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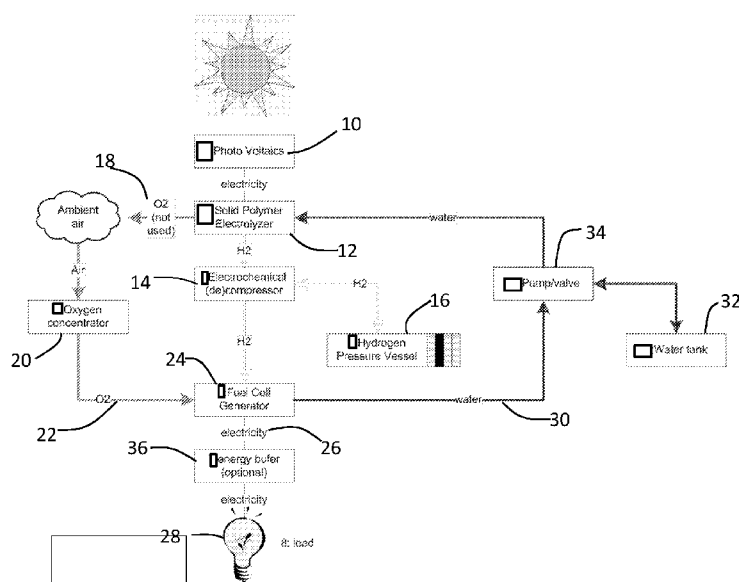


FIG. 2

(57) Abstract: The invention provides a power supply system comprising a solar panel for generating electricity and a fuel cell for supplying electricity to a load. The fuel cell is regenerated using the electricity generated by the solar panel. This regeneration is based on supply and demand data for at least a full year cycle. In this way, an energy shift method is used to create an energy efficient system to store summer surplus energy, for either longer endurance or even over the winter. This fuel cell system can for example break the geographical barrier for off grid street lighting system with high light output by downsizing the photo-voltaics while upsizing energy storage, thereby reducing cost compared to battery driven systems.

Solar power supply system

FIELD OF THE INVENTION

This invention relates to solar powered systems, in particular to systems which are intended to operate all year. An example is solar powered lighting, such as street lighting.

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BACKGROUND OF THE INVENTION

Present solar powered lights use batteries to store the energy for use in the night. Current battery powered solar lighting systems fail in required light output. In particular, at geographical latitudes higher than Paris there is no solution for high lumen, battery powered street lighting.

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The reason is simple: the system needs to be dimensioned for the shortest day in winter, which means large photovoltaic (PV) cells and bulky batteries. Geographical latitude is a barrier. The batteries become too bulky and the solar panels too large to install on the pole. The cost increase is non-linear: at a certain point there is for example a requirement for expensive ground works or a stronger pole.

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A solution would be cheap energy storage for very large capacities. This energy store should store summer surplus energy without self-discharge and use this for either longer endurance or even over the winter. This would enable downsizing of the expensive solar cells.

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Figure 1 shows the energy surplus in the summer caused by the increased ratio of day length to night length. The shortest day in winter drives the PV component size, as is signified by the line 1 in Figure 1, as well as ability to store energy in batteries (which is not optimal at low temperature). The longest day in summer produces surplus energy 2 which cannot be stored, unless the battery is over dimensioned, thereby not fitting inside lighting pole. The line 3 in Figure 1 signifies a downsized energy scenario which is made possible if part or all of the summer surplus energy could be stored for later use in the winter. The result is a down sized PV requirement, which is one of the most expensive components in a solar powered, battery driven lighting system.

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There various reasons why a solar powered street lighting solution is of interest.

The current technology of grid connected outdoor lighting has high installation cost. For example the cost of cable installation can vary greatly due to local wage cost, ground class, etc., but is high. The pole installation is also costly and connecting this to the grid as well as disconnecting this from the grid is costly. There are also maintenance costs, for example cable repair can be required when tree roots penetrate cables.

The current technology of a solar powered, battery driven system is not optimal.

There is PV over dimensioning by dimensioning for the shortest day in winter and therefore over dimensioning for summer. The difference between summer and winter increases with higher geographical latitude.

Backup capacity is also provided: if the system implements a backup capacity in the energy storage, it can bridge several days of bad weather. Longer autonomy requires costly expansion of battery storage. Typically, the systems are designed to enable 4 days of autonomy, possibly making use of intelligent dimming. During the bad weather, when the system's PV does not generate enough energy for a whole next night of lighting, the missing energy is taken from the backup capacity. However, once the backup capacity is depleted, it must be recharged and this requires additional PV capacity. The PV cell does not only need to generate the energy for the next night, but should also generate (part of) the backup capacity to restore its function.

Photovoltaic panels for electricity production are very expensive and any over dimensioning is thus costly. Lighting in particular is an application with a very long time discharging the energy storage, therefore requires a large capacity but only modest power.

Batteries cannot scale power and capacity independently.

Long term seasonal storage is impossible with batteries due to self-discharge. Depending on battery technology, state of charge and temperature, this may be larger than 10% capacity loss per month. What is required is a technology without self-discharge.

Battery discharge performance in the cold is a fraction of the performance under warmer test conditions of typically 25 degrees C. This is caused by the Arrhenius factor, which describes limited chemical kinetics at lower temperatures. In addition, when using Lead acid batteries, at temperatures slightly below zero the electrolyte will freeze up. The solution is to over dimension the battery, so it can still release enough power.

Alternatively a heater can be included, but the power for that would need to be stored in the battery first, requiring additional capacity and again requiring a larger PV array.

Some battery technologies will also degrade when charged at sub-zero temperatures. An example is Li-Ion technology, which will suffer from Lithium plating under such conditions when it is charged with a high current. Again, an internal heating system is a solution.

It has been proposed to use a fuel cell ("FC") within a street lighting application, for example in WO 2007/052960. A fuel cell system can solve many of the above problems of solar powered, battery driven, energy storage. The proposed system uses a fuel cell as a backup energy source.

Even when using a fuel cell approach, the problem remains that the system has to be designed for worst case weather conditions.

SUMMARY OF THE INVENTION

It is an object of the invention to address the above problem. The invention is defined by the independent claims. The dependent claims define advantageous embodiments.

According to the invention, there is provided a power supply system comprising:

a solar panel for generating electricity;

a rechargeable fuel cell for supplying electricity to a load;

a system for recharging the fuel cell using the electricity generated by the solar panel; and

a control system for controlling the recharging,

wherein the control system controls the recharging based on supply and demand data for at least a full year cycle.

This system makes use of a rechargeable fuel cell, which will also be referred to as a regenerative fuel cell ("RFC") as a power source and provides optimum control of the regeneration (i.e. recharging) function based on at least a full year cycle. This enables the power requirement or size of the solar panel to be reduced to a minimum to achieve all year operation.

The regenerative fuel cell can store summer surplus energy without self-discharge and use this for either longer endurance (i.e. to overcome multiple successive days with bad weather) or even over the winter. This enables downsizing of the expensive solar cells. This system charges and discharges like a battery, but large storage expansion is much

cheaper than for batteries, simply because it requires only that a certain amount of reactant gas (typically hydrogen) is stored at a higher pressure inside the pressure vessel.

