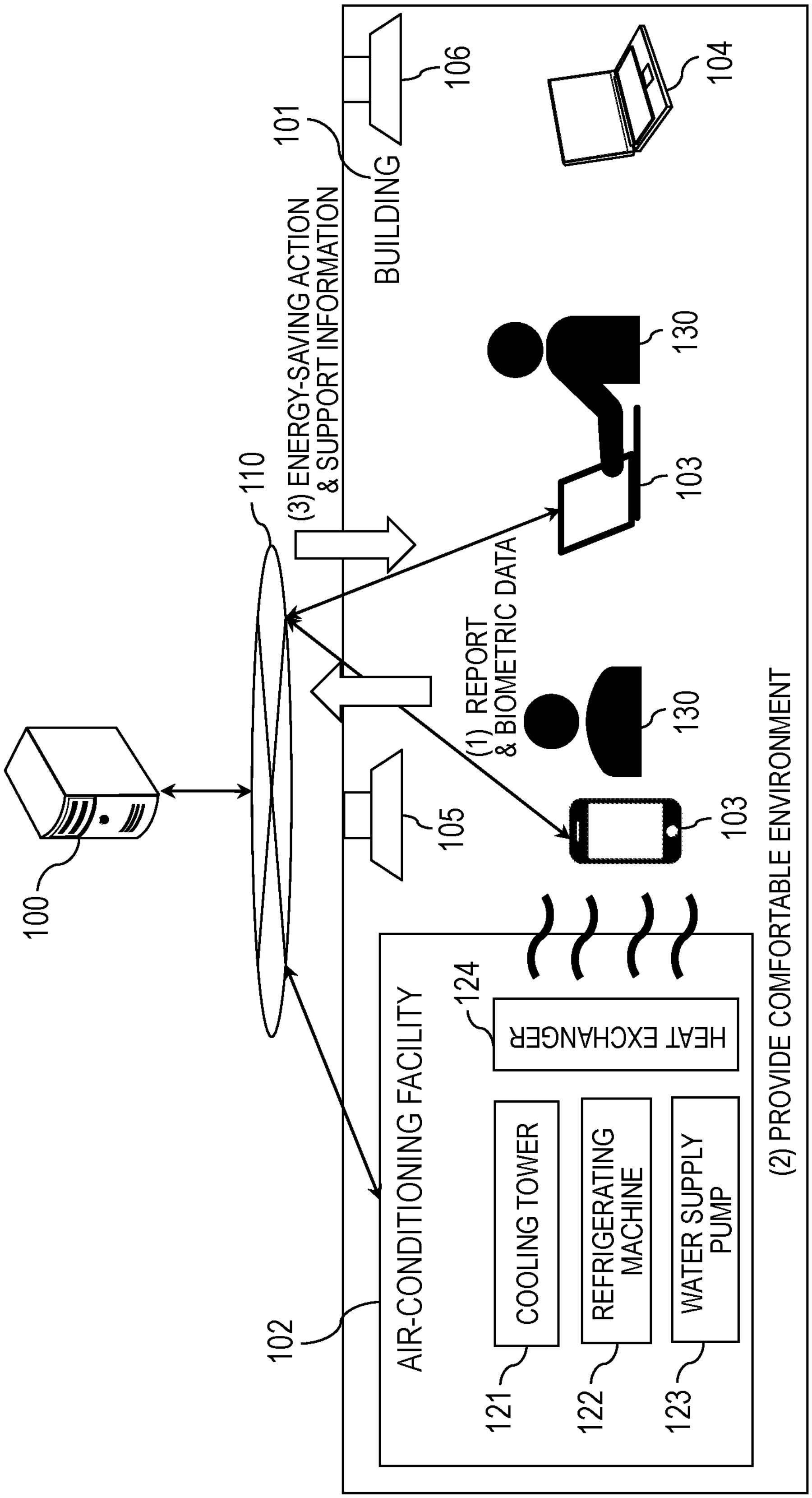
100
110
101
106
104
BUILDING
(3) ENERGY-SAVING ACTION
& SUPPORT INFORMATION
(1) REPORT
& BIOMETRIC DATA
130
103
105
(2) PROVIDE COMFORTABLE ENVIRONMENT
102
AIR-CONDITIONING FACILITY
124
HEAT EXCHANGER
COOLING TOWER
REFRIGERATING MACHINE
WATER SUPPLY PUMP
121
122
123

FIG.12

ENERGY MANAGEMENT SYSTEM AND ENERGY MANAGEMENT METHOD

CLAIM OF PRIORITY

The present application claims priority from Japanese patent application JP 2020-093535 filed on May 28, 2020, the content of which is hereby incorporated by reference into this application.

BACKGROUND

This invention relates to a system and method for managing energy.

In recent years, spread and expansion of renewable energies for reducing greenhouse gases have continued. Of the renewable energies, variable renewable energies (VREs), in particular, energies from wind power generation and solar power generation, are pointed out as requiring to have a supply-demand balance adjusted in a mode that does not depend on fossil fuels for thermal power generation, which have hitherto been adopted, in accordance with variations in energy supply.

In recent years, business sectors of, for example, office buildings, commercial facilities, and public facilities have shown an increasing trend in a ratio of power demand to the total power demand. The power demand in the business sectors has a feature of various trends in power consumption due to a variety of consumers and a feature of difficulty in its demand forecast.

In view of the difficulty in forecast of the trends in power consumption, there is “area energy management” in which a certain zone is set to comprehensively including locations of individual office buildings, commercial facilities, public facilities, and other facilities, a total value of power demand in a building group included in the zone is obtained, and an upper limit value of the power consumption in the zone is set at or below a certain level. The “area energy management” has been proposed as a method of avoiding uncertainty about the forecast of the power demand in the individual office buildings, commercial facilities, public facilities, and other facilities.

In addition, in order to cooperate with VREs, it is essential for consumers to make adjustments by, for example, suppressing an energy consumption amount and actively using surplus energy, and it is required for residents, workers in the office buildings, and employees and customers in the commercial facilities (those people are hereinafter referred to as “users”), which are the consumers, to continue to be satisfied with comfortableness defined by, for example, a temperature and a humidity. A decrease in comfortableness may adversely lower productivity in offices and affect sales of the commercial facilities.

In JP 2015-4480 A, there is disclosed a request discrimination apparatus for reliably improving an indoor environment when there is a high need for improvement of the indoor environment and avoiding transition to an extreme indoor environment due to continuation of a specific individual's reporting. This request discrimination apparatus includes: a request holding module configured to receive a request for a surrounding environment from a reporter; an environmental state quantity management module configured to calculate an environmental state quantity indicating a state of the surrounding environment of the reporter based on environmental element measurement values collected from a reporter's seated space, and to obtain a degree of dissatisfaction with the surrounding environment of the reporters from the environmental state quantity; and a discrimination processing module configured to discriminate whether the request received from the reporter is a temporary request or a regular request based on the degree of dissatisfaction.

In JP 2002-135977 A, there is disclosed a system for operating and controlling a power facility by setting a target value for an amount of power during a predetermined period. In this system, a power management apparatus configured to control the power facility and a control terminal apparatus configured to create control data based on data transferred from the power management apparatus and other data are coupled to each other in a data exchangeable manner. The power management apparatus includes power data creation means for detecting power usage of the power facility, operational data creation means for creating operational data of a facility in which the power facility is installed, and environment data creation means. The control terminal apparatus includes past data analysis means for analyzing a past operational status of the power facility based on each piece of the above-mentioned data transferred from the power management apparatus, predicted power amount calculation means for calculating a predicted amount of power based on an analysis result of the past data analysis means, and target power amount calculation means for calculating a target amount of power from the predicted amount of power. The control terminal apparatus is configured to transfer data corresponding to the target amount of power obtained by the target power amount calculation means to the power management apparatus, to thereby control the power facility.

