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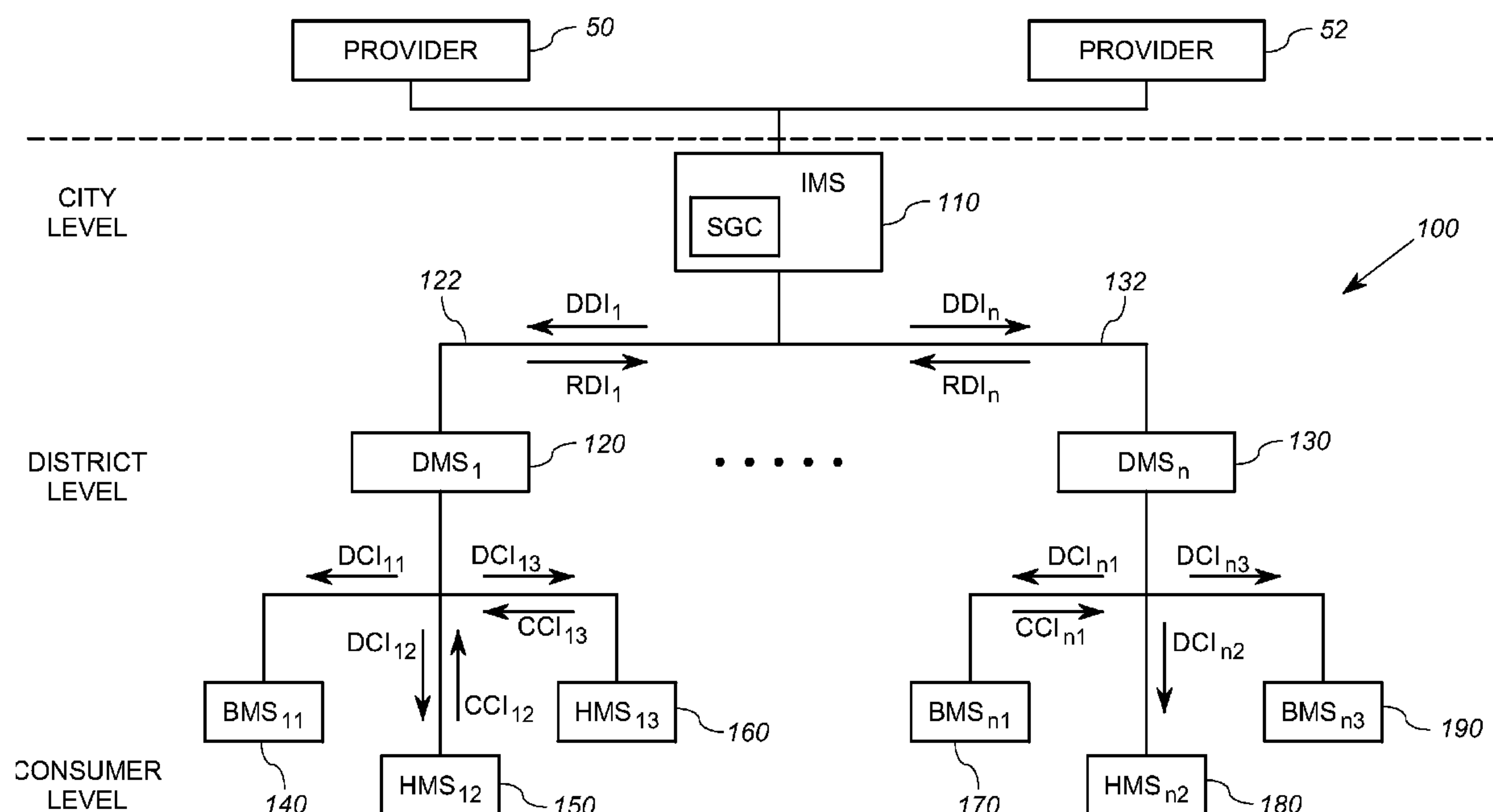
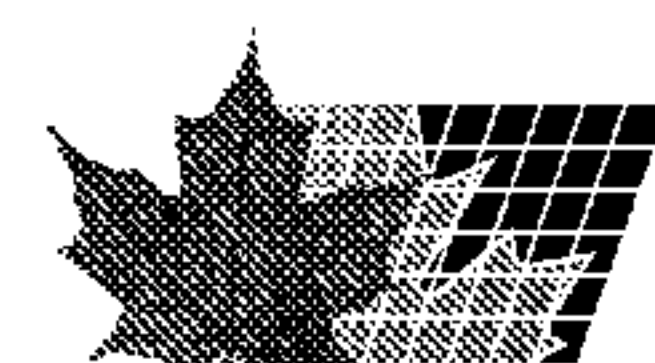


FIG. 1

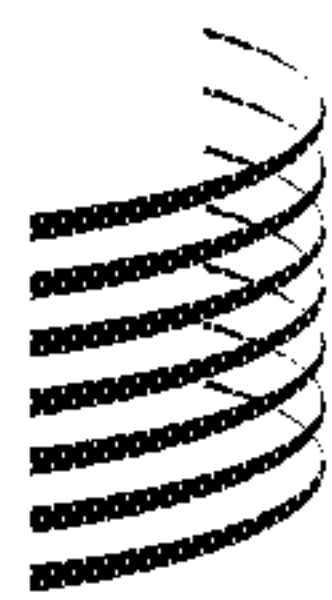
(57) **Abrégé/Abstract:**

An arrangement for use in a distributed system for an energy grid includes a processing circuit and a plurality of destination nodes coupled to the processing circuit. The processing circuit is configured to calculate a desired destination index for each of the plurality of destination nodes based on a desired aggregate index for the plurality of destination nodes, wherein the desired aggregate index includes information representative of carbon consumption, and communicate each desired destination index to the corresponding one of the plurality of destination nodes. Each of the plurality of destination nodes is configured to receive the desired destination index from the processing circuit, and display the desired destination index on a display.



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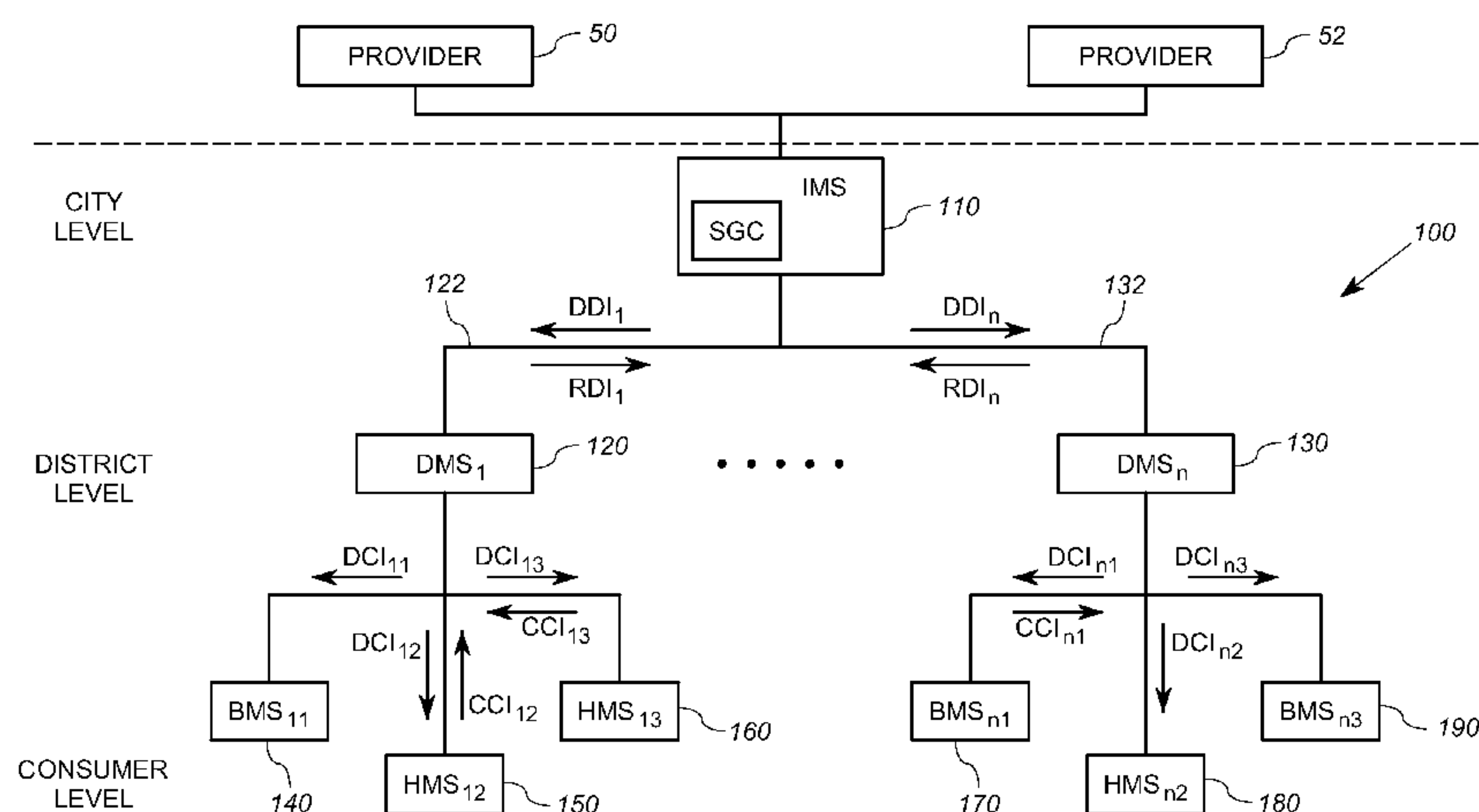


FIG. 1

(57) Abstract: An arrangement for use in a distributed system for an energy grid includes a processing circuit and a plurality of des-
tination nodes coupled to the processing circuit. The processing circuit is configured to calculate a desired destination index for each
of the plurality of destination nodes based on a desired aggregate index for the plurality of destination nodes, wherein the desired ag-
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DISTRIBUTED ENERGY GRID MANAGEMENT

FIELD OF THE INVENTION

[0001] The present invention relates to the field of energy management systems, and more particularly, to a management system directed to generating and distributing energy allocation goals to a plurality of nodes within the grid.

BACKGROUND OF THE INVENTION

[0002] The issue of climate change has spawned, among other things, goals of creating carbon neutral homes, facilities, and even municipalities. Achieving carbon neutrality, or something near carbon neutrality, requires ways of characterizing carbon usage, and ways of controlling carbon usage in an intelligent manner.