The system can work at higher latitudes, and can enable 4 or more days autonomy easily. Thus, the invention for example enables the geographical boundary, that is imposed on battery powered solar lighting systems to achieve high lumen light output, to be crossed

The invention provides a system that can be lower cost than solar charged batteries. Only a small primary energy source is needed. The system is flexible in that the power and capacity can be scaled independently and the extension of the storage capacity is possible at low additional cost. This, after the initial investment, expansion of fuel cell storage is cheaper than for batteries. This is particularly the case when there is a large asymmetrical relation between a small power need and large capacity requirements, as is for example the case in street lighting applications or water irrigation pumping.

Thus Off grid Solar powered Lighting technology ("OSL") is one particular application. In this case, the invention can avoid the need for a ground box containing a large battery, as all parts can be in the pole. A smaller battery can be used for start-up of the system, or to enable the fuel cell output to be made more constant over time.

In one implementation, the system for recharging the fuel cell comprises:

a water tank for storing water generated by the fuel cell;

an electrolyser for generating hydrogen from the water;

a hydrogen storage vessel; and

a compressor for compressing the hydrogen and providing it to the hydrogen storage tank.

This is a hydrogen fuel cell system for example a regenerative water proton exchange membrane ("PEM") system.

The system for recharging the fuel cell can further comprise an oxygen concentrator for providing oxygen from the air to the fuel cell. The electrolyser in this case can expel generated oxygen to the ambient surroundings. Alternatively, the system for recharging the fuel cell can further comprise a compressor for supplying oxygen produced by the electrolyser to an oxygen storage vessel for providing oxygen to the fuel cell. This is a closed system.

The system can be for supplying power to a street lamp. The yearly cycle thus takes account of the lighting requirement over the year as well as the solar panel illumination over the year. By taking account of the full year cycle, the solar panel can be dimensioned to

an optimum level which takes account of the ability to average the regeneration function over a yearly cycle. The design can be based on this simple averaging but it can also be more complicated to provide regeneration only when most efficient, in order to prolong the life of the system.

5 The system can be provided within a lamp post, with the water tank vertically above the electrolyser and the compressor vertically above the hydrogen storage vessel. This makes use of gravity to assist in the movement of the various reaction products.

 The control system is preferably adapted to derive a power supply map which indicates the expected power supply over a period of at least one year, and which takes
10 account of at least the sun exposure times of the system and the performance of the solar panel.

 It is also adapted to derive a power demand map which indicates the expected power demand over a period of at least one year, and which takes account of at least the expected load over time and a desired backup capacity.

15 A power surplus map can then be derived which indicates the power surplus over a period of at least one year, and which takes account of at least the power demand map and the power supply map, and then an energy production schedule can be derived for controlling the system from the power surplus map. The aim is to balance maximising energy production and limit run time.

20 Operational runtimes of the system components can be reduced to extend the life of the system yet at the same time maximising energy production, and the system can adapt proactively to changes in the predictions.

 The system can further comprise a battery for use in starting up the system and for temporary supply of power.

25 The invention also provides a method of generating a power supply, comprising:

 using a solar panel to generate electricity;

 supplying electricity to a load using a regenerative fuel cell; and

 recharging the fuel cell using the electricity generated by the solar panel,

30 wherein the recharging is controlled based on supply and demand data for at least a full year cycle.

 By "recharging the fuel cell" is meant replenishing the fuel used by the fuel cell.

DESCRIPTION OF THE FIGURES

Examples of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 shows how power generation varies over a yearly cycle;

Figure 2 shows a first example of system of the invention;

Figure 3 shows a second example of system of the invention;

Figure 4 shows how the system of the invention can be integrated into a lamp post;

Figure 5 shows the power supply map for several solar panel angles;

Figure 6 shows how a power supply map is generated in the system of the invention;

Figure 7 shows the power demand map;

Figure 8 shows how a power demand map is generated in the system of the invention;

Figure 9 shows how a surplus balance map is generated in the system of the invention and used to control the production schedule;

Figures 10 and 11 show different energy surplus situations for different system configurations and times during the year when the system is initiated;

Figure 12 shows how PV size and energy storage size can be traded for different use cases;

Figures 13 and 14 show two further different energy surplus situations for different system configurations and times during the year when the system is initiated;

Figure 15 shows different use cases for adapting the production strategy proactively; and

Figure 16 shows the complete control system of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

The invention provides a power supply system comprising a solar panel for generating electricity and a rechargeable (i.e. regenerative) fuel cell for supplying electricity to a load. The fuel cell is recharged (i.e. the system is regenerated) using the electricity generated by the solar panel. This regeneration is based on supply and demand data for at least a full year cycle. In this way, an energy shift method is used to create an energy efficient system to store summer surplus energy, for either longer endurance or even over the winter. This regenerative fuel cell system can for example break the geographical barrier for

off grid street lighting system with high light output by downsizing the photo-voltaics while upsizing energy storage, thereby reducing cost compared to battery driven systems.

The invention makes use of regenerative fuel cell technology. This has been used in the Gemini space flights in the 60s and has been studied intensively in the 90s.

5 Examples of state of the art product announcements are for example the "Greenergy" system of Areva which is a very large scale, 2MWh, 200kW-2MW power system. It uses a regenerative fuel cell system with H₂ and O₂ stored, exhaust water released and new water taken from the water grid. The "Xstorra" of Infinity is large scale, 5kW power system with H₂ stored and O₂ released. Exhaust water is released and new water is taken from the water
10 grid.

These systems are for large power and large capacity and they make use of a fresh water supply. The invention is intended for very small power and large capacity without needing a water supply.

Two implementations of the invention for an Off grid System Lighting
15 ("OSL") system will now be described.

Figure 2 shows a first example in which O₂ and H₂ are generated to drive the fuel cell at the highest possible energy efficiency, but only the H₂ is stored. The O₂ is released into the ambient air. When the fuel cell needs to generate power, the required O₂ is concentrated from ambient air with the support of an oxygen concentrator.

20 The system comprises a solar PV array 10 which generates electricity. The solar generated electricity is used by an electrolyser 12 to split water into hydrogen and oxygen. The electrolyser can generate very pure hydrogen. The hydrogen is compressed by compressor 14 and stored in a (lightweight) pressure vessel 16, while the oxygen 18 is released into the air.

25 An electrochemical compressor 14 will use electrical energy during compression of the hydrogen but regains most of the energy back during decompression.

An oxygen concentrator 20 filters ambient air and creates very pure oxygen 22. The clean/pure oxygen and hydrogen are offered to the fuel cell 24. The fuel cell 24 generates electricity 26 to provide power to the load 28 and produce waste heat and water at
30 the exhaust 30. Note that the electrolyzer and fuel cell can be combined in a unitised regenerative fuel cell.

The water is collected and stored in a water tank 32, for example using a pump 34 for renewed use in the electrolyser 12. The waste heat is reused in the thermal system to

keep the fuel cell and other components at an optimal working temperature. An energy buffer, e.g. a battery 36 is also shown.

The various functions are now described in more detail.

The sun provides insolation for the Photo Voltaics 10, which generate electricity. A state of the art solar charger will find the optimal working point under all temperature and irradiance levels. A backup energy source 36 starts the processes, absent sunlight.

The solid polymer electrolyser 12 ("SPE") is offered water from the local water tank and electricity from PV, to split water to generate Hydrogen (H₂) and Oxygen (O₂). The SPE 12 can generate moderate pressures of up to 20-30bar and implements adaptive control to cope with the intermittency of the solar power profile. The control system implements dynamic control strategies to maximize H₂ (and O₂) production under intermittent solar profiles. This new function is comparable with maximum power point tracking ("MPPT") in a solar charger: the system will always find the most optimal working point of the SPE under altering power conditions.