In Jongyeon Lim, Yasunori Akashi, Doosam Song, Hyokeun Hwang, Yasuhiro Kuwahara, Shinji Yamamura, Naoki Yoshimoto, Kazuo Itahashi, “Hierarchical Bayesian modeling for predicting ordinal responses of personalized thermal sensation: Application to outdoor thermal sensation data” (Building and Environment Volume 142, September 2018, pages 414-426), as a method of estimating a correlation between a thermal sensation and satisfaction, there is disclosed a method of estimating, through the Bayesian inference, the cause of satisfaction being the thermal sensation when the outcome variable being satisfaction with the thermal sensation is known.

The power demand in the business sectors of, for example, office buildings, commercial facilities, and public facilities has the feature of various trends in power consumption due to a variety of consumers and the feature of difficulty in its demand forecast. In the related-art “area energy management” for comprehensively setting a certain zone and controlling the power demand in the building group included in the zone to have a total value equal to or smaller than a certain value, there is a fear in that energy use in each individual building may be operated in such a form as to impair the comfortableness of the residents.

Meanwhile, in order to obtain the comfortableness of users, the reports of comfortableness from the users can be used for grasping the situation, but it is still difficult to maximize the comfortableness of users in the entire living space. This is because users tend to proactively report when the users are dissatisfied but tend not to report when the situation is optimal, and hence the comfortableness cannot simply depend only on the report information.

In addition, when air conditioning for a staying space is controlled in such a manner as to maximize the comfortableness of users, energy consumption due to the air-conditioning control may increase or decrease compared to the related art. Therefore, in order to cooperate with renewable energy in terms of energy use while controlling the air conditioning of the living space so that a percentage of dissatisfied users falls within a certain range, it is essential to be able to predict a relationship between the comfortableness of users and the energy consumption.

In addition, in order to achieve such energy consumption as to utilize VREs as much as possible while maintaining the comfortableness of residents, it is essential to take specific measures not only for facility control of architectural structures for residential purposes but also for integrated control in consideration of operation modes and demand schedules.

SUMMARY

This invention has an object to distribute appropriate energy demand plans to a group of buildings in consideration of a percentage of satisfied users, and to achieve appropriate air-conditioning control based on the energy demand plan.

An aspect of the invention disclosed in this application is an energy management system, which is configured to control operations of air-conditioning facilities in a plurality of buildings, the energy management system comprising: a processor configured to execute a program; a storage device configured to store the program; and an interface communicable to/from a plurality of terminals, wherein the storage device is configured to store, for each of the plurality of buildings: a first piece of data indicating a relationship between the operation of each of the air-conditioning facilities and an energy consumption amount of each of the air-conditioning facilities; a second piece of data indicating an operational status of each of the air-conditioning facilities; a third piece of data indicating weather; and a fourth piece of data indicating warm and cold in the each of the plurality of buildings, and wherein the processor is configured to: receive, for each of the plurality of buildings, report data indicating a satisfaction feeling relating to warm and cold in a staying space of a user in the each of the plurality of buildings from each of the plurality of terminals; calculate a percentage of satisfied based on the report data for each of the plurality of buildings, the percentage of satisfied representing the satisfaction feeling as a ratio of an estimated number of users who have expressed satisfied to a number of users being a population in the staying space by a statistical method; create, for each of the plurality of buildings, a plan for operating each of the air-conditioning facilities based on the percentage of satisfied and a predetermined target percentage of satisfied; calculate a first energy consumption amount based on the first piece of data, the first energy consumption amount being obtained when each of the air-conditioning facilities in the plurality of buildings is operated by the plan distributed to the each of the plurality of buildings; calculate a second energy consumption amount based on the second piece of data, the third piece of data, and the fourth piece of data, the second energy consumption amount being obtained when the each of the air-conditioning facilities is operated after a lapse of a predetermined time period; and control, when the first energy consumption amount is larger than the second energy consumption amount, the operation of the each of the air-conditioning facilities so as to achieve the second energy consumption amount.

According to at least one representative embodiment of this invention, it is possible to achieve appropriate air-conditioning control in consideration of the percentage of the satisfied users. The details of one or more implementations of the subject matter described in the specification are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an explanatory diagram for illustrating management of a plurality of building groups among examples of energy management by an energy management system according to a first embodiment of this invention.

FIG. **2** is an explanatory diagram for illustrating energy management inside the building by focusing on one building in the building group illustrated in FIG. **1** among the examples of the energy management by the energy management system according to the first embodiment.

FIG. **3** is a block diagram for illustrating a hardware configuration example of each of computers (energy management system and terminal).

FIG. **4** is an explanatory diagram for illustrating energy demand distribution to a plurality of buildings in the first embodiment.

FIG. **5** is an explanatory diagram for illustrating an example of a report screen displayed on the terminal.

FIG. **6** is a block diagram for illustrating a functional configuration example of the energy management system.

FIG. **7** is a flow chart for illustrating a basic operation example of the energy management system.

FIG. **8** is a graph for showing an example of the correlation of the operative temperature based on the report on the satisfaction.

FIG. **9** shows a specific energy consumption amount (power consumption) with respect to a target load for each of the cooling tower, the refrigerating machine, and the water supply pump of the air-conditioning facility.

FIG. **10** is an explanatory flow chart for illustrating estimation of opinions of the entire users with respect to the report data.

FIG. **11** is a flow chart for illustrating an example of integrated control of the percentage of satisfied of the users, a power demand adjustment of the building, and the decarbonization, which is to be performed by the energy management system according to the second embodiment.

FIG. **12** is an explanatory diagram for illustrating an example of the energy management by the energy management system according to the third embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Now, embodiments of this disclosure are described with reference to the accompanying drawings. The embodiments of this disclosure are not limited to the embodiments described later, and various modifications can be made within the gist of its technical spirit. Corresponding parts of each drawing to be used for describing each of the embodiments described later are denoted by the same reference symbols, and duplicate description is omitted.

First Embodiment

<Example of Energy Management by Energy Management System>

FIG. **1** is an explanatory diagram for illustrating management of a plurality of building groups among examples of energy management by an energy management system according to a first embodiment of this invention. An energy management system **100** is a building group **101***s* including a plurality of buildings **101** (Examples thereof include buildings **101-1**, **101-2**, and **101-3**, which are referred to simply as "buildings **101**" unless otherwise specified. The number of buildings **101** may be two, or equal to or larger than four.), and those buildings are coupled to one another by a power system in terms of energy. As long as the buildings **101-1**, **101-2**, and **101-3** are coupled to one another by the power system in terms of energy, the buildings **101-1**, **101-2**, and **101-3** may be physically distant from one another. The buildings **101** are, for example, office buildings, complex buildings, schools, commercial facilities, apartment buildings, and other building structures including a plurality of rooms.

FIG. **2** is an explanatory diagram for illustrating energy management inside the building **101** by focusing on one building **101** in the building group **101***s* illustrated in FIG. **1** among the examples of the energy management by the energy management system **100** according to the first embodiment. The energy management system **100** is configured to control an air-conditioning facility **102** installed in the building **101** to provide a comfortable environment to users **130** in the building.

The air-conditioning facility **102** includes a cooling tower **121**, a refrigerating machine **122**, a water supply pump **123**, and a heat exchanger **124**. The cooling tower **121** is an apparatus configured to input a coolant to dissipate the coolant and to output the dissipated coolant to the refrigerating machine **122**. The refrigerating machine **122** is an apparatus configured to cool the coolant from the cooling tower **121** through use of refrigerant to produce chilled water. The water supply pump **123** is configured to output the chilled water from the refrigerating machine **122** to the heat exchanger **124**. The heat exchanger **124** is configured to cool the air for air conditioning with the chilled water of the refrigerating machine **122** which has been supplied by the water supply pump **123**. This cooled air is blown into the building **101**.