[0003] An important element in measuring and controlling carbon usage involves determining the “carbon-content” per unit of energy used by consumers. A consumer’s energy consumption, combined with the carbon-content of the energy consumed, defines a “carbon-footprint” for the consumer. The carbon footprint may be loosely defined as a measure of the total greenhouse gas emissions caused directly and indirectly by a person, organization, event or product. The carbon content per unit energy affects the quantity of energy that may be consumed for a given carbon footprint. For example, if the carbon-content per unit of energy is low, such as in wind-turbine generated electricity, then higher consumption can still produce a relatively modest carbon footprint. If the carbon-content per unit energy is high, such as in energy generated by coal-fired electrical plants, then lower consumption can still produce a relatively large carbon footprint.

[0004] Accordingly, consumers and other organizations attempting to reduce their carbon footprints are concerned about whether the consumed energy is from a renewable source (e.g., solar power) which are usually associated with low carbon-content energy, or from a non-renewable source (e.g., hydrocarbon fossil fuels). There are limited incentives to use low carbon-content renewable sources of energy. As a result, the ratio of renewable to non-renewable sources of energy remains low.

[0005] At present, there is little communication to consumers as to the carbon content of the energy available to them. The availability of renewable source energy to a consumer can vary greatly, depending on such factors as weather conditions for wind, solar and wave energy systems, and excess production from other parts of the grid. Accordingly, at present a consumer cannot regulate its energy consumption in real time to adjust to the amount of renewable source energy that is available on a given day. Furthermore, there exists no system that can help coordinate carbon usage on a municipality wide basis.

[0006] Therefore, there is a need for a novel energy grid design that assists in providing information to consumers to assist in achieving carbon usage goals on an individual and municipality-wide basis.

SUMMARY OF THE INVENTION

[0007] The above goals may be overcome by a system and method implemented in accordance with the principles of the present invention. In at least some embodiments of the invention, a regional carbon usage goal is allocated to, and communicated to, individual consumers within the region.

[0008] A first embodiment is an arrangement for use in a distributed system for an energy grid that includes a processing circuit and a plurality of destination nodes coupled to the processing circuit. The processing circuit is configured to calculate a desired destination index for each of the plurality of destination nodes based on a desired aggregate index for the plurality of destination nodes, wherein the desired aggregate index includes information representative of carbon consumption, and communicate each desired destination index to the corresponding one of the plurality of destination nodes. Each of the plurality of destination nodes is configured to receive the desired destination index from the processing circuit, and display the desired destination index on a display.

[0009] The above-described features and advantages, as well as others will become more readily apparent to those of ordinary skill in the art by reference to the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 shows a block diagram of an energy management system that incorporates at least some embodiments of the invention;

[0011] Fig. 2 shows a representative diagram of an exemplary city in which the embodiment of Fig. 1 may be implemented;

[0012] Fig. 3 shows a block diagram of a computer system that may be used as various components of the energy management system of Fig. 1;

[0013] Fig. 4 shows a flow diagram of an exemplary set of operations of the integrated management system of Fig. 1;

[0014] Fig. 5 shows a flow diagram of an exemplary set of operations of the district management system of Fig. 1;

[0015] Fig. 6 shows a schematic block diagram of a consumer system interface to the system of Fig. 1; and

[0016] Fig. 7 shows a flow diagram of an exemplary set of operations of a consumer system interface of Fig. 6.

[0017] The present invention may take form in various components and arrangement of components and in various methods. The drawings are only for purposes of illustrating exemplary embodiments and alternatives and are not to be construed as limiting the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] Referring to FIG. 1, a schematic for an energy management system 100 is provided. The energy management system 100 has a hierarchical design with nodes positioned at multiple levels. The levels and nodes correspond to a division of the consumers within the city. In this exemplary system of Fig. 1, the energy management system 100 corresponds to a city that is divided into districts, with each district having a plurality of energy users or consumers. Fig. 2, for example, shows a representative block diagram of a simplified example of a city 80 that is divided into districts 82, 84 and 86. Each of the districts has several consumers of energy.

[0019] Referring to Fig. 1, the exemplary embodiment of the system 100 thus includes three levels: a city level, a district level, and a consumer level. It will be appreciated, however, that other number of levels are also possible. For example, the grid may be designed with four or

five levels of hierarchy, such that the additional levels are for townships and neighborhoods (or city blocks).

[0020] In the exemplary embodiment described herein, the system 100 includes a single city level node in the form of integrated management system (IMS) 110. The system 100 further includes n district level nodes referred to as district management systems $DMS_1 \dots DMS_n$. Only the nodes DMS_1 120 and DMS_n 130 are shown in Fig. 1. The IMS 110 is operably connected to communicate with the DMS_1 120 and DMS_n 130 through suitable data links 122, 132. The IMS 110 is further configured to communicate with one or more energy suppliers or distributors 50, 52, etc. through suitable data links. Each energy supplier or distributor 50, 52 is configured to deliver electrical energy to the various consumers associated with the system 100. Moreover, each energy supplier or distributor 50, 52 is configured to supply energy from different types of generators, such as coal, solar, hydroelectric, nuclear, and the like. The energy suppliers 50, 52 are configured to communicate energy availability information, including information regarding availability from various sources, or in the alternative, information regarding the carbon content of energy delivered.

[0021] The system 100 also includes a number of consumer or end user nodes, each coupled to corresponding DMS_x . In the simplified example of Fig. 1, the end user nodes include building management systems BMS_{11} , BMS_{n1} , and BMS_{n3} , and home management systems HMS_{12} , HMS_{13} and HMS_{n2} . The DMS_1 120 is operably coupled to communicate with a building management system BMS_{11} 140, a home system HM_{12} 150, and another building management system HMS_{13} 160, via respective communication links 142, 152 and 162. Similarly, the DMS_n 130 is operably coupled to communicate with a building management system BMS_{n1} 170,

building management system HMS_{n2} 180, and building management system BMS_{n3} 190, via respective communication links 172, 182 and 192.

[0022] In the embodiment of Fig. 1, the IMS 110 includes the functionality of a smart grid controller (SGC) 102. Fig. 3 shows an example of a computing system 300 that may be used to carry out the operations of the IMS 110 and SGC 102. A similar structure may be used to carry out the operations of the DMS₁ 120 and DMS_n 130. With reference to Fig. 3, the computing system 300 includes a processing circuit 302, a display 304, one or more user input devices 306, a communication circuit 308, and multiple types of memory 310.

[0023] The processing circuit 302 includes one or more microprocessors or co-processors, and all supporting circuitry known in the art to support such microprocessors in a general purpose or special purpose computing device. The display 304 may suitably be a commercially available display, such as for example, an LCD or other type of flat screen display. The user input devices 306 include keyboards, touch screen, key pads, pointing devices, and/or any other well-known computer input device. The communication circuit 308 may be a suitable communication circuit for connecting in a wired or wireless fashion to local area network, not shown, which in turn may operably connect to the Internet, a power line carrier network, wireless network or the like. The memory 310 may include volatile and non-volatile memory devices normally associated with general purpose computing devices. It will be appreciated that the memory 310 as shown herein may include a mass data store that is not physically located within the same box or housing as the processing circuit 302. It will further be appreciated that the computing system 300 may operate as a server that cooperates with client computers, not shown, to carry out the user interface operations of the computing system 300 in a manner well known in the art.

[0024] The memory 310 includes programming instructions for grid index allocation 311 that are carried out by the processing circuit 302. These instructions, when executed by the processing circuit 302, perform the operations described herein attributable to the IMS 110 and/or smart grid controller 102.

[0025] With reference to both Figs. 1 and 3, the memory 310 includes the historic data associated with the grid. The grid historic data includes periodic information associated with the grid. The periodic data may be based on hourly data for each calendar day, daily data, weekly data, or monthly data. Further, the historic data includes goals for energy consumption. For example, the historic data for each day of the past several years includes desired energy consumption limits/goals as well as actual energy consumption levels. The processing circuit 302 stores such data to, and obtains such data from, the memory 310 as necessary to carry out the operations of the SGC 102 and/or IMS 110 as described herein.

[0026] In accordance with this embodiment of the invention, the SGC 102 is configured, via the index allocation software 311 stored in the memory 310, to generate a desired index DI for the entire city. The desired index is a desired value (e.g. a set point) for a parameter defined herein in this exemplary embodiment as a green index. The *green index* is a parameter that provides an indication, measure or approximation of carbon usage. With respect to electricity consumption, carbon usage may be approximated based on energy consumption and carbon-content per unit energy. As discussed above, the type of energy generator can greatly affect carbon usage. For example, a large amount of energy consumed that is generated by solar power has a low carbon usage value, while a relatively small amount of energy generated by a coal-fired electrical plant has a high carbon usage value. Accordingly, the green index is a measure of energy consumption, weighted by the carbon-content per unit energy of the energy consumed.

The green index may also take into account any “embedded” carbon, such as the carbon that was consumed in the construction of the relevant electrical energy generating equipment.

Accordingly, with respect to electrical energy consumption, the green index for a person, facility or area may be calculated as

[0027]
$$GI = \sum_{n=1}^N (cons_n * cc_n)$$

[0028] where there are N different generators of electricity, the value $cons_n$ is a measure of consumption of energy provided by each generator n , and the value cc_n is a measure of the carbon content for each unit of energy generated by the generator n . In this implementation of the green index, it is desirable to reduce the green index GI . However, it will be appreciative that other variants of the green index (based on energy consumption and carbon-content of energy consumed) may be employed where it may be desirable to increase the green index. It will be appreciated that while the term “green index” is used herein for clarity, the actual index is not definitively a measure of “greenness”, but rather a measure of carbon consumption as it relates to electrical energy.

[0029] Reduction in the green index GI in the embodiments discussed herein may be accomplished by consuming less energy, using energy generators that provide energy having less carbon content, or both. In the examples discussed herein, the green index values are normalized, for example, as a per person value. In this manner, an individual consumer’s green index may be intuitively measured against the overall green index for the city, as well as against the green index for other entities. Various methods may be used to account for businesses, which have no permanent “population”. In the alternative to normalizing by population, green indices may be normalized for per unit area occupied (such as per building square foot). Other

methods of normalizing the green index to allow for meaningful comparison between city, district and consumer green index goals may be implemented.

[0030] It will also be appreciated that carbon usage necessarily includes items other than electricity consumption, such as heating fuel (natural gas, oil, propane, etc.) and vehicle fuel. While the description provided herein does not directly address those factors, it will be apparent that methods described herein can be combined with methods of determining, allocating and controlling carbon usage specifically related to heating fuel and vehicle fuel, in order to determine a comprehensive green index for a person, location or community.

[0031] Referring again specifically to Fig. 1, the SGC 102 is configured to generate a *desired* green index, or simply desired index (DI), for the city. The desired index DI is a green index value that represents the goal for the city for a time period, such as a day, week or month. The desired index is calculated based on many factors, including historical meteorological data (e.g., average daily high temperature and humidity), meteorological forecasts, forecasted energy consumption needs, and an overall carbon usage goal. The SGC 102 also considers historical performance data for the grid/region and predicted availability of energy from renewable energy sources (hereinafter referred to generally as “green energy”). Finally, the desired index DI may be determined in part by commitments of specific consumers to meet energy consumption goals.