The O₂ is released into the air in a way to avoid corrosion and unsafe conditions. A sensor may detect the wind flow speed. The system may use this information to determine if it is "safe" to release O₂ during calm periods. If not, the system may eventually decide to halt offloading the O₂: this may happen for example by halting the electrolyser or temporarily store some of the gas in a small buffer or an entirely different strategy to prevent unsafe conditions.

The resultant H₂ gas from the SPE 12 is directed to the electrochemical compressor 14 either directly or via a buffer between the electrolyser and the electrochemical compressor. The electrochemical compressor compresses the gas to high pressures and stores this in the hydrogen pressure vessel 16. This step will consume electrical energy. The electrochemical compressor may be a separate component or may be integrated into the hydrogen storage pressure vessel. The control system finds the optimal working point for the electrochemical compressor to be able to cope with fluctuating H₂ supply, as may happen due to the electrolyser being driven by intermittent solar power. The control system will also implement a strategy against back diffusion, with valves or solenoids for example.

When the RFC system switches on load 28, the fuel cell generator may directly provide electricity to power the load and/or the system may use the energy buffer 36 (e.g. a battery) between the load 28 and the generator 24 to facilitate buffering of load fluctuations when the load would for example implement adaptive light dimming during

(parts of) the night or is switched on during a solar eclipse or other intermittent lighting events.

The control system attempts to keep the system running at a constant power level for as much as possible to extend the life of the fuel cell. The control system

5 implements a strategy when and how it is appropriate to recharge the energy buffer.

The reactant gases must be provided to the fuel cell generator to be able to generate power. A fuel cell based on PEM technology requires H₂ and O₂ for its chemical process.

10 Reactant gas hydrogen is fed from the hydrogen pressure vessel 16. The electrochemical (de)compressor 14 scavenges electrical power from the energy that is contained in the pressure of the compressed hydrogen gas. The electrochemical (de)compressor 14 expands the high pressure from the hydrogen pressure vessel 16 to the lower input pressure of the fuel cell generator 24. During this step the electrochemical (de)compressor will “generate” electrical energy. The control system finds the optimal
15 working point of the electrochemical (de)compressor to be able to cope with eventual fluctuating H₂ demand, as may happen when the fuel cell generator would have to adapt to a fluctuating load (for example adaptive dimming).

The control system also implements a strategy for safety, with valves or solenoids for example. A small overpressure of typically 2-5 bar increases performance in
20 PEM fuel cells. It is well known that a moderate overpressure of reactant gas yields higher fuel cell performance.

The oxygen required to drive the chemical fuel cell reaction is produced from ambient air by the oxygen concentrator 20. The oxygen generator 20 filters the ambient air and removes traces of CO, which may occur in polluted air in e.g. cities or industrial sites.
25 Since CO is a poison to the membrane of the PEM fuel cell and CO would degrade the life of the fuel cell generator, the oxygen concentrator will increase life of the fuel cell generator. It is well known that pure and clean oxygen yields higher fuel cell performance and longer life.

The fuel cell generator's chemical reaction will result in electricity to power the load, but also water at the exhaust and (waste) heat. The water is accumulated into the
30 water tank 32, which may be supported by a water pump and/or valve 34. The waste heat may be used to store heat in the water tank to prevent the tank from freezing up in very cold winter conditions: the heat may be used to heat the water or to “dump” it into Phase Change Materials or entirely different means.

A suitable thermal design of the water tank will make sure that a minimal amount of energy is required to keep the water liquid. In addition to insulation the system may implement a heater in the water tank to cope with extreme winter conditions, in conjunction with the energy buffer 36 that allows the system to start that heater.

- 5 The fuel cell generator and/or SPE can optionally work in a mode to produce heat for anti-freeze operation and the required additional energy is taken into account by a predictive planning module (described below).

Subsequently, the water can be offered to the Solid Polymer Electrolyser 12. The process repeats and the loop is complete.

- 10 An example system overview of the second embodiment is shown in Figure 3 which shows a fully closed RFC system for example OSL application.

The same reference numbers are used as in Figure 2 for the same components with the same functions.

- 15 The difference is that the O₂ 18 generated by the SPE 12 is not released into the air but using a compressor 40 it is stored in an oxygen pressure vessel 42. When the Fuel Cell Generator 24 is required to create power for the load 28, the Fuel Cell Generator is fed with O₂ from the oxygen pressure vessel 42 and H₂ from the hydrogen pressure vessel 16.

- 20 To minimize energy use for pumping, the component placement can utilize gravity as much as possible. An example of possible layout within a street lighting pole is shown in Figure 4. This is for the system of Figure 2.

As shown, the H₂ pressure vessel 16 is below the (de) compressor 14 which is below the water tank 32. The water tank is below the fuel cell generator 24.

- 25 The fuel cell generator 24 is fed with reactant gases, which flow from their sources to the fuel cell stack, including upwards. The water from the exhaust of the fuel cell 24 is collected in the water tank situated below the fuel cell generator thus using gravity, but above the electrolyser which can thus also be fed by gravity.

- 30 Since there can be overpressure in the water tank 32, a control function as part of the system management unit manages the interfaces from the water tank to the fuel cell generator 24 and electrolyser 12 via valves, solenoids, or other means. This eliminates a (mechanical) water pump, which may have more limited life than valves for example. Other configurations are of course possible.

The figure shows the height in meters (about 8m). The length of the pole is chosen arbitrarily, but a fracture zone from 0 to 1m is often mandated by legislation.

Figure 4 also shows a system management unit 50 (i.e. a controller). This controls the solar charging and maximum power point tracking ("MPPT"). This can include directing the solar panels at an angle to maximize power supply in the winter, since that is the most optimal placement for a solar powered, battery driven appliance and it will limit the over dimensioning a little.

The MPPT solar charger information (I, V, irradiance, temperature) can be used by the controller 50 to control the electrolyser, so that the electrolyser control electronics can adapt to the fluctuating PV power and maximize the H₂ production.

In addition, the MPPT solar charger information is passed to a power supply planning module of the system management unit 50 to enhance the quality of the power supply map.

Figure 5 shows a power supply map that can be integrated into the system architecture. This is the power supply map for Eindhoven. To create this map, there is recording of the energy production from the PV panels over time (as is known). This information (e.g. I, V, T-ambient, T-panel) is passed to a planning module part of the system management unit 50. The map enables the system to be able to predict the yearly available energy production and identify periods with surplus production for the energy shift from summer to winter. It shows the solar panel angle. Plots are shown for angles 90,40,25,15 and 0 degrees (in that order along line 51), but of course other angles can be used.

The power supply map is key to determine the periods during the day, but also the periods in the year, when the energy supply is highest. Equally important is to define the periods where the energy supply is very low, as the system may use this information to decide which periods to (partly) ignore and shift energy production to more suitable periods with much higher energy production in shorter time. This can be used to reduce runtimes of the SPE and electrochemical compressor components.

Thus, the fuel cell regeneration function is not simply carried out whenever there is surplus energy. Instead, the regeneration is planned over the year so as to maximise the lifetime of the components by using them only when most efficient. As explained below, this yearly cycle is used to determine the require PV and fuel cell capacities, and also optionally the battery capacity.