As described above, each of the users **130** is a resident or a worker in the building **101** or an employee or a customer in each of the commercial facilities. The user **130** uses a terminal **103**. The terminal **103** can communicate to/from the energy management system **100** through a network **110**, for example, the Internet, a local area network (LAN), or a wide area network (WAN).

In addition, an electronic apparatus **104**, for example, a personal computer, a copying machine, a printer, or a refrigerator, and lighting fixtures **105** and **106** are provided in the building **101**. It is assumed that the lighting fixture **105** illuminates a staying space in which the user **130** is present and the lighting fixture **106** illuminates a space in which the electronic apparatus **104** is placed.

(1) The terminal **103** transmits report data indicating a satisfaction feeling characterized by a temperature and a humidity in the staying space in the building **101** and an amount of clothes and an amount of metabolism of the user **130**, to the energy management system **100** through operation input by the user **130**. The energy management system **100** is also coupled to a sensor (not shown) configured to detect radiation temperatures from the user **130**, the electronic apparatus **104**, the lighting fixtures **105** and **106**, and a floor so as to enable communication therebetween, and acquires the radiation temperatures separately from the report data. The energy management system **100** is also coupled to a sensor (not shown) configured to detect a wind velocity of the wind output from the air-conditioning facility **102** so as to enable communication therebetween, and acquires the wind velocity separately from the report data. In the following description, the term "report data" may include the radiation temperature and the wind velocity.

(2) The energy management system **100** receives the report data from the terminal **103**, analyzes the satisfaction feeling of the user **130**, determines an operation policy of control relating to the air-conditioning facility **102**, and executes the control of the air-conditioning facility **102**. (3) When a target energy reduction amount is not expected to be reached only by the control of the air-conditioning facility **102**, energy-saving action information for encouraging the user **130** to take an energy-saving action is sent to the user **130** to encourage reduction of an energy consumption amount through the energy-saving action. The energy-saving action information is information for encouraging an energy-saving action of, for example, turning off the power of the electronic apparatus **104** or the lighting fixture **106** that is not being used even after the power is turned on.

<Hardware Configuration Example of Computer>

FIG. **3** is a block diagram for illustrating a hardware configuration example of each of computers (energy management system **100** and terminal **103**). A computer **200** includes a processor **201**, a storage device **202**, an input device **203**, an output device **204**, and a communication interface (communication IF) **205**. The processor **201**, the storage device **202**, the input device **203**, the output device **204**, and the communication IF **205** are coupled to one another through a bus **206**. The processor **201** is configured to control the computer **200**. The storage device **202** serves as a work area for the processor **201**. The storage device **202** is also a non-transitory or transitory recording medium configured to store various programs and various kinds of data. Examples of the storage device **202** include a read only memory (ROM), a random access memory (RAM), a hard disk drive (HDD), and a flash memory. The input device **203** is configured to input data. Examples of the input device **203** include a keyboard, a mouse, a touch panel, a numeric keypad, and a scanner. The output device **204** is configured to output data. Examples of the output device **204** include a display, a printer, and a speaker. The communication IF **205** is coupled to the network **110**, and is configured to transmit and receive data.

<Demand Distribution to Building Group>

In the building group **101***s* formed of a plurality of buildings **101-1**, **101-2**, and **101-3**, in order for each individual building **101** to utilize renewable energy as much as possible to achieve decarbonization, it is required to grasp the power demand in the building **101** and distribute an appropriate power demand plan. The power demand plan is a plan relating to the power consumption of the entire building to be exhibited in conjunction with the distribution of renewable energy, and also includes an air-conditioning plan. The distribution of the power demand plan to each building **101** is determined with reference to, for example, a greenhouse gas emission amount or another index relating to the energy consumption, the performance and scale of an air-conditioning facility in each building, and an expected power demand amount in each building. For example, when the power demand plan is implemented in consideration of the performance and scale of the air-conditioning facility **102** of each building **101**, the planning can be performed in consideration of the users **130** by, for example, encouraging appropriate power demand in the building **101** including the high-performance air-conditioning facility **102**.

As illustrated in FIG. **4**, a specific method of distributing the power demand plan to each building **101** is to set goals for decarbonization, power consumption costs, and other targets against the background of various factors relating to decarbonization which include a trend in power generation of renewable energy, a time trend in power wholesale unit price, a time trend in emissions per unit of power being supplied, and a time trend in power wholesale unit price of energy other than the renewable energy. For the distribution of the power demand plan to each building **101**, it is possible to employ a known technology for predicting power supply and demand, for example, a technology for predicting power demand or a technology for predicting a power generation amount of renewable energy.

<Report Screen>

Next, description is given of a method of reporting, by a resident, his or her own degree of satisfaction. FIG. **5** is an explanatory diagram for illustrating an example of a report screen displayed on the terminal **103**. A report screen **300** includes a thermal sensation report area **301**, a satisfaction feeling report area **302**, a stress report area **303**, and a submit button **304**. The thermal sensation report area **301** includes a first slider **311** and a first horizontal axis **312**. A thermal sensation of the user **130** due to the air-conditioning facility **102** is designated by operating the first slider **311** in a direction of the first horizontal axis **312**. The satisfaction feeling report area **302** includes a second slider **321** and a second horizontal axis **322**. A satisfaction feeling of the user **130** with an environment air-conditioned by the air-conditioning facility **102** is designated by operating the second slider **321** in a direction of the second horizontal axis **322**. The stress report area **303** includes a third slider **331** and a third horizontal axis **332**. A magnitude of stress of the user **130** is designated by operating the third slider **331** in a direction of the third horizontal axis **332**.

The submit button **304** is a button for transmitting, when pressed by the user **130**, values of the thermal sensation, the satisfaction feeling, and the stress which have been designated through the first slider **311** to the third slider **331** as the report data from the terminal **103** to the energy management system **100**.

On the report screen **300**, as an example, the thermal sensation report area **301** enables one of a plurality of degrees from hot to cold to be designated through the first slider **311**, but may be an area that enables the thermal sensation such as hot and cold to be designated based on the temperature, the humidity, the radiation temperature, the wind velocity, and the amount of clothes and the amount of metabolism of the resident.

The satisfaction feeling report area **302** enables the designation through the second slider **321** in the form of choosing between two options of satisfied and dissatisfied with the staying space of the user **130**, but may be an area that enables the satisfaction feeling to be designated based on the temperature, the humidity, the radiation temperature, and the wind velocity in the staying space and the amount of clothes and the amount of metabolism of the resident.

The energy management system **100** may also acquire sequential data on the temperature and the humidity, which are basic data on the staying space of the user **130**, from the terminal **103**. The energy management system **100** is desired to acquire a plurality of points of sequential data on the temperature and the humidity so as to cover the staying space of the user **130** as much as possible.

Under the present circumstances, the radiation temperature and the wind velocity may not always be detected as sequential data due to the fact that the sensors therefor are expensive, but the energy management system **100** is desired to acquire data on the radiation temperature and the wind velocity during typical operations from the terminal **103** and refer to the data. The energy management system **100** is also desired to acquire the amount of clothes and the amount of metabolism which exert influences on the satisfaction of the user **130** from the terminal **103**, but an influence on an evaluation of satisfaction is known to be small even when values of the amounts are fixed according to the related art, and hence there is no problem even when the values are fixed.

<Functional Configuration Example of Energy Management System **100**>

FIG. **6** is a block diagram for illustrating a functional configuration example of the energy management system **100**. In the energy management system **100**, individual power demand plans are formulated for the plurality of buildings **101-1**, **101-2**, and **101-3**, reports on the degrees of satisfaction are received from the users **130** based on the demand plans, and a target thermal sensation is calculated.