[0032] Among the historical data that may be used for the desired index DI is the *actual* index AI achieved by the area in previous time periods. The actual index is the green index calculated from the actual energy used, and the carbon-content per unit energy of the energy used. The SGC 102 may consider the AI from the immediate preceding time period, as well as those AIs from several time periods using a weighted time window that captures seasonal trends, captures trends related to days of the week (workdays vs. weekends) and other trends affecting

carbon usage. Determination and calculation of the AI for previous periods is discussed below in further detail.

[0033] The SGC 102 is further configured to generate a desired index ($DDI_1 \dots DDI_n$) for each of the n districts in the hierarchical system 100. The SGC 102 calculates the values $DDI_1 \dots DDI_n$ based on the desired grid green index DI for the city and other parameters. In particular, the SGC 102 preferably generates desired green indices $DDI_1 \dots DDI_n$ for the various districts such that the composite weighted average (weighted by population or area) is equal to the city green index DDI. In a simple case, if the desired grid green index DDI has a value of 25, then the each of the desired district indices $DDI_1 \dots DDI_n$ could suitably have values of 25.

[0034] However, in accordance with the present invention, the SGC 102 need not allocate the green indices to the various districts equally. Instead, the SGC 102 allocates the desired district indices $DDI_1 \dots DDI_n$ based on additional factors, such as historical consumption data for each district. For example, in a particularly old part of a city, it may be more difficult for the area to achieve the same green index (carbon usage per person) as a newer area that has been constructed to be more energy efficient. Likewise, in a largely industrial area, the carbon usage per resident will be several times that of a largely residential area. As a consequence, the SGC is configured to use historical energy usage data for each district to determine the desired district indices $DDI_1 \dots DDI_n$. In this embodiment the historical data can include one or more prior actual green index values $ADI_1 \dots ADI_n$ for each district. The SGC 102 further determines desired district indices $DDI_1 \dots DDI_n$ based on customer commitments, if any, to a specific green index level.

[0035] An exemplary determination of the desired district indices $DDI_1 \dots DDI_n$ is provided with reference to Fig. 2. Referring again to Fig. 2, it is assumed that the city 80 has a

population of 1000, and three districts 82, 84 and 86 of populations 400, 400 and 200, respectively. It will be assumed that the district 82 is largely residential, consisting of is older and relatively less energy-efficient homes. It is further assumed that the district 84 is also residential, but has newer and more efficient dwellings, and that the district 86 is largely industrial.

[0036] With these assumptions, the total carbon usage value is determined for the city 80, and then the total carbon usage value is allocated among the various districts based on the factors discussed above. The district green indices may then be obtained from allocated total carbon usage values for the districts. For example, if the desired index DI for the city is “25”, then the total carbon usage value (population * DI) for the city 80 is 25000 (in arbitrary units). The SGC 102 in such a case generates green indices DDI_{82} , DDI_{84} and DDI_{86} for the districts 82, 84 and 86 such that the total carbon usage value for all the districts combined equals the total carbon usage for the city. In other words, the SGC 102 follows the following equation:

$$DI * 1000 = DDI_{82} * 400 + DDI_{84} * 400 + DDI_{86} * 200$$

or

$$25000 = DDI_{82} * 400 + DDI_{84} * 400 + DDI_{86} * 200$$

[0037] If historical data indicates that the first and third districts 82, 84 require more energy usage per person, then the desired district indices DDI_{82} and DDI_{86} for those districts will be higher than the desired district index DDI_{84} for the second district 84. Thus, in one example, the SGC 102 may determine the values of $DDI_{82} = 28.3$, $DDI_{86} = 28.3$, and $DDI_{84} = 20$. This allows the first and third districts 82, 86 to use more carbon per capita than the second district 84.

[0038] In addition to the foregoing functions, the SGC 102 and/or the IMS 110 is configured to calculate the *actual* green index AI for a prior period for the city based on

information received from external sources. The AI value represents the actual green index achieved for a prior day, or other period of time. The IMS 110 may suitably calculate the AI based on consumption information provided by other elements in the system 100, such as from the district management systems $DMS_1 \dots DMS_n$.

[0039] In addition to the foregoing, the SBC 102 and the IMS 110 may also be configured to provide information regarding the availability of energy from a variety of energy generators. As will be discussed below, the IMS 110 may be able to identify how much energy generated by solar, wind, hydro-electric and coal fired plants is available for use on a given day. Such information may suitably be provided by the energy providers/distributors 50, 52. Further detail regarding the operations of the IMS 110/SBC 102 are discussed below in connection with Fig. 4.

[0040] Referring again to the elements of the system 100, the DMS_1 may suitably be a computing device similar to that of Fig. 3, except that the memory 310 stores program instructions suitable to carry out the DMS operations described herebelow.

[0041] The DMS_1 is configured, via software, to receive the district's desired index DDI_1 from the IMS 110. The DMS_1 is further configured to generate, among other things, a green index (DCI_{11} , DCI_{12} and DCI_{13}) for each end user or consumer, i.e. each building/home in its district. The DMS_1 120 is configured to generate each desired building/home index DCI_{1x} based on the desired district index DDI_1 , and other parameters. In particular, the DMS_1 is configured to generate desired green indices $DCI_{11} \dots DCI_{13}$ for the various homes and buildings such that the overall carbon usage for the district achieves the district's DCI_1 . To this end, the DMS_1 120 may suitably generate the values $DCI_{11} \dots DCI_{13}$ in a manner analogous to that used by the SGC 102 to generate the desired district green indices $DDI_1 \dots DDI_n$. As with the district desired

green indices, the desired index for each end user or consumer is generated based on historical consumption information for the location, commitments by specific consumers, and other factors. By taking into account historical factors (including past consumption), realistic green indices may be generated for each location. The DMS₁₁ 120 is also configured to provide the values DCI₁₁, DCI₁₂ and DCI₁₃ to, respectively, the BMS₁₁ 140, the HM₁₂ 150, and the HMS₁₃ 160.

[0042] As will be discussed below in further detail, the DMS₁ 120 is further configured to determine and provide a revised district index RDI₁ based on the original desired district index DDI₁ and any commitments by consumers BMS₁₁, HMS₁₂, and HMS₁₃ to further reduce their individual carbon consumption. For example, if the consumer served by HMS₁₂ can commit to a lower (or better) index than its allocated index DCI₁₂, then it can provide a committed index CCI₁₂ to the DMS₁ 120. The DMS₁ 120 in such a case would generate a revised district index RDI₁ that is based on the original desired index DDI₁ adjusted by the customer's commitment CCI₁₂. In this manner, the district can actually achieve a better overall index than originally allocated. The DMS₁ is configured to communicate the revised district index RDI₁ to the IMS 110.

[0043] Similar to the DMS₁ 120, the DMS_n 130 is configured to generate a desired index (DCI_{n1}, DCI_{n2} and DCI_{n3}) for each building/home in its district. The DMS_n 130 is configured to generate each desired building/home index DCI_{nx} based on the desired district index DDI_n, and other parameters. The DMS_n 130 is further configured to provide the values DCI_{n1}, DCI_{n2} and DCI_{n3} to the respective systems BMS_{n1} 170, HMS_{n2} 180, and BMS_{n3} 190. The DMS_n is also configured to determine and provide a revised district index RDI₁ based on the original desired

district index DDI_1 and any commitments by consumers BMS_{n1} , HMS_{n2} , and BMS_{n3} to further reduce their individual carbon consumption.

[0044] The home devices (e.g. HM_{12}) include interfaces to the system 100, or system interfaces, that display for a consumer its desired green index as calculated by its respective DMS_x . The system interface may take the form of a home computer, a personal communication device (such as a smart phone), or a special unit installed into, or connected to, the user's home thermostat or other equipment, such as a utility meter or load control device, not shown, but which are known in the art. Preferably, the user's system interface has the ability to communicate the desired index to the person, as well as other information that identifies how a person may alter his or her consumption patterns to effect achievement of the desired index. Such devices may take advantage of information available over the smart grid, such as the amount of "green" energy available to the consumer. In addition, the user's system interface preferably also has the ability to communicate upstream "commitments" from the consumer to achieve a better green index than the consumer's initial DCI value. Additional detail regarding this capability is provided further below.

[0045] The building management systems (e.g. BMS_{xy}) are part of more complex building automation systems for larger buildings, for example, office buildings. The system interface of a BMS_{xy} may take the form of a HVAC system workstation, security workstation, or another controller. Further detail regarding the operations and structure of the system interfaces for the systems HM_{xy} and BMS_{xy} are provided below in connection with Fig. 7.

[0046] In the general operation of the system of Fig. 1, the SGC 102 determines the grid's desired index (DI) at the beginning of each period, such as daily. As discussed above, the

SGC 102 generates the DDI_1 based on historical information for the grid, prior day consumption information, as well as weather information and other external information.

[0047] Preferably the SGC 102 determines the DI value with an overall goal to achieve carbon neutrality for the district. To this end, the SGC 102 may receive a carbon neutral goal or threshold value from a suitable source that calculates such a value, such as a scientific or government facility. In other words, such a source may determine what level of carbon consumption per capita, per building, or per area, is required to achieve a carbon neutral condition for the day (or week, month or year). In determining the desired index DI, however, the SGC 102 does not merely select a value of the DI that achieves or corresponds to carbon neutrality for that specific period. In reality, daily energy needs vary substantially from day to day, as does the availability of green energy. As a consequence, maintaining a steady daily green index is not realistic. Accordingly, the SGC generates the value of the DI such that the trend for the city over long periods of time is toward carbon neutrality. Thus, on any given day, the DI may be selected to be above or below that which is required to achieve carbon neutrality for that day, taking into account the energy needs, weather, and availability of green energy.

[0048] Fig. 4 shows an exemplary set of operations that may be carried out by the SGC 102 and/or IMS 100 of Fig. 1 in the operation of the system 100. It will be appreciated that while the operations of Fig. 4 are shown in flow diagram form, the steps of Fig. 4 need not be carried out in any particular order, and indeed may constitute different processes executed on the computing device (e.g. the device 300 of Fig. 3). The steps of Fig. 4 may suitably be carried out once per day.

[0049] In step 401, the IMS 110 receives from an energy provider 50, or more specifically, a computing device of the energy provider 50 (hereinafter referred to as energy

provider 50), an identification of the amount and/or pricing of energy available from each of a plurality of generators. Each of the generators has associated with it a carbon-content value. By way of example, the energy provider may provide to the IMS 110 an identification of how much energy can be made available for the next period from coal-fired plants, hydro-electric plants, wind turbine sources, and solar sources. The energy provider 50 may provide the information in any suitable manner, such as by providing pricing quotations for energy from each source, and/or maximum allocations and prices from each source.