The power supply map lists the expected future energy supply per day over the whole year (or multiple years). Figure 6 shows how to generate the power supply map (which is shown in Figure 5) and shows the inputs to enable the computation.

A simple power supply map is created from readily available "insolation" information. This is provided as a "climate profile".

Databases can be used with recorded data such as for example but not limited to:

average daily temperature & daytime temperature (influencing voltage performance in PV modules)
irradiance (influencing current performance in PV modules)
solar average (in Wh/m²/day) or standard test condition ("STC") sun hours.
statistical averages over longer periods.

This data is used to create a power supply map over (more than) the whole year.

The power supply map is augmented by additional data. The system management will implement refinement algorithms to improve the yearly (PV) power supply map, resulting in an adaptive Total Solar Resource Factor ("TSRF") of the local site that can vary over the year(s), but will results in a strategy how maximum energy can be harvested over the whole year. Examples are for example but not limited to:

The required period in e.g. day cycles to restore the backup capacity. This is the "backup restore duration" information shown. The installed backup capacity may be adaptable, but must be restored when it was used/depleted during multiple days of bad weather. The restoration will require additional PV capacity.

Local Line Of Sight obstructions from local vegetation such as e.g. forestry. This data may be integrated into or uploaded to the system (for example growth tables of certain vegetation types). In addition, a sensor may record growth of forestry (for example via pictures or detection of Line Of Sight obstruction) and predict reduction of TSRF (i.e. future progression in solar obstruction). This information can be used in the surplus balance map to refine the planned energy production by taking into account what periods in the year will produce enough energy. This information may be communicated to off-board systems to plan e.g. vegetation maintenance or for other maintenance tasks such as e.g. a refill operation or some different operations.

Statistic averaging of locally recorded bad weather phenomena such as snow or clouds, leading to less PV power. This improves predictions after the first year. Alternatively this information may be augmented via data download over e.g. memory storage or data communication networks.

Local Line Of Sight obstructions from e.g. buildings, mountains, hills, etc.

Linke Turbidity data.

Local average daily and daytime temperatures, potentially increasing or reducing PV performance.

Past and recorded PV performance (I, V, T-ambient, T-panel). This is shown as "recorded local PV performance".

As shown, all of this information is combined to enable computation of the yearly power supply and to provide a power supply map. The list of possible data to be used as outlined above (other than the climate profile, backup restore capacity and recorded PV performance) is shown as "Augmented data".

In addition to modelling the power supply (i.e. how much energy is expected to be available throughout the year) there is also power demand planning management (i.e. how much energy will be needed). This can include taking account of light & dimming profiles.

A power demand map of the year is created, so as to be able to plan the amount of energy that needs to be stored for the energy shift from e.g. summer to winter. This power demand map comprises of basic information about geographically computed hours of light and dark, combined with the light and dimming information, and computes information such as (but not limited to) average load/day to plan the energy production and energy storage management.

With the power demand map the system can improve predictions in what month or season the system would need to increase energy production or alternatively execute a different power demand profile on e.g. lower (or higher) load to help manage the energy storage and avoid depletion.

An example of a power demand map for Eindhoven is shown in Figure 7. The light load per day is plotted as well as the average over a year. The curved plot is the required energy per month and the straight line is the average.

The power demand map lists the expected future energy demand per day over the whole year or longer. An example of how to create the power demand map is shown in Figure 8, which shows the inputs to enable the computation.

A simple power demand map is created based on the day and night time data of the local site using readily available geographic information (shown as "daily sunrise sunset"). Other sources are available, such as geographical tables and formulas from marine/aerial navigation of celestial navigation.

This data is used to create a darkness overview over the whole year. The resultant hours of darkness are incorporated into a light profile. The light profile may implement many reasons to offset the time of sunset or sunrise, to accommodate for e.g. darker conditions due to bad weather, legislation, energy conservation or other reasons. In addition, dimming during darkness may be included.

Thus, the "recorded adaptive dimming" is taken into account, since this will alter the power demand profile, as well as the anticipated dimming profile, shown as "light load & dimming profile").

The data is augmented using the same additional data as discussed above ("augmented data"), for example relating to local phenomena such as for example mountain ranges, buildings, forestry, etc. which may lead to a TSRF<100%. Many databases have already done so.

The system management also implements refinement algorithms to improve the yearly power demand map. Examples are for example but not limited to:

Statistic averaging of the duration of adaptive dimming (the "recoded adaptive dimming" shown), leading to longer periods of the light being turned on. This improves predictions after the first days/weeks/months of use as this depends on the local adaptive dimming, which is subject to local traffic in the vicinity of the installed pole. Alternatively this information may be augmented via data download over e.g. memory storage or data communication networks.

Statistic averaging of locally recorded bad weather phenomena's such as e.g. snow or clouds, leading to longer periods of the light being turned on. This progressively improves predictions, especially after the first whole year. Alternatively this information may be augmented via data download over e.g. memory storage or data communication networks.

Parasitic loads of other system components that need to consume electrical energy (shown as "parasitic load(s)"). The data may be dynamic, coming from e.g. measuring alternating loads, which may be locally recorded. This data could also be defined by static budgets or a combination of both.

Applicable values for the (configurable) backup capacity limit (shown as "backup capacity limit").

Anti-freeze operation, which dictates the required additional energy for round the clock heat production to prevent freeze up of water in the water tank, pipes and manifolds of the fuel cell stacks or in other components of the system. This is shown as "anti freeze operation". The required additional energy may be defined as the number of days where

temperatures are below zero, in combination with data from thermal design modelling.

Alternatively the data may be augmented by local recordings of temperatures and additional energy use. In addition, waste heat from a the electrolyser function, for example from a solid polymer electrolyser (SPE) and/or from a the fuel cell generator can be used to melt snow on PV modules. If PV is covered with snow, start-up from the energy source (e.g. battery) can be required to bridge time until heat is available from the processes. The required energy is taken into account. The same ideas can be applied to prevent/reduce ice build-up on the light.

The system management system 50 also implements monitoring and control of the fuel cell performance and balance of plant.

For the O₂ offloading system, a sensor may detect the wind flow speed. The system may use this information to determine if it is "safe" to release O₂ during calm. If not, the system may eventually decide to halt offloading the O₂: this may happen by e.g. halting the electrolyser or temporarily store some of the gas in a small buffer or an entirely different strategy to prevent unsafe conditions

The system plans energy storage over a whole year (or more) and this involves decisions about PV size and storage size as well as advanced planning modules to avoid depletion of the energy storage. This energy storage management module can plan that energy demand and supply to be matched over the whole year or more and create a running energy surplus balance, that is to be updated continuously. The energy storage can be managed and the most optimal working points of the components in the charging function can be planned (i.e. the SPE and electrochemical compressor) and the discharging function (i.e. electrochemical de-compressor and fuel cell generator) to achieve system wide, maximum overall energy efficiency over the (whole) year.

By planning the energy that is to be produced and by creating a production schedule, it is possible to limit the runtime hours of the electrolyser and fuel cell generator components to maximize life, by prediction of the most suitable periods to yield energy surpluses, which are high enough to sustain the energy supply for the demanded load in future periods.

This in turn enables rightsizing of the PV and energy storage units and to plan fuel logistics during installation. This calculation involves calculation of the energy surplus.

Figure 9 shows how the energy surplus balance map is used.