The energy management system **100** includes a reception module **401**, an analysis module **402**, a setting module **403**, an air-conditioning control module **404**, a generation module **405**, an output module **406**, and an integrated calculation module **407**. Specifically, the reception module **401** to the integrated calculation module **407** are implemented by, for example, causing the processor **201** to execute the program stored in the storage device **202** illustrated in FIG. **2**.

The reception module **401** is configured to receive the report data provided by the user **130** and various kinds of data, for example, from weather situation data **411** to biometric data **418**, from the terminal **103** or the network **110** for each building **101**. The analysis module **402** is configured to analyze the percentage of satisfied of the users **130** present in the staying space. The setting module **403** is configured to set conditions for air-conditioning control. Thus, a method of controlling the air-conditioning facility **102** is determined.

The air-conditioning control module **404** is configured to control an operation of the air-conditioning facility **102** based on settings of the setting module **403**. The generation module **405** is configured to generate energy-saving action information for each building **101** when an energy consumption amount required for the operation of the air-conditioning facility **102** is insufficient. The output module **406** is configured to output the energy-saving action information generated by the generation module **405** to the terminal **103**. The integrated calculation module **407** is configured to create an air-conditioning plan for each building **101** in accordance with a set target percentage of satisfied, and calculate an energy consumption amount A and a target energy consumption amount B of the entire plurality of buildings **101-1**, **101-2**, and **101-3**, which are described later.

The energy management system **100** further stores the weather situation data **411**, weather forecast data **412**, building operation calendar **413**, building past operation data **414**, facility operational data **415**, energy-saving category data **416**, indoor thermal data **417**, and the biometric data **418**, in the storage device **202** for each building **101**.

The weather situation data **411** includes weather data on, for example, current weather (e.g., sunny, cloudy, rain, or snow), temperature, and humidity. The weather situation data **411** is data that can be measured in the building **101** or acquired from a website of a weather forecast company (business entity licensed to provide forecasting operations).

The weather forecast data **412** is forecast data on the weather (including the temperature and the humidity) after a predetermined time period, and is data that can be acquired from the websites of the Japan Meteorological Agency and the weather forecast company.

The building operation calendar **413** includes data on details and date/time of an event to be held in the building **101**.

The building past operation data **414** is actual record data obtained by recording the temperature, the radiation temperature, the humidity, and the wind velocity in the building **101** when the air-conditioning facility **102** was operated in the building **101** in the past. As the building past operation data **414**, pieces of past operation data are accumulated in a log format, but the energy management system **100** may classify the building past operation data **414** to create a plurality of operation patterns. Instead of creating the operation patterns in advance, the energy management system **100** may search for similar log data to create an operation pattern each time.

The facility operational data **415** indicates an operational status of the air-conditioning facility **102** in the building **101**, and includes data on, for example, a water supply temperature, a coolant temperature, operation states of valves and pumps, and the number of refrigerating machines **122** in operation.

The energy-saving category data **416** is data indicating a correspondence relationship between the energy-saving action information and the energy consumption amount reduced by the energy-saving action. The energy-saving action information is information in which energy-saving actions of, for example, turning off the lighting fixture, reducing overtime work, and proposing a break, and facilities to be subjected to the energy-saving actions (for example, the lighting fixture for the energy-saving action of turning off the lighting fixture) are associated with each other. Thus, when an energy amount for the operation of the air-conditioning facility **102** is insufficient, the generation module **405** can generate the energy-saving action information regarding the shortage by referring to the energy-saving category data **416**.

The indoor thermal data **417** includes data on the indoor temperature and humidity in the building **101**, and may include data relating to human sensations and behaviors (for example, thermal indices (including an effective temperature, a discomfort index, and a thermal sensation index), a sensible temperature, a thermal sensation, comfortableness, a sense of the season, and the amount of clothing).

The biometric data **418** includes, for example, a heart rate of the user **130**, capillary data on a face of the user **130** photographed by a Web camera, and an observed value of a vibration sensor provided on a seat surface of a chair in which the user **130** is seated. The heart rate is transmitted from a wearable apparatus attached to the user **130** to the energy management system **100** through the terminal **103** of the user **130**. The Web camera and the vibration sensor are installed in the building **101**, and can transmit the capillary data and the observed value to the energy management system **100**.

The individual buildings **101** differ in peak daily energy demand among office buildings, complex buildings, schools, commercial facilities, apartment buildings, and other buildings, and also differ in operation control of the air-conditioning facility **102**. The buildings **101** exhibiting such different patterns of energy demand are handled as one building group **101***s*, and the energy consumption in this building group **101***s* is minimized, to thereby enable the energy management system **100** to achieve energy operation based on appropriate control corresponding to performance of the building **101** and scales of apparatus.

<Basic Operation of Energy Management System **100**>

FIG. **7** is a flow chart for illustrating a basic operation example of the energy management system **100**. With the air-conditioning plan, energy management is implemented based on the power demand plan distributed to each building **101**. The energy management system **100** controls the reception module **401** to receive report data **500** indicating “satisfied” or “dissatisfied” and “hot” or “cold” regarding the thermal sensation in the staying space of the user **130**, and controls the analysis module **402** to estimate a correlation between the thermal sensation and the satisfaction (Step S**501**). As a method of estimating the correlation between the thermal sensation and the satisfaction, it is appropriate to employ a method of estimating, through the Bayesian inference, the cause of the satisfaction being the thermal sensation when the outcome variable being the satisfaction with the thermal sensation is known (see, for example, “Hierarchical Bayesian modeling for predicting ordinal responses of personalized thermal sensation: Application to outdoor thermal sensation data” described above), but there is no particular limitation thereto. In this case, an example of the correlation of an operative temperature based on the report on the satisfaction is illustrated.

FIG. **8** is a graph for showing an example of the correlation of the operative temperature based on the report on the satisfaction. In a graph **600**, the horizontal axis represents the operative temperature, and the vertical axis represents the percentage of satisfied. The operative temperature is a temperature determined based on the indoor temperature and the radiation temperature. A first correlation data **601** indicates a related-art theoretical value. A second correlation data **602** is formed of estimated values based on observed values **603** determined by the report data **500**. In general, the percentage of satisfied being a ratio of the users **130** satisfied with the thermal sensation in the staying space is about 70% at most, and it is required to reduce the number of dissatisfied users **130** as much as possible by controlling the thermal sensation with the 70% being regarded as satisfied.

In this case, a ratio of the users **130** who have reported satisfied to the total users **130** in the staying space, which are an example of a population, is defined as the percentage of satisfied.

$$\text{Percentage of satisfied}=(\text{estimated number of users 130 who have reported satisfied})/(\text{total number of users 130}) \quad (1)$$

When the case of FIG. **8** is taken as an example, the percentage of satisfied decreases as a set temperature in the staying space increases after a maximum temperature (22° C.) of the second correlation data **602**. In FIG. **6**, the energy management system **100** controls the setting module **403** to set the percentage of satisfied to be controlled, which is to be applied to operational control of the air-conditioning facility **102**, based on the percentage of satisfied obtained by Expression (1) and the target percentage of satisfied (Step S**502**).

When the target percentage of satisfied has not yet been input, the energy management system **100** requests a system administrator to input the target percentage of satisfied (for example, to display the request on a display screen or transmitted to the terminal **103** of the system administrator) to encourage the input of the target percentage of satisfied. When the target percentage of satisfied has already been input, the energy management system **100** reads the target percentage of satisfied from the storage device **202**.