[0050] In step 402, the IMS 110 determines the AI for the city for a prior time period, such as the previous day. To this end, the IMS 100 obtains from the DMS₁...DMS_n the aggregate ADI_x values for their respective districts on from the prior day. The IMS uses these values, ADI₁ ... ADI_n, to determine the city-wide AI for the prior day. If the AI is normalized on a per person basis, then the aggregate AI may be calculated by the following sum:

[0051]
$$AI = \sum_{j=1}^n (ADI_j * population_j)$$

[0052] for each district *j*.

[0053] In step 404, the IMS 110 stores the calculated AI value and the district values ADI₁ ... ADI_n in a memory (e.g. memory 310 of Fig. 3), along with a time stamp or other indicator of at least the date to which it pertains.

[0054] In step 406, the IMS 110 (via the SGC 102) calculates the desired index DI for the city for the next time period. As discussed further above, the SGC 102 determines the DI based on historical data (such as recent AI values), seasonal data (such as consumption data or AI data for similar dates over past years), weather forecasts, the predicted capacity of the various energy generators, and any other information that may be helpful in predicting energy usage on a city-wide basis. At a minimum, the SGC 102 should either generate or obtain an energy demand

prediction for the next day, and a prediction or estimate of the potential city usage of energy from various energy generators for the next day. The prediction or estimate of energy available from various types of energy generators is derived from the pricing/availability information on the various types of generators provided by the energy provider 50, 52 in step 401. When the available capacity of the various generators (coal-fired plants, hydro-electric, wind, solar) and the predicted demand is known, an intelligent green index goal may be calculated. The SGC 102 can determine the city-wide usage of energy from the various sources based on pricing factors. For example, even though sufficient solar energy may be available for the city, it may be too expensive to purchase exclusively solar energy from the provider 50, 52. Accordingly, the SGC 102 may suitably determine a favorable mix of energy from the various sources based on availability and pricing, the data of which is received from the energy provider 50, 52.

[0055] It will further be appreciated that SGC 102 will determine the DI such that it would not require an unrealistic reduction in consumption. As discussed above, while the goal may be to achieve an average green index approaching carbon neutrality, the day to day goals will vary based on consumption patterns and availability of green energy.

[0056] Thereafter, in step 408, the SGC 102 calculates the district desired indices DDIs, or $DDI_1 \dots DDI_n$ based on the overall DDI. As discussed above, the SGC 102 effectively allocates the green index goals among the districts to taken into account the specific needs, structure and capabilities of each district. To this end, the SGC 102 finds a solution wherein the following equation is satisfied:

[0057]
$$DI * POP = DDI_1 * DIST_POP_1 + \dots + DDI_n * DIST_POP_n$$

[0058] where POP represents the total population (or other normalizing factor), and $DIST_POP_x$ is the population (or other normalizing factor) for the district x .

[0059] Once the values of $DDI_1 \dots DDI_n$ are determined, the IMS 110 in step 410 provides the values to the respective district management systems $DMS_1 120 \dots DMS_n 130$. The IMS 110 may also provide information regarding the available energy from the various energy generators to the respective district management systems $DMS_1 120 \dots DMS_n 130$. It is possible that the IMS 110 could play some role in allocating energy from the various generators (coal-fired, hydro, solar, wind, etc.) to the various districts. However, it is also possible that other systems perform this allocation independently. Accordingly, it is also possible that the IMS 110 provides no information regarding the available energy from the various generators, or provides information regarding the allocation of energy from the various generators that had been determined by another system.

[0060] Thereafter, in step 412, the IMS 110 receives from the respective district management systems $DMS_1 120 \dots DMS_n 130$ a revised district desired index, $RDI_1 \dots RDI_n$. The revised index, RDI_x is calculated by the various district management systems $DMS_1 120 \dots DMS_n 130$ based on the original desired district index $DDI_1 \dots DDI_n$ and any commitments to achieve a lower consumption value or green index by consumers. This operation will be discussed below in further detail in connection with Fig. 5.

[0061] In step 414, the IMS 110 calculates a revised index RI based on a sum of all revised district indices $RDI_1 \dots RDI_n$. For any district that does not have a revised district index, the original value DDI_x may be used.

[0062] As a consequence of the operations of Fig. 4, the IMS 110/SGC 102 performs multiple roles, including that of aggregating and storing consumption information from prior periods, determining a desired city-wide carbon consumption index DI, and determining desired district carbon consumption indices such that, if achieved, the entire city will achieve the desired

index DI. In this embodiment, the IMS 110/SGC 102 further determines a revised carbon consumption index RI based on the cumulative commitments of individual end users to reduce their consumption and/or achieve reduced carbon consumption for a given day (or other time period).

[0063] As discussed above, the revised desired index RI may be used in a number of ways. In one embodiment, the IMS 110 may communicate the consequent reduced demand level to the provider 50, 52 in an effort to achieve better pricing, or to challenge the provider 50, 52 to make available even more low-carbon energy at a given price point. In this manner, the consumers and end users have the ability to coordinate to demand more energy generated by lower carbon sources.

[0064] For example, one or after step 414, the SGC 102/IMS 110 may communicate information to the provider 50 requesting revised energy availability information based on the revised index RI. In particular, if the revised index RI is substantially improved over the originally calculated desired index DI, the IMS 110 may request more favorable pricing based on reduced carbon usage (or even reduced overall usage) resulting from the commitments that resulted in the revised index. The IMS 110 would then receive from the provider 50 revised availability information as per step 401, preferably with better pricing terms. In some cases, the provider 50 may provide information indicating even better terms if the city can reduce its needs still further. The IMS 110 would then calculate a new desired index based on the further proposal from the provider. Thereafter, the IMS 110 can execute again the operations of Fig. 4 using the new desired index. In this manner, the IMS 110 (and the city in general) can challenge the energy provider 50, and vice versa, in an iterative manner to reduce carbon usage and/or overall energy consumption.

[0065] Fig. 5 shows the operations carried out by each DMS_x to carry out the functionality of the system 100. As with Fig. 4, the operations of Fig. 5 need not be carried out in the precise order given, and may constitute different processes executed on the computing device (e.g. the device 300 of Fig. 3). The steps of Fig. 5 may suitably be carried out once per day.

[0066] In step 502, the DMS_x (e.g. DMS_1 110) determines the ADI_x for the district for the prior time period, such as the previous day. To this end, the DMS_x obtains from the various consumer systems BMS_{xy} and HMS_{xy} their respective actual green index ACI_{xy} values from the prior day. The DMS_x uses these values ACI_{xy} to determine the district-wide ADI_x for the prior day. If the ADI_x is normalized on a per person basis, then the aggregate ADI_x may be calculated by the following sum:

[0067]
$$ADI_x = \sum_{j=1}^n (ACI_{xj} * population_{xj})$$

[0068] wherein ACI_{xj} is the actual green index for the j th building or home system in the district x , and the value $population_{xj}$ is the population normalization value for (i.e. number of people associated with) the j th building or home system in the district x .

[0069] In step 504, the IMS 110 stores the calculated district ADI_x value and further communicates the district value ADI_x to the IMS 110.

[0070] In step 506, the district management system DMS_x receives the desired green index DDI_x for the district from the IMS 110.

[0071] Thereafter, in step 508, the DMS_x calculates the desired indices DCI_{xj} for each consumer system in the district, based on the overall desired index DDI_x for the district. For example, the DMS_1 would calculate the desired green index DCI_{11} for the BMS_{11} 140, the desired green index DCI_{12} for the HMS_{12} 150, and the desired green index DI_{13} for the HMS_{13}

160, based on the value DDI_1 . As discussed above, the DMS_x effectively allocates the green index goals among the consumer systems in a manner that takes into account the specific needs, structure and capabilities of each consumer. To this end, the DMS_x finds a solution wherein the following equation is satisfied:

[0072]
$$DDI_x * DIST_POP_x = DCI_{x1} * CUST_POP_{x1} + \dots + DCI_{xn} * CUST_POP_{xn}$$

[0073] where $DIST_POP_x$ represents the total population (or other normalizing factor) of the district x , and $CUST_POP_{xj}$ is the population (or other normalizing factor) for the j th customer in the district x .

[0074] Once the values of DCI_{xj} are determined, the DMS_x in step 510 provides the values to the respective consumer systems in the district. Thus, for example, the DMS_1 would provide the values DCI_{11} , DCI_{12} and DCI_{13} to the respective systems BMS_{11} 140, HM_{12} 150 and HMS_{13} 160. The DMS_x may also provide information regarding the available energy from the various energy generators to the respective consumer system.

[0075] In this manner, the desired indices for the various end user building systems CMS_{111} 140, HM_{112} 150, CMS_{113} 160, CMS_{1n1} 170, CMS_{1n2} 180 and CMS_{1n3} 190 are selected intelligently to achieve the desired carbon consumption index DI for the entire city.

[0076] It can be seen that in addition to the downward propagation and allocation of desired green indices for the systems, districts and city, the system 100 also operates to effectuate upward propagation of *actual* green indices for the previous time period to the SGC 102 and other intermediate nodes.

[0077] One advantage of the embodiment of Fig. 1 is that it allows for the communication of carbon usage goals to individual end users, wherein the goals are selected to help achieve a community-wide carbon usage goal. In this manner, individual energy consumers

can be made aware of how they can contribute meaningfully to reducing or at least limiting carbon and/or energy usage. As will be discussed below, the system 100 of Fig. 1 makes possible a number of further enhancements that can assist in achieving carbon neutrality for a city or region. These enhancements can include automatic load shedding to achieve a desired green index, trading of excess carbon usage allotments, and the like.

[0078] Thereafter, in step 512, the DMS_x receives from the respective end user building management systems (e.g. BMS_{11} 140, HM_{12} 150 and HMS_{13} 160) any end user commitments to achieve a carbon consumption index that differs from the desired index $DCI_{x,y}$ provided to them in step 510. As will be discussed below, the end user or consumer has the option to commit to a green index or carbon consumption index for a period (i.e. the next day) based on a number of factors, such as the user's ability to reduce consumption or gain access to additional green (low-carbon) energy. This commitment value, CIC_{xy} is preferably lower than the DCI_{xy} provided to the user in step 510.

[0079] In step 514, the DMS_x calculates a revised district index $RDI_1 \dots RDI_n$. The revised index, RDI_x is calculated by taking the original desired district index DDI_x and changing it based on the CIC_{xy} values.