To compute the surplus balance, the power supply map and power demand map are used. These are processed together with augmented data which is specific to the site in question, to derive the required PV size. Again this is the "augmented data" discussed above.

The calculation of required PV size based on this type of information is known, and can involve the following steps:

The total energy value of a power demand map is derived;

The system energy efficiency (which is $\text{EnEff Energy Storage} * \text{EnEff PV}$) is calculated and the Total Solar Resource Factor (which is the energy efficiency of the local site) is obtained;

The daily required energy ($\text{power demand} * \text{EnEff system} * \text{TRSL}$) is calculated. The peak sun hours under Standard Test Conditions ("STC") are obtained and the PV array size for the daily load is computed;

A backup capacity is defined in days (the additional night cycles) and the total required energy for the current day plus additional backup days is obtained. A backup restore duration is defined in days and a corrected daily required energy (current day plus part to restore backup) is calculated; and

The PV array size to support the corrected daily required energy (current day plus part to restore backup) is calculated and the associated cost of the PV array is derived.

The invention takes the approach further, and the daily numbers are added up to months and the months to a year (i.e. a running period of 12 or more months). The result is the average over the year.

An energy balance figure compares energy input (i.e. the power supply map) and energy output (i.e. the power demand map). Negative values show an energy deficit and the required energy has to come from energy storage. Positive values show an energy surplus above the daily required load which may be (partially) stored.

The required energy over the year is computed. The required storage capacity is then computed.

The computation of the energy input uses the energy efficiency of the chain from sun to storage (e.g. $\text{EnEff TSRF} * \text{PVarray} * \text{electrolyser} * \text{electrochemical compressor}$). TSRF is the "total solar resource factor" which represents the efficiency of a system compared to an optimal system.

The computation of the energy output uses the energy efficiency chain from storage to load (e.g. $\text{EnEff electrochemical de-compressor} * \text{FC generator} * \text{light driver}$).

The installation date will have a large influence on the system performance. The present invention, if empty, will start to fill its energy storage, but as just explained before, there may be months where it starts with an energy deficit and it may also not collect enough surplus energy during the high period to sustain in the next low period of energy

deficit. Tanking interfaces on the system will allow supplying a full load of reactant gases and water, and it is possible to compute which months in the year will require which additional energy. This allows planning of fuel logistics during installation (i.e. be able to plan how much gas must be supplied by e.g. a truck after installation of the regenerative system on location).

Going one step further than simply taking the average surplus, an energy "surplus balance map" can be constructed as shown, which takes into account all energy that the system can possibly generate over the year in the boundaries of the actual PV array. By optimizing the system by increasing the energy storage, more surplus energy from the summer can be stored. This can further reduce the PV power requirement, although it will increase the influence of a string of days with bad weather. The system can accommodate for this by increasing the backup capacity, which simply means storing additional energy from solar which is available in the summer surplus. At a certain point the system will level off and the PV power requirements cannot be further reduced. It is this feature that will allow breaking the geographical barrier that is imposed on battery driven OSL systems, for which the required PV area physically becomes too big to install on the pole.

Thus, the energy surplus balance over a whole year (or longer) is calculated to identify if the generator (i.e. PV) and storage (i.e. pressure vessel) match and the system remains in balance.

As shown in Figure 9, this energy surplus map is then used to calculate an energy production schedule which is used to control the regeneration components.

Figure 10 shows an example of the surplus balance map based on the starting month.

Each plot represents a different starting month. For each starting month, the x-axis shows the time progression from the time of installation. The y-axis shows the accumulated energy, which starts at the maximum of the normal usage capacity, which is a small margin below the installed capacity. There is also a low level watermark below which the capacity is not allowed to fall, so that a normal usage capacity is smaller than the total installed capacity.

The same type of plots are shown in Figures 10, 11, 13 and 14, and they represent the same load conditions (in Eindhoven based on an average of 5 days backup). Figures 10, 13 and 14 assume the system is fully tanked at installation.

As shown in Figure 10, some plots immediately drop, and these are for installation months where the demand initially exceeds supply, such as October to February.

There are three main use cases shown in Figures 10, 11 to 13 and 14.

In use case 1, the system is in balance; the PV and storage match as shown in Figures 10 and 11. Figure 10 is for a system which is tanked full on installation whereas Figure 11 is for a system which is empty on installation, meaning no gas is supplied to the system, and the system is regenerated from empty.

In the case of Figure 11, it can be seen that the system only functions correctly in the second year after installation. The system creates energy for the storage, but not enough in the first year, when installed in some months of the year when the load is too large for the energy generated by sunlight.

Figure 11 is based on an "average", 854Wp, 85kWh not filled during installation.

In use case 2, the system runs empty because the PV is under dimensioned and/or storage is too small as shown in Figure 13.

In use case 3, the system always is fuller because the PV is over dimensioned and/or storage is too large as shown in Figure 14.

For the system of Figure 11, the installation timeslot needs to be limited to surplus months of the year in order to avoid an energy deficit. The system of Figure 11 is dimensioned based on the average PV power supply over the year. The energy storage is capped at the required energy for the current night cycle plus additional backup capacity, so lights do not go out. The system comes into balance in the first year and each year thereafter. A simple tanking procedure allows year round installation of this system. Additional derating of the energy storage system (to provide additional capacity than is essential) would allow higher availability (i.e. larger backup) if end customers would demand so.

Referring back to Figure 10 this system represents one in which the expensive PV is downsized by upsizing the energy storage capacity compared to the system of Figure 11. The system is tanked upon installation. The system is balanced after being "downsized" to 500Wp, and the storage system is upsized to 130kWh.

Figure 12 shows how different "use cases" (i.e. combinations of PV size and fuel capacity) can be chosen. The top plot shows the PV capacity and the bottom plot shows the energy storage capacity.

Figure 13 shows an example of a system that is dimensioned incorrectly. Although in the first year there is enough energy, the system is not capable to replenish the energy buffer enough and will run empty in the subsequent year. The method of present

invention will perform this double check. The system of Figure 13 is under dimensioned at 300Wp, 185kWh.

Figure 14 shows a dramatically oversized system. The energy storage of this system is filled up ever more. But there will be a point where, even with very high requirements for availability (e.g. 99,985%) not all energy will be required, or never used. The present invention finds the balance point to level above the backup limit, i.e. the low level watermark and run the system less filled up, corresponding to a lower pressure in the pressure vessel, electrochemical compressor and other components. It will effectively define an adaptable capacity cap, even if more could be stored. The system of Figure 14 is over dimensioned at 600Wp, 500kWh.

These use cases explain the system dimensioning as well as the surplus energy balancing. The balancing is a task that is constantly repeated to enhance the “predictive” quality of the future energy surplus balance. The system will plan to keep the system always in a future surplus condition, but there may be times where the actual charging can be deferred to a later time.

The actual power surplus to be harvested can be much higher depending on the geographical latitude so the method supports correct sizing of the PV and fuel cell size based on the computed energy surplus balance, in order to find the lowest cost.

With correct dimensioning of PV, there is a period in the year where there the potential surplus energy is much larger than would be needed for the application. This can be utilized to limit operational runtimes. Thus, the system is dimensioned so that there is the potential to generate surplus energy over the year, and this is used to enable control of the timing of fuel cell regeneration.