When the percentage of satisfied is equal to or larger than the target percentage of satisfied, the energy management system **100** determines the target percentage of satisfied as the percentage of satisfied to be controlled. When the percentage of satisfied is not equal to or larger than the target percentage of satisfied, the energy management system **100** determines the percentage of satisfied as the percentage of satisfied to be controlled in a case in which a difference between the percentage of satisfied and the target percentage of satisfied falls within an allowable range, and forcibly determines the target percentage of satisfied as the percentage of satisfied to be controlled in a case in which the difference falls out of the allowable range.

When the percentage of satisfied to be controlled is set, the energy management system **100** refers to FIG. **6** to determine an operative temperature to be controlled in the building **101** corresponding to the percentage of satisfied to be controlled. The energy management system **100** back-calculates a temperature to be controlled and a radiation temperature to be controlled from the operative temperature to be controlled. The energy management system **100** further determines a humidity to be controlled by giving the temperature to be controlled, the radiation temperature to be controlled, and a wind velocity to be controlled (fixed value) to a freely-set thermal sensation index, for example, a predicted mean vote (PMV). Then, the energy management system **100** identifies, from a plurality of operation patterns **501**, a specific operation pattern **501** including the temperature to be controlled, the radiation temperature to be controlled, the humidity to be controlled, and the wind velocity to be controlled.

Then, the energy management system **100** controls the air-conditioning control module **404** to create the air-conditioning plan with reference to the weather forecast data **412**, the building past operation data **414**, the operation pattern **501**, and the building operation calendar **413**, which are external factors.

The air-conditioning plan can be calculated based on simulations of the temperature to be controlled, the radiation temperature to be controlled, the humidity to be controlled, and the wind velocity to be controlled, which are parameters obtained by setting the percentage of satisfied to be controlled, but the calculation is not realistic due to its large calculation amount. Therefore, the energy management system **100** creates the air-conditioning plan by selecting the operation pattern **501**. Subsequently, the energy management system **100** estimates the energy consumption amount A of the air-conditioning facility **102** when the air-conditioning facility **102** is operated based on the selected operation pattern (Step S**503**).

FIG. **9** is a graph for showing a relationship between the operation of the air-conditioning facility **102** and the power consumption. A graph **700** is a graph created based on the building past operation data **414** and the building operation calendar **413**. The curves of the graph **700** varies depending on the weather forecast data **412**. The energy management system **100** controls the power consumption being an example of the energy consumption amount based on a balance among the operations of the refrigerating machine **122** (control of the water supply temperature), the water supply pump **123** (control of a differential pressure between headers and a water supply amount), the cooling tower **121** (control of the coolant temperature), which are included in the air-conditioning facility **102**.

FIG. **9** shows a specific energy consumption amount (power consumption) with respect to a target load for each of the cooling tower **121**, the refrigerating machine **122**, and the water supply pump **123** of the air-conditioning facility **102**. A total of those energy consumption amounts is the energy consumption amount A of the air-conditioning facility **102** to be estimated. Therefore, the energy management system **100** controls the operating number and output of the refrigerating machine **122**, the pressure of the water supply pump **123** for supplying chilled water, and the air flow for air-conditioning the room in Step S**506**, which is described later, so as to optimize the cooling tower **121**, the refrigerating machine **122**, and the water supply pump **123** for the target loads. Thus, instead of detailed control conditions, it is possible to achieve the shortening of both time periods for determining the percentage of satisfied of the users **130** and a control policy.

In this manner, the energy consumption amount A is estimated by the integrated calculation module **407** based on the report data **500**. The energy consumption amount A is estimated with the satisfaction of the user **130** being maintained at a constant level, and hence the energy consumption amount generally becomes smaller than a related-art energy consumption amount based on a uniform temperature setting, for example, a room temperature setting of 28° C. in summer.

The energy management system **100** controls the integrated calculation module **407** to determine whether or not "A−B>0" is satisfied (that is, whether or not A is larger than B). The symbol B represents a target energy consumption amount. The energy management system **100** controls the integrated calculation module **407** to calculate the target energy consumption amount B after a predetermined time period (for example, after 30 minutes) based on the weather situation data **411**, the weather forecast data **412**, the facility operational data **415**, and the indoor thermal data **417** (Step S**504**). Step S**504** is executed when, for example, the energy management system **100** receives a demand response from a consumer using the building **101**. The target energy consumption amount B may be an energy consumption amount set in advance.

Subsequently, when "A−B>0" is satisfied (Yes in Step S**505**), the energy management system **100** controls the operating number and output of the refrigerating machine **122**, the pump pressure for supplying chilled water, and the air flow for air-conditioning the room so as to achieve the target energy consumption amount B (Step S**506**).

Meanwhile, when "A−B>0" is not satisfied (No in Step S**505**), the energy consumption amount of the air-conditioning facility **102** is insufficient only with the energy reduction amount by the operational control of the air-conditioning facility **102**. Therefore, in order to make up for the shortage, the energy management system **100** controls the generation module **405** to select an energy-saving action corresponding to the shortage from the energy-saving category data **416** (Step S**507**).

Then, the energy management system **100** controls the output module **406** to transmit the selected energy-saving action information to the terminal **103** (Step S**508**). Thus, when there is a shortage, replenishment corresponding to the energy reduction amount can be performed by the energy-saving action instructed for the user **130**.

In regard to the energy-saving action, it is known from the field of behavioral psychology that it is effective to give a plurality of options. In the first embodiment as well, it is desired that the energy management system **100** transmit a plurality of pieces of energy-saving action information through use of the terminal **103**, for example, a smartphone or a personal computer for work. Specifically, it is clear that there is an energy-saving action that is easily allowed depending on a transmission time slot, the weather, and the target percentage of satisfied, and in the first embodiment as well, the energy management system **100** may control the generation module **405** to select the energy-saving action information with reference to the transmission time slot, the weather, and the target percentage of satisfied.

For example, when the transmission time slot is a working time slot (which may vary depending on the weather), the generation module **405** may select an energy-saving action of, for example, temporarily refraining from using a heat source in a common area including a hot water supply area. Meanwhile, when the transmission time slot is outside working hours (which may vary depending on the weather), the generation module **405** may select an energy-saving action relating to turning off, for example, an energy-saving action of turning off the lighting fixtures in the office or turning off the lighting fixtures in the common area, or may select an energy-saving action relating to lowering of concentration, for example, an energy-saving action of suppressing overtime work or lowering work efficiency. This can suppress the energy consumption amount by encouraging the users to return home or take a break. When a plurality of target percentages of satisfied are set, the generation module **405** may select energy-saving action information for each of the plurality of target percentages of satisfied.

Further, the energy management system **100** controls the generation module **405** to set, as a success rate, a ratio of the users **130** who have returned a response corresponding to the energy-saving action to the energy management system **100** out of the number of terminals **103** to which the energy-saving action information has been transmitted, and to record the success rate together with the energy-saving action information (Step S**509**). The generation module **405** sorts pieces of energy-saving category data **416** in descending order of the success rate, to thereby evaluate the energy-saving category data **416**, namely, the energy-saving action. When a plurality of energy-saving actions can be selected, the energy management system **100** may control the generation module **405** to select, from among the plurality of energy-saving actions, the energy-saving action having a high success rate or an energy-saving action having a success rate equal to or higher than a threshold value. Thus, the energy-saving action is selected with great importance placed on actual records. In this manner, the pieces of energy-saving category data **416** are classified into categories that are highly relating to the transmission time slot of the energy-saving action information, the weather, and the target percentage of satisfied.

As described above, in order to achieve both the minimized emission of greenhouse gases and the satisfaction of each individual user, the energy management system **100** can formulate the air-conditioning plan based on the report data **500** so as to ensure the percentage of satisfied equal to or higher than a certain level, the percentage indicating the ratio of users who are satisfied in the entire staying space, and can send the energy-saving action information to the users when the energy consumption amount is insufficient.