[0080] By way of example, consider a user in the HM_{12} has committed to carbon usage for the period that is 50% of the carbon usage originally allocated to the HM_{12} in step 510. In other words $CDC_{12} = 0.5 * (DCI_{12})$. The DMS_1 calculates a revised district index RDI_1 based on the original desired district index DDI_1 reduced by the amount of the user's 50% reduction in its allocation. In this manner, the district's index DDI_1 for the period can be reduced by accumulated commitments of users within the district to reduce their carbon/energy consumption.

[0081] In step 516, the DMS_x provides the revised district index RDI_x to the IMS 110. As discussed above, the IMS 110 can calculate a new city-wide or region-wide index RI based on the revised district indices $RDI_1 \dots RDI_n$.

[0082] In order to carry out the green index communication and propagation features of the system 100 to the consumer, the end user device (e.g. HM_{12} 150, BMS_{n1} 170, etc.) includes a user interface that allows for communication of information to (and from) the end user. In the case of a business or larger facility (e.g. BMS_{11} 140), the building automation system (e.g. HVAC, fire safety, or security system) will likely have a computer workstation that may be used as the user interface to the system 100. In the case of a residential end user, a home computer may be used as the user interface to the system 100. However, it will be appreciated that HVAC controllers (i.e. thermostats) in residential environments often contain sufficient user interface tools (e.g. touch screens) that can allow for interactivity with the system 100.

[0083] Fig. 6 shows an exemplary system interface 600 that includes the basic components required to carry out the enhanced features of the system of Fig. 1. The system interface 600 may suitably be employed as any of the BMS_{xy} systems or HM_{xy} systems of Fig. 1. The system interface 600 includes a processing circuit 602, a display 604, user input devices 606, communication circuits 608, and memory 610. The processing circuit 602 is operably coupled to receive input from the user input devices 606, to provide output display information to the display 604, and to communicate data to and from the memory 610 and the communication circuits 608. As discussed above, the elements of the system interface 600 may be configured as a home computer, a building system work station, or even a wall thermostat device with a touchscreen display. The communication circuits 608 include any circuit that is capable of

communicating with at least a district management system DMS_x via a communication link, such as any of the links 142, 152, 162 of Fig. 1.

[0084] The memory 610 includes programming instructions sufficient to carry out, among other things, the consumer interface operations of Fig. 7 discussed below. If the system interface 600 is implemented as a home computer or other computer workstation, the consumer interface programming instructions may be downloaded from a server over the Internet, or some other network. The server may in some cases be implemented within the IMS 110 of Fig. 1.

[0085] Referring now to Fig. 7, the depicted flow diagram comprises an exemplary set of operations that may be carried out by the processing circuit 602 of the system interface 600 to provide an end user with information communicated by the system 100 of Fig. 1, and to provide the user with various options for controlling energy usage and/or information that may be used to tailor energy usage.

[0086] In step 702, the processing circuit 602 receives the desired index (e.g. DCI_{xy} of Fig. 1) for the user. As discussed above in connection with claim 1, the processing circuit 602 receives the DCI_{xy} for the user via a communication link from its corresponding district building management system (e.g. DMS_x). Referring to Fig. 6, the information is conveyed from the communication link to the processing circuit 602 by the communication circuit 610.

[0087] In step 704, the processing circuit 602 receives information regarding the electrical energy available to the user from different energy generators. In particular, on a given day, there may be a large amount of energy from renewable energy generators (wind/solar/wave) and on other days, there may be little energy available from such sources. As discussed further above, the availability of such sources may differ day to day based on weather, equipment status, demand, and/or green energy demand. Thus, in step 704, a particular user may obtain

information stating that x kilowatt-hours of electrical energy from renewable sources (wind/solar/hydro/wave) is available, and a larger amount of electrical energy from non-renewable sources (coal-fired) is available. In the embodiment described herein, the processing circuit 602 receives this information from its district management system DMS_x . In other cases, a separate energy brokering entity, not shown in Fig. 1, can communicate allocations of electrical energy from various energy sources, including renewable and non-renewable source electrical energy generators, to individual end users. In general, the processing circuit 602 receives information regarding how much energy from each source the user may consume.

[0088] In step 706, the processing circuit 602 calculates an energy consumption goal (i.e. maximum) for the user based on the received desired index (step 702) and the information regarding the sources of available electrical energy (step 704). If a relatively large amount of green energy is available, then the energy consumption goal may be relatively lax. If, however, a relatively small amount of green energy is available, then the energy consumption goal may be stringent (i.e. a low consumption limit).

[0089] As discussed further above, it will be appreciated that green index management will likely implicate more than electrical energy consumption through the utilities. Natural gas, oil and coal heating systems also contribute to the carbon footprint. To the extent such information is available, it can be incorporated in to the electrical energy consumption goal. For example, the processing circuit 602 may use the prior day's gas or oil usage (and weather) to predict the usage of natural gas for the current day. For predicted vehicle fuel, the processing circuit 602 may simply inquire the user for a predicted gasoline or diesel fuel usage for the day. In any event, the processing circuit 602 could be configured to incorporate the predicted usage of non-electrical energy into the carbon usage for the day. In such a system, the processing circuit

602 would determine the electrical energy goal based also on the predicted usage of other (non-electrical energy) carbon-based energy.

[0090] In step 708, the processing circuit 602 displays the user's desired index and the user's electrical energy consumption goal for the day. As discussed above, the electrical energy consumption goal is preferably calculated as the energy consumption limit that would be required to achieve the desired green index.

[0091] In step 710, the processing circuit 502 provides the user with a number of options for further action regarding the received desired green index. These options may include trading access to green energy, allowing automated load control, requesting advice on reducing consumption, requesting incentives for achieving different enhanced levels of the DCI.

[0092] It will be appreciated that the particular options shown in step 710 are given by way of example only, and other systems may selectively implement any combinations of these options, as well as others.

[0093] Referring specifically to the options presented in step 710, the first option 1) is to allow the user to engage in trading of access to green energy. In particular, while the availability of energy from various sources, including green and non-green sources, is provided to the user in step 704, it is possible through the system 100 to allow for trading of access to green energy. For example, if one user believes that it cannot achieve its nominal consumption goal as displayed in step 708, and therefore cannot achieve its desired green index, then the user may consider paying a premium to obtain access to more green energy for the day. If additional green energy is obtained, then the user may be able to meet the DCI for the day when otherwise reducing consumption to a required amount is impracticable. Meanwhile, another user may not need to use its allotted energy consumption to achieve its green index, and therefore may not need to use

as much green energy as it was nominally allotted. Accordingly, the system 100 allows for trading of green energy access. Such trading would allow people to request additional green energy access at a premium, and allow others to relinquish their green energy access for a credit. This trading of green energy access allows for financial incentives to reduce consumption even when a particular user can otherwise meet its desired green index.

[0094] Such a green energy trading system can be maintained, for example, by the IMS 110 for the entire district, or by another entity such as an energy brokering system, not shown in Fig. 1, but which are known in the art.

[0095] In the second option 2) of step 710, the processing circuit 602 permits the user to select whether to employ automated load control. Automated load control may be used for the purpose of achieving the desired green index and energy consumption goal for the day. In particular, it is known to provide load control systems for residences, as well as large building automation systems. Load control includes load shedding to reduce consumption. Load control is typically carried out such that load shedding does not create dangerous situations or damage to property. For example, load shedding may be used to temporarily disable air conditioning units, water heating units or electric appliances in a residence. Load control may be used in larger scale HVAC systems to alter temperature set points.

[0096] If the user selects this option in step 710, then the user allows for software executed either by the processing circuit 602, by the DMS_x or even the IMS, to perform load control and/or load shedding at the user's residence (or facility) as is necessary to achieve the user's DCI value. It will be appreciated that many users do not want to relinquish control over their use of electrical energy. Such users need not select this option. Nevertheless, others that

desire to achieve their desired green index without having to determine how and where to adjust their consumption may elect this option.

[0097] In the third option 3) of step 710, the user may simply request advice on reducing consumption. For example, the user may request advice on how increasing their temperature set point from 74° to 76° for two hours may decrease their electricity consumption, and hence affect their green index for the day. To this end, the processing circuit 602 may execute energy management software that is able to predict and/or calculate electrical energy consumption based on changes in behavior. In some cases, the energy management software resides at the DMS_x, IMS 110, or some other remote server device. In any event, once the predicted energy consumption reduction is determined, the effect on green index may be determined based on the predicted reduction and the electrical energy sources available to the user as determined in step 704. Using this function, the user can actively participate to reduce his or her green index by exploring potential methods of reducing consumption and their effect on carbon usage.

[0098] An additional option d) of step 710 facilitates incentives for a user to exceed expectations or goals defined by its desired green index. In particular, the processing circuit 602 in this option would allow the user to inquire as to whether a monetary or other incentive is available to achieve 90% or less of the user's desired green index for the day. The incentives may be managed at the DMS_x and/or the IMS of Fig. 1. To this end, the DMS_x or IMS may communicate available incentives to the processing circuit 602 in response to the execution of this option. The available incentives might include those that provide a credit for keeping the DCI below a prescribed lower limit for the day. The use of incentives can achieve further reduction of carbon usage even among those who can readily meet their DCI for the day.

[0099] Finally, in step 712, the user may enter a commitment to a different green index for the next period based the original desired index $DCI_{x,y}$, the user's ability to obtain access to additional low-carbon energy (i.e. by trading access to more in step 710), and the user's ability to reduce consumption below the consumption goal displayed to the user in step 708.

[00100] In this manner, the user can assist in further reducing the carbon consumption. In step 714, the consumer index commitment CIC_{xy} , is transmitted upward to the respective district management system DMS_x . As discussed above in connection with steps 512 and 514, the DMS_x gathers all consumer commitments $CIC_{x,y}$ and determines a revised district index RDI_x based on those commitments.

[00101] One of the features of the options of the above-described system is that each consumer in the community can contribute to helping the entire community achieve its own green index. While the communication of the desired green index to the individual consumer provides a benchmark for each user, the additional options of step 710 help each user tailor its consumption and/or purchasing of energy to meet its individual goal.

[00102] While the present invention has been illustrated by the description of exemplary processes and system components, and while the various processes and components have been described in considerable detail, applicants do not intend to restrict or in any limit the scope of the appended claims to such detail. Additional advantages and modifications will also readily appear to those skilled in the art. The invention in its broadest aspects is therefore not limited to the specific details, implementations, or illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicants' general inventive concept.