For this purpose, a planning module can create a production schedule. This production schedule attempts to run the SPE and the electrochemical compressor at times where there is higher performance to quickly fill the energy storage, and may ignore times where there is only very low performance that would result in long runtimes but does not result in much energy stored. This is important to limit operational runtimes and extend life. The trade-off may be a slightly larger PV and possibly larger energy storage, although that would not be required in all conditions.

Limiting runtimes and deferring energy production into the future can be done at certain periods of the year cycle, when there is ample future surplus energy to be expected. But this strategy introduces the risk that energy surplus balance is not achieved when future

predictions on power supply and demand prove wrong through progressive insight. The planning module will take that into account and adapt the production strategy proactively.

Figure 15 shows several use cases as identified in the table below:

Use case	Description	Adapt
UC1	Installed capacity	N/A
UC2	Normal usable capacity	High Level Watermark.
UC3	Iron Supply	Iron Supply Watermark.
UC4	Backup capacity	Low Level Watermark.

5 Use case 1

The production strategy uses all available resource

Use case 2

10 The planning module may learn from normal operation that the planned amount of stored energy is not required for normal operation. This may for example happen in case a pressure storage vessel was installed that is dimensioned too large for this particular location. This could happen when there is a limited range of pressure vessel sizes to accommodate for major cases but not all. In this case the system may opt to keep the energy storage not completely filled, and adapt the high level threshold which effectively runs the system at a
15 lower pressure in the storage vessel. The system will adapt the working points of the SPE, electrochemical (de)compressor and fuel cell generator accordingly to maximize system wide overall energy efficiency. The system may reverse this decision and opt for a higher ceiling as well.

20 Use case 3

The planning module can take future surplus or deficits into account to keep an “iron supply” which is one that never surpasses minimum storage capacity. The planning module may learn from normal operation that an originally planned amount of to store energy will likely not be achievable anymore in the coming period. In that case the planning module may adapt its
25 production schedule and compute a more aggressive energy harvest in the remaining time. This progressive insight can be a combination of several factors putting a higher load on the system than was previously expected, such as for instance but not limited to bad weather, increased shading through vegetation growth or new buildings in the vicinity of the pole,

reduced adaptive dimming opportunities due to e.g. more traffic triggering higher lighting levels, increased parasitic load, increased anti-freeze operation, etc.

The decision also depends on the period in the surplus of deficit part of the energy shift cycle. At the beginning of a surplus period of any given year, the system may fare more defensively than when time has progressed further into the surplus period and the chance to make up the losses is more limited. The system will adapt the working points of the SPE, electrochemical (de)compressor and FC generator accordingly to maximize system wide overall energy efficiency.

10 Use case 4

The planning module may be updated with new requirements for a larger or smaller backup capacity. Alternatively this information may be augmented via data download over e.g. memory storage or data communication networks. In that case the low level threshold will be adapted. The backup capacity plus the normal usage capacity will never exceed the installed capacity.

The system management unit can also enable data communication via communication link(s) such as for example but not limited to wired (e.g. cable), Line Of Sight (i.e. LoS), Radio Frequency (i.e. RF) or entirely different means to an offsite data collector, for integration in a back office. This back office can comprise of lighting oriented facility management tools (such as for example City touch) or maintenance planning tools, etc. System parameters used in the energy management methodology can be improved offline and transmitted back to the light pole, such as the power demand and/or the power supply and/or surplus balance and/or production schedule information.

Safety control loops are established to prevent unsafe conditions in hydrogen gas flows. A shutdown may for example be prudent after an unidentified mass has crashed into the pole. A combination of a shock detector and an inclination detector can detect if the pole has been knocked over or be tilted too much from e.g. a car crash and immediately interrupt all gas flows, close all pressure vessels and interrupt operation of the system components.

A shock detector can detect a shock by acceleration (e.g. a certain G loading) and an inclinometer can detect that there was a sudden change of x degrees in the stationary upright position of 90 degrees.

As mentioned above, the fuel cell generator and/or electrolyser can dump heat into the water tank to prevent freezing up. The system may be run for this purpose alone and

the additional energy required is taken into account in the planning module. Waste heat of the electrolyser 12 and /or fuel cell can be used to melt snow on the light or PV modules, but at temperatures low enough to prevent negative influence on PV performance. A control module in the system management unit 50 can use temperature and day information to

5 determine the additional energy required for this heater functionality, compute an anti-freeze map and pass this information onto the energy storage management module to plan the additional energy into power demand map and the energy surplus balance. The system thus provides a heater function, based on the fuel cell, electrolyser and (de)compressor. The system thus needs to know how much heat each unit can produce and at what energy cost.

10 The calculations can make use of statistic averaging of recorded low ambient temperatures, statistic averaging of recorded water tank temperatures and statistic averaging of recorded water tank heater events.

The electrochemical compressor consumes energy during compression and regains most of that energy during decompression. The component enables an energy

15 efficient (de)compression cycle and eliminates the need for a mechanical component.

The system of the invention requires a very slow compression under fluctuating H₂ flow conditions as occur from intermittent solar charging currents over the day, influencing electrolyser (i.e. SPE) performance. In addition, decompression may fluctuate due to the fuel cell adapting its power when the load (i.e. the light) would alternate

20 discharge currents from an adaptive dimming profile. Moreover, pressures and temperatures in the pressure vessel will constantly change. A control module passes information from other system components to the electrochemical compressor, so it can charge its working points for optimal performance (i.e. highest energy efficiency under both compression and decompression).

The H₂ pressure vessel is preferably placed at the bottom (but above a typical fracture zone which is often mandated) to limit weight at the top of the pole: this helps to avoid cost in concrete foundations. The H₂ pressure vessel may be a structural part of the pole. It should be constructed crash resistant according to any applicable safety guidelines and legislation. Alternatively, the hydrogen pressure vessel may be placed under the ground.

The system can be built in a modular way, where the hydrogen pressure vessel is a structural part of the pole and may even form the outside surface. The interfaces to the tank (e.g. appendages and sensory interconnections) can be constructed that they can break in a controlled way upon impact of a heavy mass (e.g. car or truck), the appendages shall close

the valves (if not done already) and the tank may move away instead of absorbing all impact energy.

An overview of the dynamic control of the system is shown in the flow chart of Figure 16.

As shown, the overall system combines the power supply map calculation of Figure 6, the power demand map calculation of Figure 8 and the surplus balance map calculation with production schedule computation of Figure 9. All of these processed can be improved by "augmented data", which is shown as a single data source for all three. The production resulting production schedule is used to control the SPE, (de)compressor and fuel cell, in combination with feedback of the actual fuel cell performance and flow pressure and temperature data.

There is interaction between the processes that compute the power supply map, the power demand map and the energy surplus balance map and that compute the production schedule of the periods in the year and timeslot over the day, when it is most optimal to run the electrolyser and (de)compressor to maximize H₂ production and extend life by minimizing runtimes.

The SPE and FC generator align with the electrochemical compressor to work at the most optimal working points for system wide maximum energy efficiency performance when possible and as required.

The system can include some or all of the following characteristics to overcome the problems explained above.

1. The charge and discharge of energy storage is via a gaseous energy carrier, based on gas compression.
2. The system can be a fully internal system.
3. The PV can be downsized by upsizing energy storage. The PV power requirement is reduced very much by using the average over the year (plus a bad weather backup capacity) instead of the worst day in winter.

Going one step further than taking the average, an "energy surplus balance" map is constructed in the preferred examples, which takes into account all energy that the system can possibly generate over the year in the boundaries of the used PV array.