<Estimation of Opinions of Entire Users **130** with Respect to Report Data **500**>

The user **130** frequently transmits the report data **500** to the energy management system **100** when he or she feels dissatisfied, but often avoids transmitting the report data **500** when he or she feels satisfied. Therefore, it is often unclear whether or not the percentage of satisfied of the entire users **130** is grasped simply by accumulating pieces of the report data **500**. In view of this, the energy management system **100** extracts a plurality of a certain number of user groups at different times, calculates the percentage of satisfied for each of the user groups by Expression (1), and compares the percentages with one another, to thereby be able to estimate an appropriate percentage of satisfied.

FIG. **10** is an explanatory flow chart for illustrating estimation of opinions of the entire users **130** with respect to the report data **500**. The vertical dotted line indicates a time axis, and it is assumed that the time passes in a direction from top to bottom. The analysis module **402** sets a certain number of target users **130** and a time and cycle period for the certain number of users **130** to transmit the report data **500** (Step S**801**). The setting may be performed in Step S**801** by a system administrator through his or her input or by the analysis module **402** through selection from past setting examples. It is also desired that the number of users to be encouraged to transmit the report data **500** be limited to a part of the entire users **130**, for example, about 10% so as to avoid an imbalance in the users **130**. In addition, it is desired to balance the time to encourage the user to transmit the report data **500** among morning, afternoon, and evening so as to avoid the imbalance.

The analysis module **402** transmits a request for the report data **500** to the terminal **103** (Step S**802**). Thus, the report screen **300** is displayed on a display of the terminal **103**. The user **130** inputs, on the report screen **300**, the report data **500** on, for example, the thermal sensation, the satisfaction feeling, and the stress (Step S**803**), and transmits the report data **500** to the energy management system **100** (Step S**804**).

After extracting a certain number of users **130** in this manner, the analysis module **402** executes an analysis of the percentage of satisfied based on the report data **500**, but at this time, determines regarding pieces of report data **500** accumulated so far whether or not the number of pieces of report data **500** indicating dissatisfied is extremely large and whether or not a distribution between satisfied and dissatisfied is normal (Step S**805**). The wording “extremely large” refers to, for example, equal to or larger than a predetermined threshold value being larger than half of the total.

When the dissatisfied is not extremely large, the analysis module **402** determines that the distribution between satisfied and dissatisfied is normal (Yes in Step S**805**), and the setting module **403** determines the percentage of satisfied calculated with the normal distribution as the percentage of satisfied to be compared with the target percentage of satisfied (Step S**806**).

Meanwhile, when the report data **500** indicating dissatisfied is extremely large, that is, equal to or larger than the predetermined threshold value larger than half of the total, there is a certain imbalance with a bias toward dissatisfied, and hence the analysis module **402** determines that the distribution is not normal (No in Step S**805**). For example, it is determined that the distribution is normal when a ratio between numbers of pieces of report data **500** indicating satisfied and dissatisfied is from 7:3 to 3:7 (Yes in Step S**805**), and otherwise it is determined that the distribution is abnormal (No in Step S**805**).

Subsequently, the analysis module **402** determines whether or not the number of pieces of report data **500** indicating dissatisfied is equal to or larger than a certain number (Step S**807**). When the number is equal to or larger than the certain number (Yes in Step S**807**), even in the case of “No” in Step S**805**, the setting module **403** temporarily determines the percentage of satisfied calculated by the analysis module **402** as the percentage of satisfied to be compared with the target percentage of satisfied (Step S**808**).

When Step S**807** results in “No”, there are a case in which specific users **130** each have transmitted a large number of reports indicating dissatisfied and a case in which there are actually a large number of dissatisfied users **130**. Therefore, the analysis module **402** selects a plurality of user groups at different times (Step S**809**), and transmits a request for the report data **500** to the terminal **103** of each user **130** of each user group (Step S**810**). Thus, the report screen **300** is displayed on the display of the terminal **103**. The user **130** inputs, on the report screen **300**, the report data **500** on, for example, the thermal sensation, the satisfaction feeling, and the stress (Step S**811**), and transmits the report data **500** to the energy management system **100** (Step S**812**).

The analysis module **402** calculates the percentage of satisfied for each user group (Step S**813**). A user group of specific users **130** each having transmitted a large number of reports indicating dissatisfied exhibits a smaller value of the denominator of Expression (1) than that of a user group actually including a large number of dissatisfied users **130**. Therefore, the user group of specific dissatisfied users **130** from which a large number of pieces of report data **500** have been received and the user group actually including a large number of dissatisfied users are distinguished from each other to exclude the percentage of satisfied of the former user group and output the percentage of satisfied of the latter user group to the setting module **403**. When there are a plurality of user groups distinguished as the latter user group, the analysis module **402** may output any one of the percentages of satisfied or output a maximum value, a minimum value, an average value, a median value, or another statistical value of the percentage of satisfied. The setting module **403** determines the percentage of satisfied calculated by the analysis module **402** as the percentage of satisfied to be compared with the target percentage of satisfied (Step S**808**).

The air-conditioning control module **404** creates the air-conditioning plan through the percentage of satisfied determined or temporarily determined in Step S**806**, Step S**808**, or Step S**814** (Step S**815**). Specifically, for example, as indicated in Step S**503**, the energy management system **100** selects the operation pattern and estimates the energy consumption amount A. The air-conditioning control module **404** determines whether the target energy consumption amount A has been reached (Step S**816**). If the target energy consumption amount A has been reached (Step S**816**: Yes), the generation module **405** executes Step S**818**. If the target energy consumption amount A has not been reached (Step S**816**: No), the generation module **405** executes Step S**817**.

After that, the generation module **405** selects the energy-saving action as indicated by Step S**507** (Step S**817**), and records the success rate as indicated by Step S**509** (Step S**818**).

As described above, according to the first embodiment, when the target value of the air-conditioning plan is not satisfied only by the operation control of the air-conditioning facility **102**, it is possible to make up for the shortage of the energy consumption amount by encouraging the users **130** to take the energy-saving action in the staying space. In addition, it is possible to calculate the percentage of satisfied of the entire users **130** with high accuracy by suppressing the imbalance in the number of pieces of report data **500** indicating dissatisfied, to thereby be able to appropriately control the air-conditioning facility **102** based on the percentage of satisfied of the users **130**.

Second Embodiment

<Integrated Control of Percentage of Satisfied of Users, Power Demand Adjustment of Building, and Decarbonization>

When the air-conditioning facility **102** is controlled while maintaining the percentage of satisfied of the users in the first embodiment, it is required to simultaneously achieve reduction of the greenhouse gas emission amount, reduction of the energy consumption, and reduction of other environmental loads in the building **101**. When the control of the air-conditioning facility performed while maintaining the percentage of satisfied of the users is based solely on requests received from the users, the power demand may rather increase in, for example, high-temperature and high-humidity summer and a severely cold season.

In a second embodiment of this invention, in view of such a problem, with the percentage of satisfied of the users, the energy consumption amount, the number of users, and the greenhouse gas emission amount being used as parameters, those parameters are formulated in the form of a product thereof, and a target value is set for each individual term. Thus, the energy management system **100** enables proper control of each of the percentage of satisfied of the users, the emission of greenhouse gases, and the energy consumption. In the second embodiment, points different from those of the first embodiment are mainly described, and hence the same parts as those of the first embodiment are omitted through use of the same reference symbols.

A specific example of formulating parameters in the form of a product thereof with a target percentage of satisfied **506** of the users, a target energy consumption amount **507**, the number of users, and a greenhouse gas emission amount **505** being used as the parameters is expressed by Expression (2).