What is claimed is:

1. An arrangement for use in a distributed system for an energy grid, comprising:
a processing circuit; and
a plurality of destination nodes coupled to the processing circuit;
wherein
the processing circuit is configured to
calculate a desired destination index for each of the plurality of destination nodes
based on a desired aggregate index for the plurality of destination nodes, wherein the
desired aggregate index includes information representative of carbon consumption, and
communicate each desired destination index to the corresponding one of the
plurality of destination nodes; and
each of the plurality of destination nodes is configured to:
receive the desired destination index from the processing circuit,
display the desired destination index on a display.
2. The arrangement of claim 1, further comprising:
a grid controller; and
a plurality of intermediate nodes, each intermediate node coupled to the grid
controller, a first intermediate node including the processing circuit; wherein
the grid controller is configured to
calculate the desired first index,
calculate the desired aggregate index

calculate at least a second desired aggregate index;

communicate the desired aggregate index to the processing circuit, and

communicate the second desired aggregate index to a second intermediate node.

3. The arrangement of claim 2, wherein the grid controller is configured to calculate the aggregate desired green index and the second aggregate desired index based on the desired first index and historic energy consumption data.
4. The arrangement of claim 3, wherein the grid controller is configured to calculate the aggregate desired index on a daily basis.
5. The arrangement of claim 3, wherein the processing circuit is further configured to:
determine each desired destination index based on the desired aggregate index and historic consumption data associated with the corresponding destination node..
6. The arrangement of claim 5, wherein the processing circuit is configured to determine each desired destination index on a daily basis.
7. The arrangement of claim 1, wherein the desired aggregate index comprises a value derived from energy consumption information, and carbon content information relating to the energy consumption information.

8. The arrangement of claim 1, wherein the desired aggregate index comprises a value derived from energy availability information from a plurality of energy sources and a carbon value associated with each of the plurality of sources.
9. An arrangement for use in an energy grid, comprising:
- a grid controller;
 - a plurality of intermediate nodes each coupled to the grid controller, and
 - a plurality of destination nodes each coupled to an associated intermediate node, wherein the grid controller is configured to
 - calculate a desired first index for the grid, the desired index representative of carbon consumption,
 - calculate desired intermediate indices for each of the plurality of intermediate nodes,
 - communicate the desired intermediate index to each of the plurality of intermediate nodes;
- each of the plurality of intermediate nodes is configured to
- receive a corresponding desired intermediate index from the grid controller,
 - calculate desired destination indices for destination nodes of the plurality of destination nodes that are coupled to the intermediate node,
 - communicate the desired destination indices to each of the plurality of destination nodes that are coupled to the intermediate node; and
- each of the destination nodes is configured to
- display the desired destination index for the destination node on a display.

10. The arrangement of claim 9, wherein the destination node is further configured to communicate a user-generated adjusted destination index to the intermediate node.
11. The arrangement of claim 9, wherein the intermediate node is further configured to:
 - receive the user-generated adjusted destination index
 - determine a revised intermediate index based at least in part on the received adjusted destination index; and
 - communicate the revised intermediate index to the grid controller.
12. The arrangement of claim 11, wherein the grid controller is further configured to calculate a revised first index for the grid based at least in part on the revised intermediate index.
13. The arrangement of claim 12, wherein the grid controller is further configured to:
 - communicate a request to an energy provider node, the request including information generated based on the revised first index;
 - receiving energy availability information from the energy provider node responsive to the request.
14. The arrangement of claim 9, wherein the desired aggregate index comprises a value derived from energy consumption information, and carbon content information relating to the energy consumption information.

15. The arrangement of claim 9, wherein the desired aggregate index comprises a value derived from energy availability information from a plurality of energy sources and a carbon value associated with each of the plurality of sources.
16. An arrangement for use in a distributed system for an energy grid, comprising:
- a memory including programming instructions;
 - a processing circuit; and
 - a communication circuit operably connected to receive a desired destination index from a remote node, the desired destination index including information representative of desired carbon consumption for an electrical load associated with the arrangement, and
- wherein the processing circuit is further configured to
- generate a revised destination index based on user-generated information, and
 - communicate the revised destination index to the remote node.