4. Higher luminance lighting is possible. Since the PV can be downsized with present invention, an appliance can support greater loads in general, and in case of the lighting appliance in particular, this translates to more lumens of light output. Models show

that 10k lumen light could be possible on higher geographical latitudes with RFC than with solar powered, battery driven systems.

5. High energy efficiency gas compression. An example of the technology for the chemical compressor is described in patent WO 2010/093240 A1 and WO 2010/092175 A1.

5 To use an electrochemical (de)compressor for a lighting application requires a very slow compression under fluctuating H₂ flow conditions as occur from intermittent solar charging currents over the day, influencing electrolyser (i.e. SPE) performance. The control module enables working points to be changed for optimal performance (i.e. highest energy efficiency under both compression and decompression). The system will align the

10 performance of the electrochemical compressor with other system components, for example the SPE and FC generator, so the system management may select the working points to be optimal on the overall system level.

6. Separate fuel cell and electrolyser can give higher energy efficiency and longer life. However unitized regenerative fuel cells can be used. Compared to a "Unitized Regenerative Fuel Cell" (i.e. URFC) system, where the charge and discharge functions are performed by a single FC stack, there are advantages in a dual RFC system with a separate electrolyser and fuel cell generator.

7. Freeze up prevention using heat production from the fuel cell generator and/or electrolyser and/or electrochemical compressor. The required additional energy is taken into account in the energy production planning. In addition, waste heat can be used to melt snow on PV modules, but at temperatures low enough to prevent negative influence on PV performance.

8. A safety shutdown feature can be based on a combination of shock detection plus inclination detection to be able to detect a crash of an e.g. car into the pole and may prevent unsafe conditions by shutting down the gas flow operations.

9. Extended life is obtained because planning modules will match energy supply and demand over the whole year or more, and derive a production schedule of the periods in the year and timeslot over the day, when it is most optimal to run the electrolyser and electrochemical (de)compressor to maximize H₂ production and extend life by minimizing runtimes.

It will be clear from the above that the invention is of interest for solar powered lighting, such as high quality, 10k lumen, street lighting with 100% availability and long life. There is a special market for isolated light points, e.g. those that would normally

require exorbitant investments to install. Currently, Philips offers solar powered, battery driven OSL products for this purpose.

The invention can also be used in horticulture: to put a pole in the ground and provide assimilation lighting to crops in particular seasons in the year. This offers safety, freedom of placement, low initial cost of installation.

Hybrid street lighting, enables to shift demand by storing excess electricity from the grid at cheap prices and operate street lighting always at low cost. This is an interesting value proposition for Public Private Partnerships running (street) lights on the scale of a whole city or highway.

Possible other markets include:

irrigation, which involves powering water pumps partly during the night and differently related to crop seasons. The pumping is for example from a canal with seasonal demand. The ideal times for irrigation and water pumping are then taken into account;

medical applications, for example post disaster power supply, which can be generated from the sun;

home storage where 4 kWh /day is needed assuming “Western” lifestyle and electricity demands. (and this is around 4x the 10k lumen street lighting requirement);

any island applications, where cost of electricity from generators is too high;

power backup applications, since RFC does not suffer from self-discharge and battery backup suffer high cost of electricity due to sustained charging to top battery banks off;

applications such as road sign lighting for example in deep valleys, where mountains block solar light on PV for large parts of the year;

tarmac areas/parking lots/pavements where tearing up the concrete would cost too much, and other cases where ground work to be avoided;

avoidance of fuel supply logistics, which can be excessive in some civilian and military applications; and

small maritime (yachting), campers, vacation condos, etc.

Only a small number of examples have been given above, and some alternatives will now be presented.

The light output can be replaced by a different electric load, for example power tools, heaters, water pumps, etc.

The O₂ concentrator (e.g. sieve bed) can be replaced with an oxygen generator, for example based on a ceramic process or another process, or simply filtered ambient air.

5 The fuel cell generator can be based on another fuel cell other than a proton exchange membrane (PEM) cell as outlined above, but the process still based on H₂+O₂=H₂O. The fuel cell can be based on unitized electrodes, where the single fuel cell stack can work as generator as well as electrolyser, but the process is still based on H₂+O₂=H₂O. The fuel cell may even be based on another regenerative chemical process.

10 The Solid Polymer Electrolyser can be based on other fuel cell technology, such as e.g. a solid oxide fuel cell ("SOFC"), or entirely different electrolyser process to generate hydrogen.

The electrochemical (de)compressor can be replaced with a mechanical compressor.

15 The H₂ pressure vessel may be replaced with other hydrogen storage methods such as e.g. (metal) hydride, liquefied hydrogen, etc.

The lamp pole could be fixed to a wall, or a system based on the ground with the light placed via a wire structure or entirely different means, or in a building.

Examples of the other fuel cell chemical processes are shown in the table below:

Name	Regenerative water - PEM; described	Regenerative Methanol	Regenerative water – SOFC
System	PEM & Water	Methanol & water mixture	SORFC & water
Reaction	2 H ₂ + O ₂ ⇌ H ₂ O	CH ₃ OH + 3/2 O ₂ ⇌ CO ₂ + 2 H ₂ O	2 H ₂ + O ₂ ⇌ H ₂ O
Works with electrochemical (de)compressor	Yes	No	Yes
Note:		US 5,928,806	

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A power supply system comprising:
 - a solar panel (10) for generating electricity;
 - a rechargeable fuel cell (24) for supplying electricity to a load (28);
 - a system (12,14,22) for recharging the fuel cell using the electricity generated5 by the solar panel; and
 - a control system for controlling the recharging of the fuel cell,wherein the control system controls the recharging based on energy supply and demand data for at least a full year cycle.
- 10 2. A system as claimed in claim 1, wherein the system (12,14,22) for recharging the fuel cell comprises:
 - a water tank (32) for storing water generated by the fuel cell;
 - an electrolyser (12) for generating hydrogen from the water;
 - a hydrogen storage vessel (16); and15 a compressor (14) for compressing the hydrogen and providing it to the hydrogen storage tank.
3. A system as claimed in claim 2, wherein the system (12,14,22) for recharging the fuel cell further comprises:
 - 20 an oxygen concentrator for providing oxygen from the air to the fuel cell (24).
4. A system as claimed in claim 2, wherein the system (12,14,22) for recharging the fuel cell further comprises:
 - a compressor for supplying oxygen produced by the electrolyser (12) to an oxygen storage25 vessel (42) for providing oxygen to the fuel cell (24).
5. A system as claimed in claim 1 for supplying power to a street lamp.

6. A system as claimed in claim 2, wherein the system is provided within a lamp post, with the water tank (32) vertically above the electrolyser (12) and below the fuel cell.

7. A system as claimed in claim 1, wherein the control system is adapted to
5 derive a power supply map which indicates the expected power supply over a period of at least one year, and which takes account of at least the sun exposure times of the system and the performance of the solar panel.

8. A system as claimed in claim 7, wherein the control system is adapted to
10 derive a power demand map which indicates the expected power demand over a period of at least one year, and which takes account of at least the expected load over time and a desired backup capacity.

9. A system as claimed in claim 8, wherein the control system is adapted to
15 derive a power surplus map which indicates the power surplus over a period of at least one year, and which takes account of at least the power demand map, the power supply map, and to derive an energy production schedule for controlling the system from the power surplus map.