[(Greenhouse gas emission amount)/(percentage of satisfied of users)]=[(greenhouse gas emission amount)/(energy consumption amount)]×[(energy consumption amount)/(number of users)]×[1/(total sum of percentages of satisfied/number of users)] (2)

In this case, [(greenhouse gas emission amount)/(percentage of satisfied of users)] on the left-hand side is a target value for maximizing the percentage of satisfied of the users of the building and minimizing the greenhouse gases, and is desired to have as small a value as possible. Hitherto, it has been general that the left-hand side is [(greenhouse gas emission amount)/(number of users)], but in this case, when the greenhouse gas emission amount is simply wished to be reduced, there is also established a solution that it suffices to sacrifice the percentage of satisfied, that is, to put up with the heat of summer and the cold of winter even temporarily. Therefore, in order to maintain the percentage of satisfied of the users, a numerical value target is set for each term on the right-hand side.

The terms on the right-hand side are expressed in the form of a product, to thereby be able to achieve overall optimization rather than individual optimization due to combined effects exerted by the terms. The representation of the product form expressed by Expression (2) is merely an example, and is not limited to this representation.

The first term [(greenhouse gas emission amount)/(energy consumption amount)] on the right-hand side is a term that can control the encouragement to use renewable energies, and is desired to have as small a numerical value as possible. In order to reduce the numerical value of the first term, there is also established a solution of reducing only the energy consumption amount, that is, sacrificing the percentage of satisfied of the users, and hence it is required to consider the reduction of the greenhouse gas emission amount, that is, the encouragement to use renewable energies.

The second term [(energy consumption amount)/(number of users)] on the right-hand side corresponds to an energy consumption amount per user, and is desired to have as small a numerical value as possible. This energy consumption amount is defined in conjunction with the first term, but is a numerical value per user. Therefore, it is desired to reflect architectural facilities and an operation status of each building **101**, and the proper energy consumption of each building **101** is indexed by the second term.

The third term [1/(total sum of percentages of satisfied/number of users)] on the right-hand side is the reciprocal of a percentage of satisfied per user, and is desired to have as small a numerical value as possible. The third term is optimized by the energy management system **100**, but is set in conjunction with the first term and the second term which are included in Expression (2). Therefore, it is possible to achieve the reduction of the greenhouse gas emission amount and the reduction of the energy consumption while satisfying the percentage of satisfied.

As an example, when the effects are estimated through use of the actual data on the building based on the first embodiment, the numerical value of [(greenhouse gas emission amount)/(percentage of satisfied of users)] can be improved by 20% to 30% compared to a case in which the energy management system **100** according to the first embodiment is not implemented, and the greenhouse gas emission amount relating to the first term on the right-hand side can be reduced by 5% to 10% on average. In addition, a loss of the energy consumption amount can be reduced by 10% to 15% on average by the demand plan and appropriate control found in the energy management system **100** according to the first embodiment.

FIG. **11** is a flow chart for illustrating an example of integrated control of the percentage of satisfied of the users, a power demand adjustment of the building, and the decarbonization, which is to be performed by the energy management system **100** according to the second embodiment. The energy management system **100** calculates [(greenhouse gas emission amount)/(percentage of satisfied of users)] on the left-hand side of Expression (2) as a validation index (Step S**601**). Subsequently, the energy management system **100** calculates each term on the right-hand side of Expression (2) as an index (Step S**602**).

When a calculation result on the right-hand side of Expression (2) is equal to or smaller than the validation index on the left-hand side, the energy management system **100** is determined to be properly operating the building group **101***s*. The indices of the terms on the right-hand side of Expression (2) have complicated relevance in terms of, for example, the percentage of satisfied and the use amount of renewable energies to be used as the reference of the greenhouse gas emission amount. Therefore, when the calculation result on the right-hand side of Expression (2) is not equal to or smaller than the validation index on the left-hand side, the energy management system **100** notifies a facility administrator or the like of each index. Thus, the facility administrator or the like can also reflect the result of the indices to manually correct the target percentage of satisfied, the energy consumption amount A, and the target energy consumption amount B which are required by the energy management system **100**.

In this manner, it is possible to achieve the reduction of the greenhouse gas emission amount and the reduction of the energy consumption in a consumer business sector by maintaining the percentage of satisfied of the users of the building.

Third Embodiment

Now, description is given of a third embodiment of this invention. In the first embodiment, the energy management system **100** executes the control of the air-conditioning facility **102** and the transmission of the energy-saving action information based on the report data **500**. The report data **500** is characterized by the thermal sensation, namely, the temperature, the humidity, the radiation temperature, the wind velocity, the amount of clothes, and the amount of metabolism. However, in the third embodiment, the report data **500** is associated with the individual's biometric data **418** including a degree of concentration and stress during work. In the third embodiment, points different from those of the first embodiment are mainly described, and hence the same components as those of the first embodiment are denoted by the same reference symbols, and description thereof is omitted.

FIG. **12** is an explanatory diagram for illustrating an example of the energy management by the energy management system **100** according to the third embodiment. In Step (1), the biometric data **418** is also transmitted to the energy management system **100** together with the report data **500**. In Step (3), not only the energy-saving action information but also support information relating to the usage of the building **101** is transmitted to the terminal **103**.

The support information is information for supporting the work in the building **101**, which includes the degree of concentration and stress of each individual user **130**. In addition to the thermal sensation, biometric information including the degree of concentration, stress, and fatigue of each individual user **130** is also indirectly reflected in the report data **500** on the satisfaction feeling based on the thermal sensation. Therefore, in the second embodiment, the biometric data **418** on each individual user **130** is added to grasp the degree of concentration, stress, and fatigue of each individual user **130**, and is transmitted to the terminal **103** as the support information.

There are no particular restrictions imposed on the biometric data **418**, but it is desired to acquire the biometric data **418** by a method having little effect on the work. For example, it is possible to grasp the degree of concentration of each individual user **130** by continuously monitoring an intensity ratio of a heart rate. The heart rate can be obtained by electrocardiogram measurement, but as an easier and simpler method, it is known that the heart rate can be obtained by observing capillary vessels of a face through use of, for example, a Web camera. In addition, in regard to drowsiness during the work, it is known that the drowsiness can be grasped by observing pupils with a Web camera. The energy management system **100** continuously acquires the biometric data **418** from each user **130**.

The analysis module **402** acquires, from the storage device **202**, the biometric data **418** on the user **130** of the terminal **103** that has transmitted a piece of report data **500** indicating dissatisfied among pieces of report data **500**. Then, the analysis module **402** determines for each type of biometric data **418** whether or not a difference value obtained by subtracting a second observed value from a first observed value has become equal to or larger than a positive threshold value, the second observed value being obtained earlier than the first observed value. For example, when the biometric data **418** is the heart rate obtained by observing the capillary vessels of the face, the difference value that has become equal to or larger than the positive threshold value indicates that tension of the user **130** is increasing.

Therefore, the energy management system **100** transmits the support information indicating that the tension is increasing to the terminal **103** of the user **130**. Meanwhile, the difference value that has become equal to or smaller than a negative threshold value indicates that the degree of concentration of the user **130** has decreased or the user **130** has become drowsy. Therefore, the energy management system **100** transmits the support information indicating that the degree of concentration has decreased or the drowsiness has increased to the terminal **103** of the user **130**.

When the type of biometric data **418** is the observed value of the vibration sensor provided on the seat surface of the chair in which the user **130** is seated, the observed value obtained within a predetermined range (for example, from 1 hertz to 4 hertz) indicates that the degree of concentration of the user **130** has decreased or that the fatigue of the user **130** has been accumulated. Therefore, the energy management system **100** transmits the support information indicating that the degree of concentration has decreased or the fatigue has been accumulated to the terminal **103** of the user **130**.