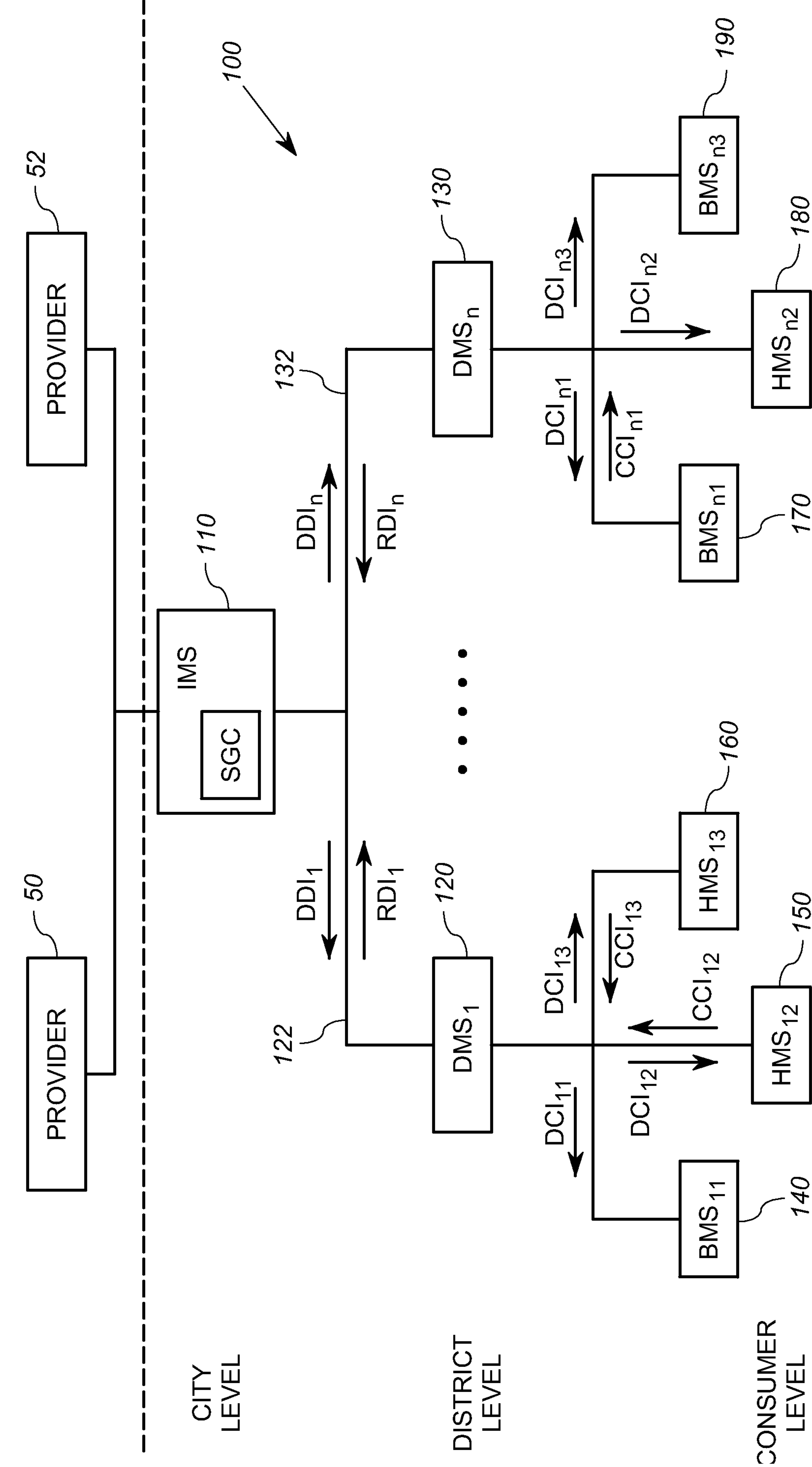


FIG. 1

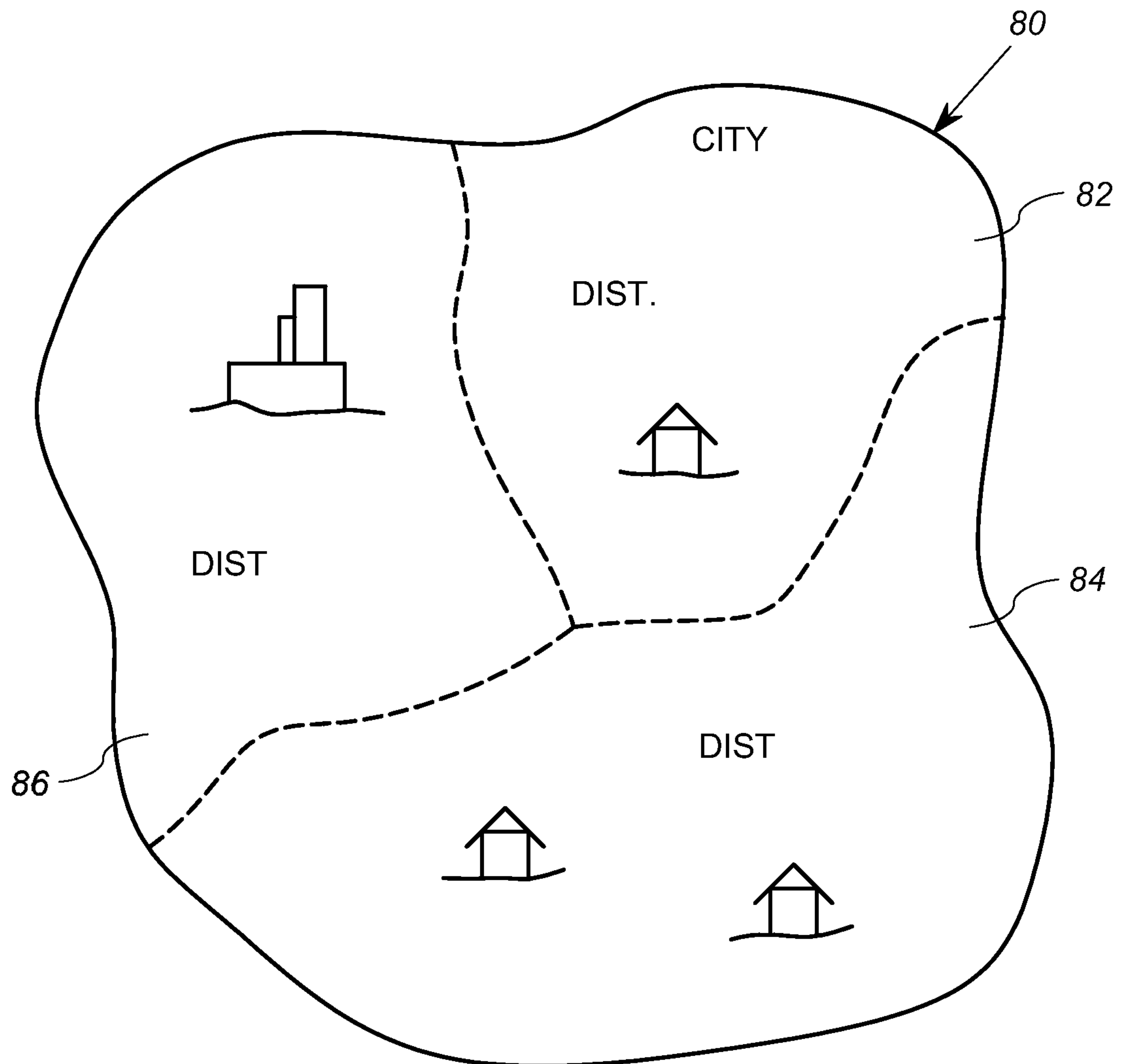


FIG. 2

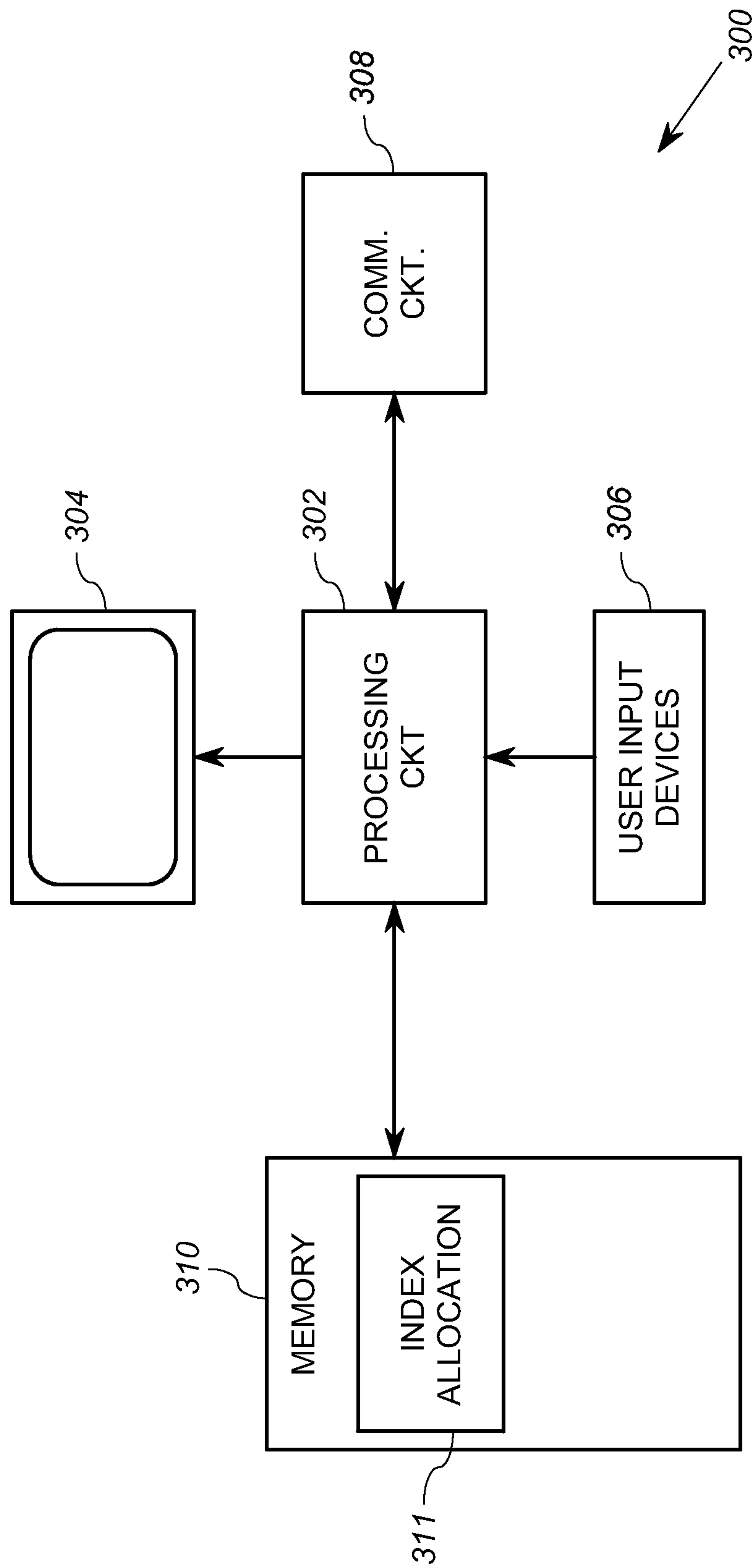
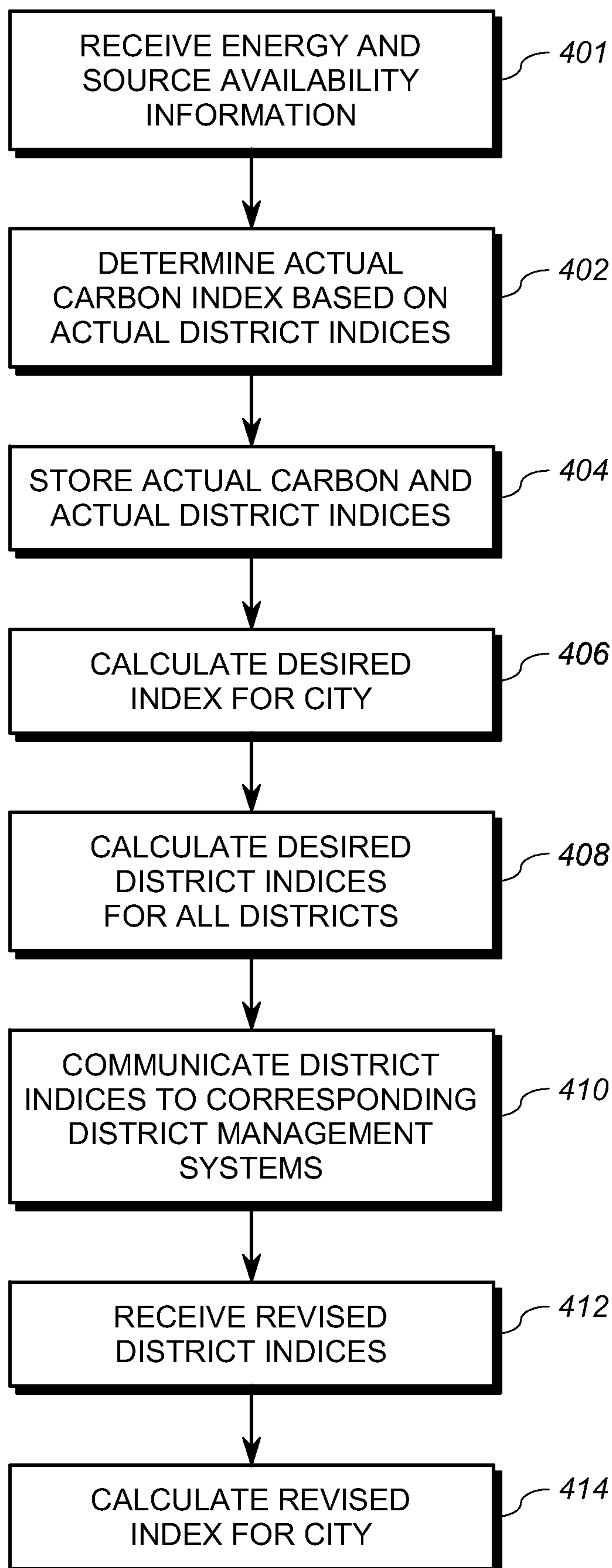
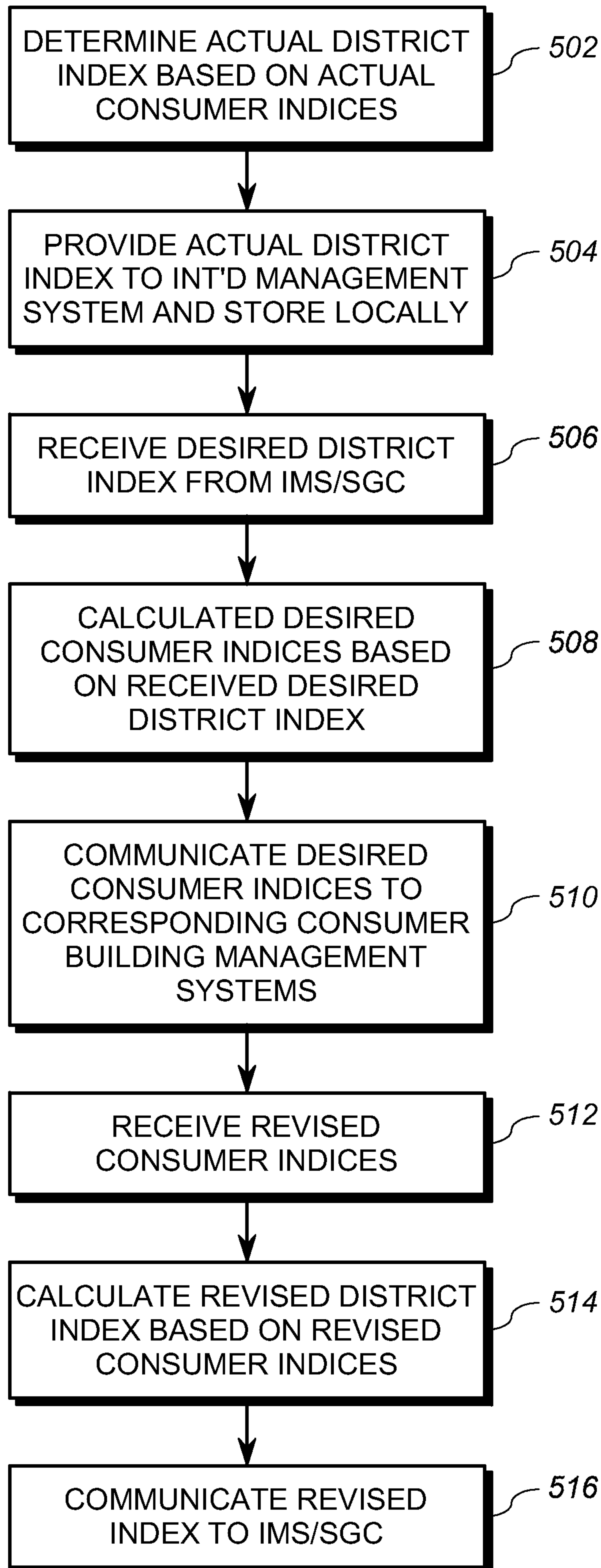