In this manner, the energy management system **100** can grasp the degree of concentration, stress, and fatigue during the work and send those pieces of information as the support information, and can provide services that contribute to improvement of productivity by, for example, encouraging the users to rest for a certain period of time. In this case, the obtained biometric data **418** is acquired on demand, but this acquisition method is simple. The obtained biometric data **418** is desired to be analyzed by relative evaluation, and strictly provides information on the relative reduction of concentration, a significant increase in stress, and an increase in fatigue, instead of guaranteeing complete accuracy. The support information is provided to the user **130** in this manner, to thereby motivate the user **130** himself or herself to input the report data **500** and lead to promotion of the acquisition of the report data **500**.

As described above, according to each of the first embodiment, the second embodiment, and the third embodiment, in order to optimize supply and demand of energy in an area in which introduction of a variable renewable energy is expanded, it is possible to provide an energy management service in which the energy is coordinated over the entire area based on the energy consumption on the consumer side with respect to the demand corresponding to varying renewable energies while enabling the comfortableness of the residents being consumers to be satisfied.

It should be noted that this disclosure is not limited to the above-mentioned embodiments, and encompasses various modification examples and the equivalent configurations within the scope of the appended claims without departing from the gist of this disclosure. For example, the above-mentioned embodiments are described in detail for a better understanding of this disclosure, and this disclosure is not necessarily limited to what includes all the configurations that have been described. Further, a part of the configurations according to a given embodiment may be replaced by the configurations according to another embodiment. Further, the configurations according to another embodiment may be added to the configurations according to a given embodiment. Further, a part of the configurations according to each embodiment may be added to, deleted from, or replaced by another configuration.

Further, a part or entirety of the respective configurations, functions, processing modules, processing means, and the like that have been described may be implemented by hardware, for example, may be designed as an integrated circuit, or may be implemented by software by a processor interpreting and executing programs for implementing the respective functions.

The information on the programs, tables, files, and the like for implementing the respective functions can be stored in a storage device such as a memory, a hard disk drive, or a solid state drive (SSD) or a recording medium such as an IC card, an SD card, or a DVD.

Further, control lines and information lines that are assumed to be necessary for the sake of description are described, but not all the control lines and information lines that are necessary in terms of implementation are described. It may be considered that almost all the components are connected to one another in actuality.

What is claimed is:

1. An energy management system, which is configured to control operations of air-conditioning facilities in a plurality of buildings, the energy management system comprising:

a processor;

a storage device, coupled to the processor, configured to store instructions; and

an interface, coupled to the processor, communicable to/from a plurality of mobile terminals via a network,

wherein the storage device is configured to store, for each of the plurality of buildings:

first data indicating a relationship between the operation of each of the air-conditioning facilities and an energy consumption amount of each of the air-conditioning facilities,

second data indicating an operational status of each of the air-conditioning facilities,

third data indicating weather, and

fourth data indicating warm and cold in the each of the plurality of buildings, and

wherein the processor, upon executing the instructions is configured to:

receive via the network, for each of the plurality of buildings, report data indicating a satisfaction feeling relating to warm and cold temperatures in a space of a user in the each of the plurality of buildings from each of the plurality of mobile terminals,

calculate a percentage of satisfaction based on the report data for each of the plurality of buildings, the percentage of satisfaction representing a satisfaction feeling as a ratio of an estimated number of users who have expressed satisfaction to a number of users being a population in the space by a statistical method,

create, for each of the plurality of buildings, a plan for operating each of the air-conditioning facilities based on the percentage of satisfaction and a predetermined target percentage of satisfaction,

estimate a first energy consumption amount based on the first data, the first energy consumption amount indicating an estimated energy consumption amount based on an operation of each of the air-conditioning facilities in the plurality of buildings according to the created plan that is distributed to the each of the plurality of buildings via the network,

calculate a second energy consumption amount based on the second data, the third data, and the fourth data, the second energy consumption amount being obtained after each of the air-conditioning facilities is operated after a lapse of a predetermined time period, and

determine whether the first energy consumption amount is larger than the second energy consumption amount, and upon determining the first energy consumption amount is larger than the second energy consumption amount, control operation of the each of the air-conditioning facilities so as to achieve the second energy consumption amount.

2. The energy management system according to claim 1, wherein the processor is configured to:

select, when the first energy consumption amount is equal to or smaller than the second energy consumption amount, an energy-saving action corresponding to a difference between the first energy consumption amount and the second energy consumption amount; and

transmit energy-saving action information for encouraging the selected energy-saving action to the plurality of terminals.

3. The energy management system according to claim 2, wherein the processor is configured to:

evaluate the energy-saving action based on a number of responses from the plurality of mobile terminals to which the energy-saving action information has been transmitted, the responses each indicating that the user has performed the energy-saving action, and

select, upon determining the first energy consumption amount is equal to or smaller than the second energy consumption amount, based on an evaluation result of the energy-saving action, the energy-saving action corresponding to the difference between the first energy consumption amount and the second energy consumption amount.

4. The energy management system according to claim 1, wherein the processor is configured to calculate the percentage of satisfaction for each of the plurality of buildings based on a distribution between a number of pieces of report data indicating satisfaction as the satisfaction feeling and a number of pieces of report data indicating dissatisfaction as the satisfaction feeling.

5. The energy management system according to claim 1, wherein the storage device is configured to store, for each of the plurality of buildings, a plurality of operation patterns obtained by categorizing actual record data obtained by recording a temperature, a radiation temperature, a humidity, and a wind velocity in the each of the plurality of buildings, and

wherein the processor is configured to select, for each of the plurality of buildings, a specific operation pattern as the plan from among the plurality of operation patterns based on the percentage of satisfaction and the predetermined target percentage of satisfaction.

6. The energy management system according to claim 1, wherein the processor is configured to:

acquire chronological biometric data of the user,

generate, based on the chronological biometric data of the user of a specific terminal that has transmitted the report data indicating dissatisfaction as the satisfaction feeling, support information relating to usage of one of the plurality of buildings for the user of the specific terminal, and

transmit the support information to the specific terminal.

7. An energy management method, which is executed by an energy management system configured to control an operation of an air-conditioning facility in a building,

the energy management system comprising:

a processor;

a storage device, coupled to the processor, configured to store instructions; and

an interface, coupled to the processor, communicable to/from a plurality of mobile terminals via a network,

wherein the storage device is configured to store:

first data indicating a relationship between the operation of the air-conditioning facility and an energy consumption amount of the air-conditioning facility,

second data indicating an operational status of the air-conditioning facility,

third data indicating weather, and

fourth data indicating warm and cold temperatures in the building,

the energy management method comprising:

receiving via the network, by the processor, report data indicating a satisfaction feeling relating to warm and cold temperatures in a space of a user in the building from each of the plurality of mobile terminals;

calculating, by the processor, a percentage of satisfaction based on the report data, the percentage of satisfaction representing the satisfaction feeling as a ratio of an estimated number of users who have expressed satisfaction to a number of users being a population in the staying space by a statistical method;

creating, by the processor, a plan for operating the air-conditioning facility based on the percentage of satisfaction and a predetermined target percentage of satisfaction;

estimating, by the processor, a first energy consumption amount based on the first data, the first energy consumption amount indicating an estimated energy consumption amount based on an operation of the air-conditioning facility according to the created plan;

calculating, by the processor, a second energy consumption amount based on the second data, the third data, and the fourth data, the second energy consumption amount being obtained after the air-conditioning facility is operated after a lapse of a predetermined time period; and

determining whether the first energy consumption amount is larger than the second energy consumption amount, and upon determining the first energy consumption amount is larger than the second energy consumption amount, controlling, by the processor, operation of the air-conditioning facility so as to achieve the second energy consumption amount.

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