FIG. 3

**FIG. 4**

*FIG. 5*

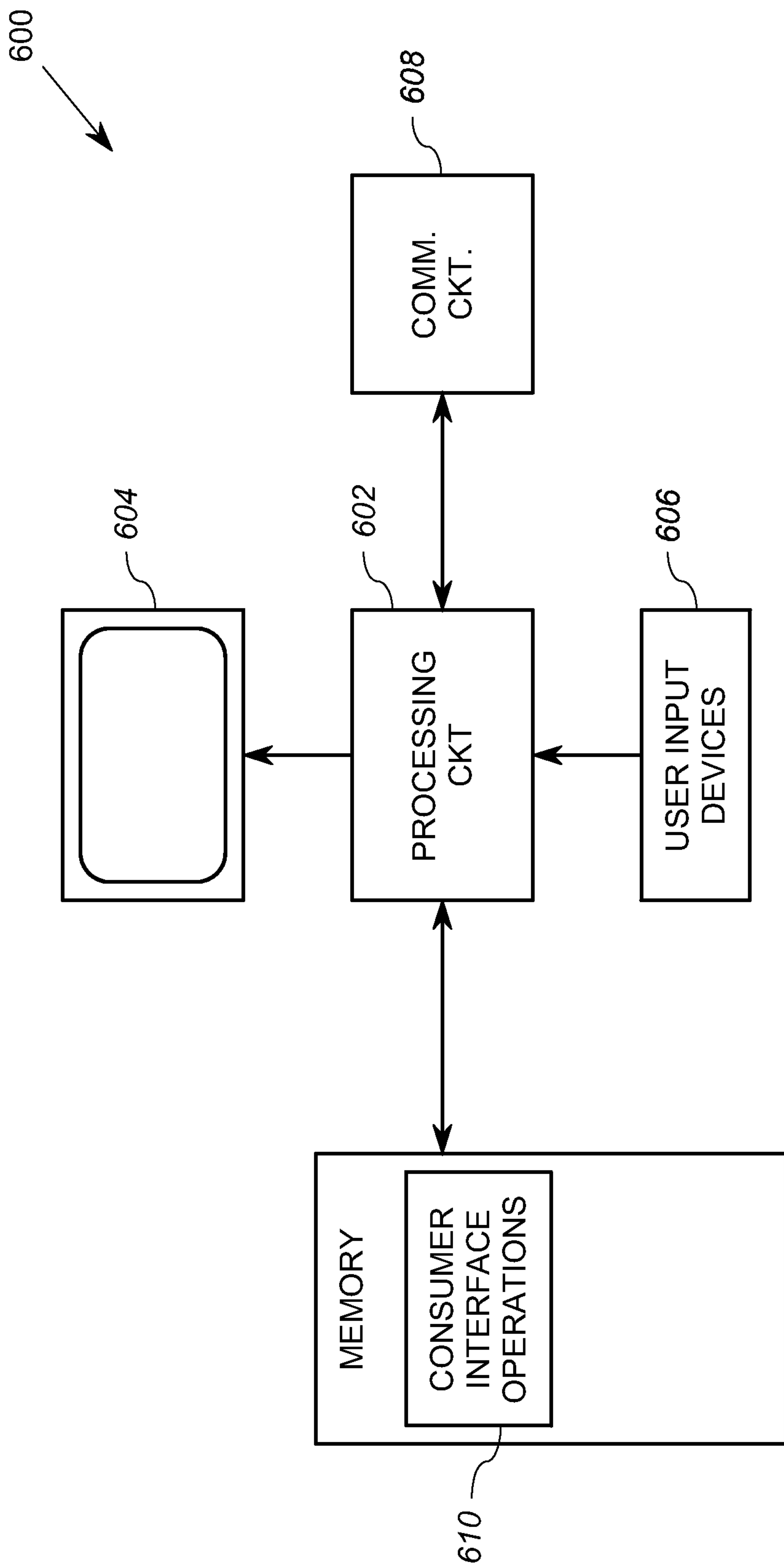


FIG. 6

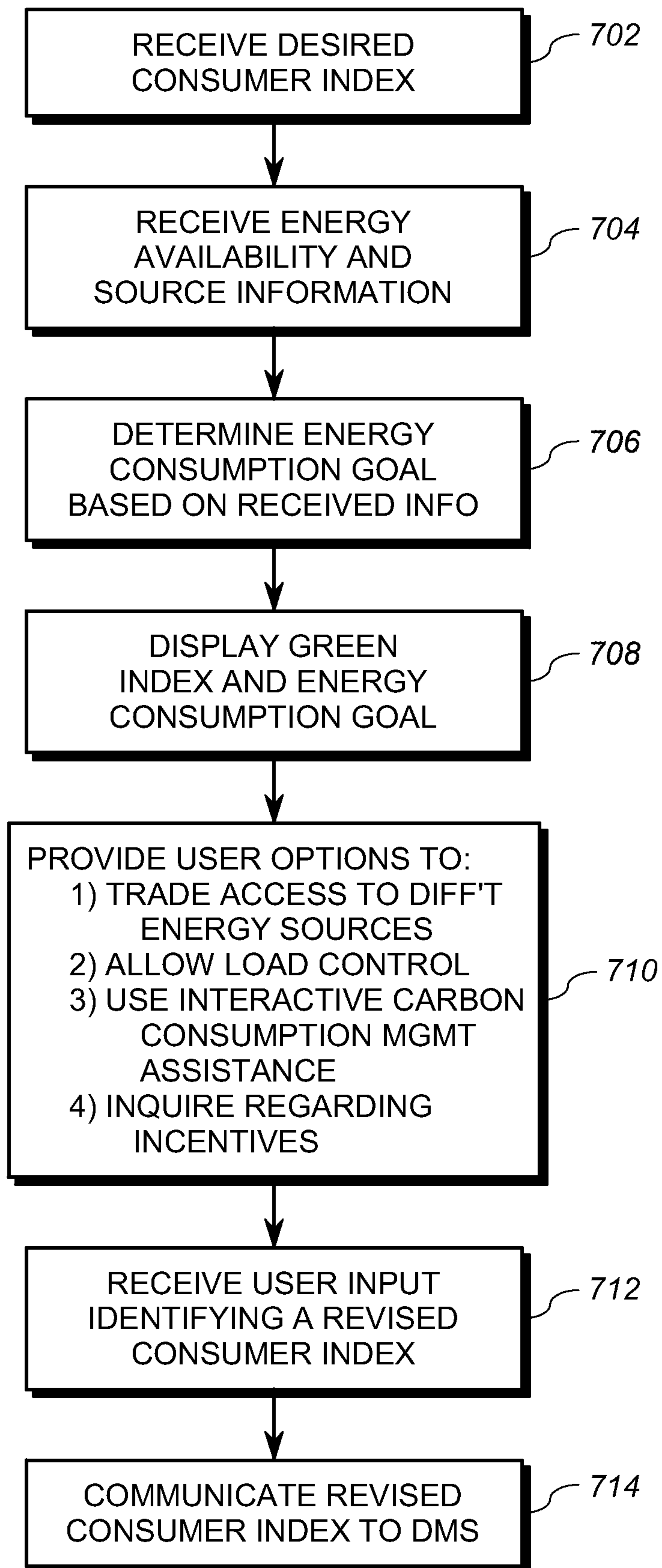


FIG. 7

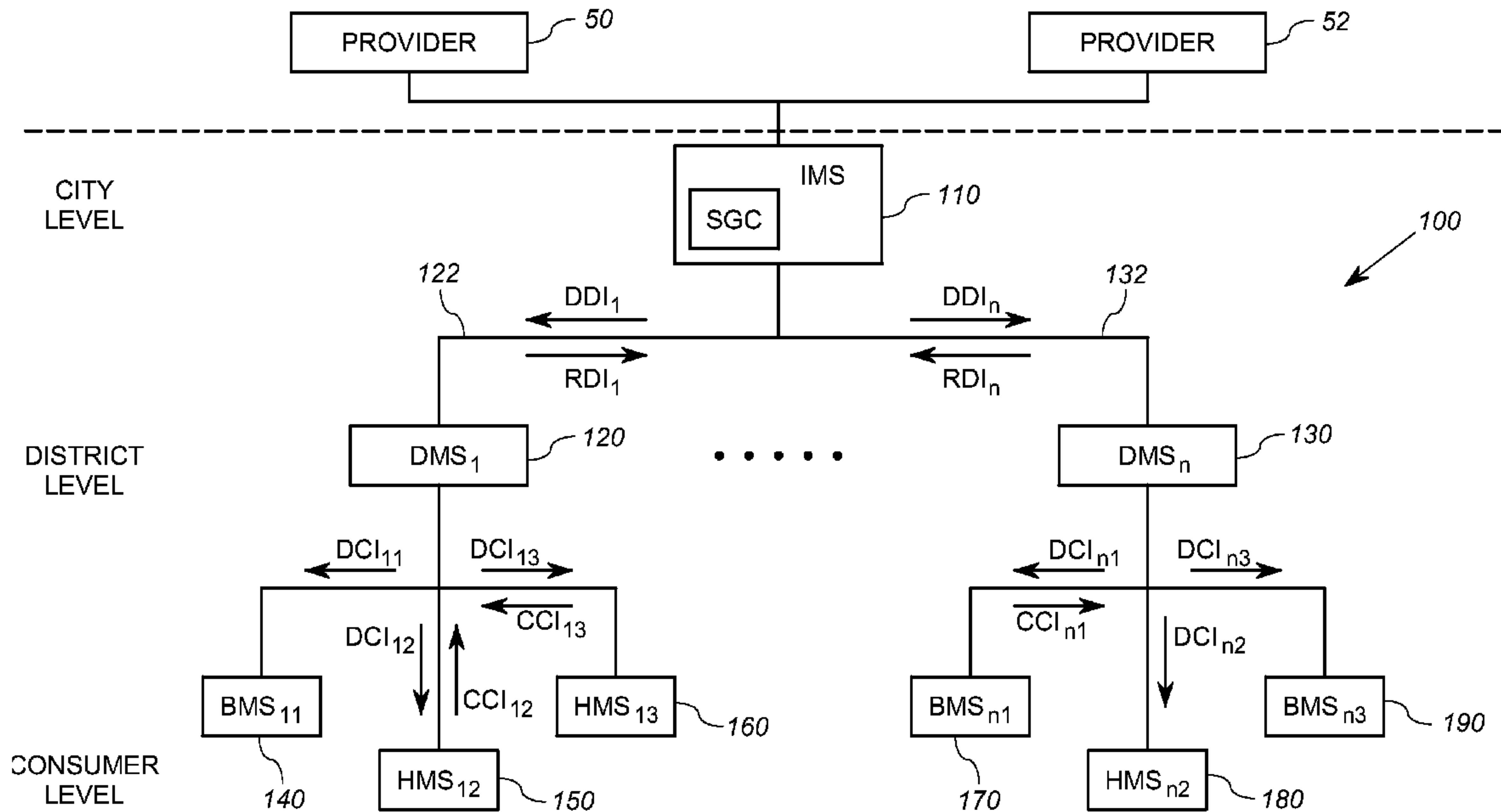


FIG. 1