10. A system as claimed in claim 1, further comprising a battery for use in starting up the system and for temporary supply of power.

11. A method of generating a power supply, comprising:
using a solar panel (10) to generate electricity;
25 supplying electricity to a load (28) using a fuel cell (24); and
recharging the fuel cell using the electricity generated by the solar panel,
wherein the recharging is controlled based on supply and demand data for at least a full year cycle.

12. A method as claimed in claim 11 for supplying power to a street lamp.

13. A system as claimed in claim 11, comprising:

deriving a power supply map which indicates the expected power supply over a period of at least one year, and which takes account of at least the sun exposure times of the system and the performance of the solar panel.

- 5 14. A system as claimed in claim 13, comprising:
 deriving a power demand map which indicates the expected power demand over a period of at least one year, and which takes account of at least the expected load over time and a desired backup capacity.
- 10 15. A method as claimed in claim 14, comprising:
 deriving a power surplus map which indicates the power surplus over a period of at least one year, and which takes account of at least the power demand map, the power supply map, and to derive an energy production schedule for controlling the system from the power surplus map.

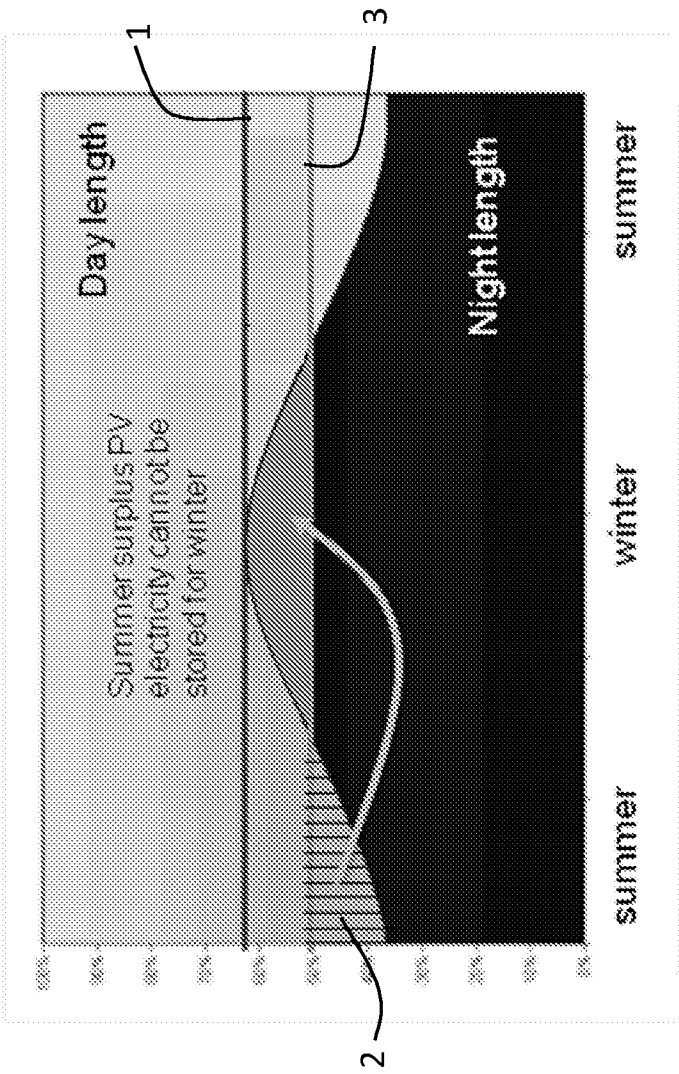


FIG. 1

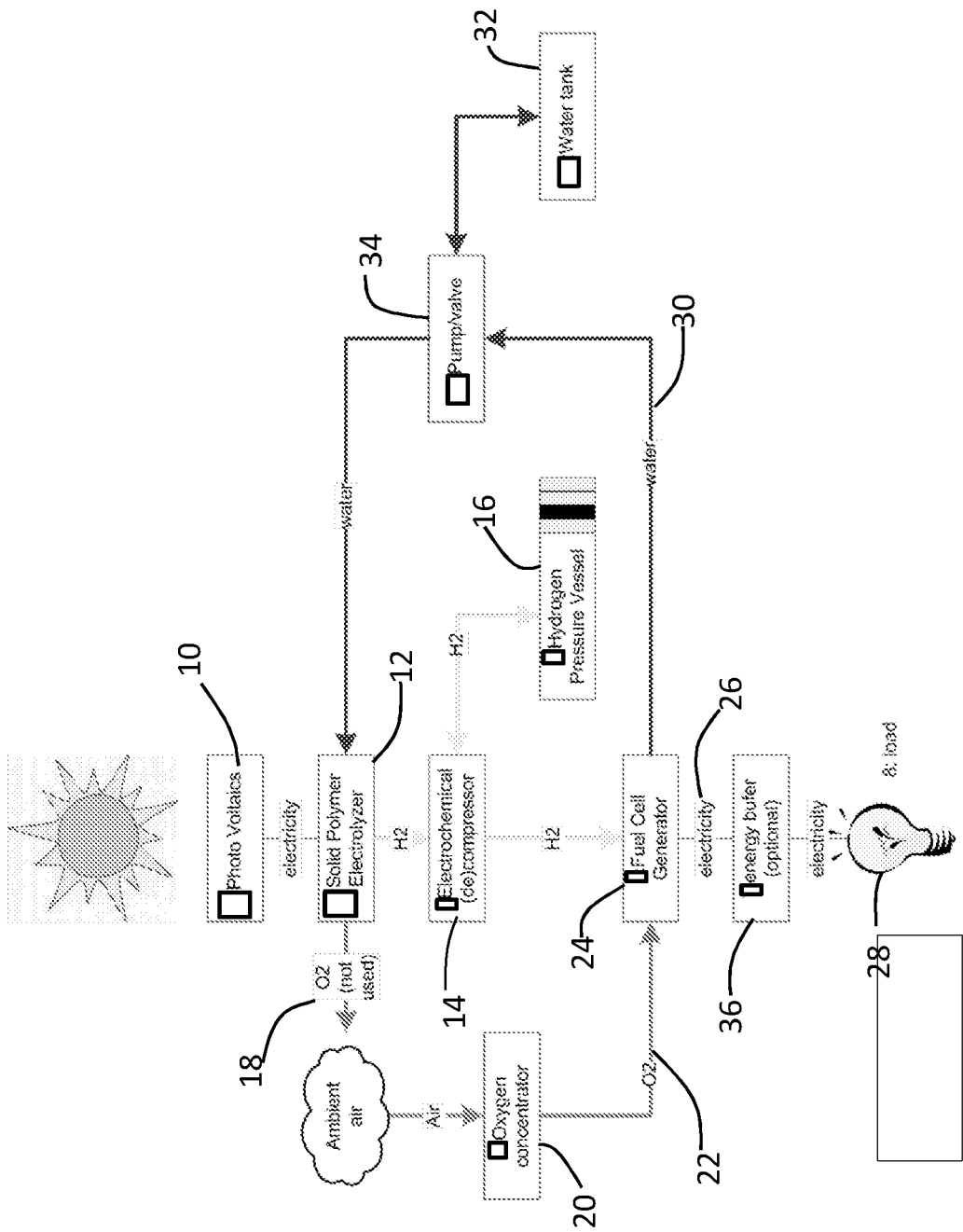


FIG. 2

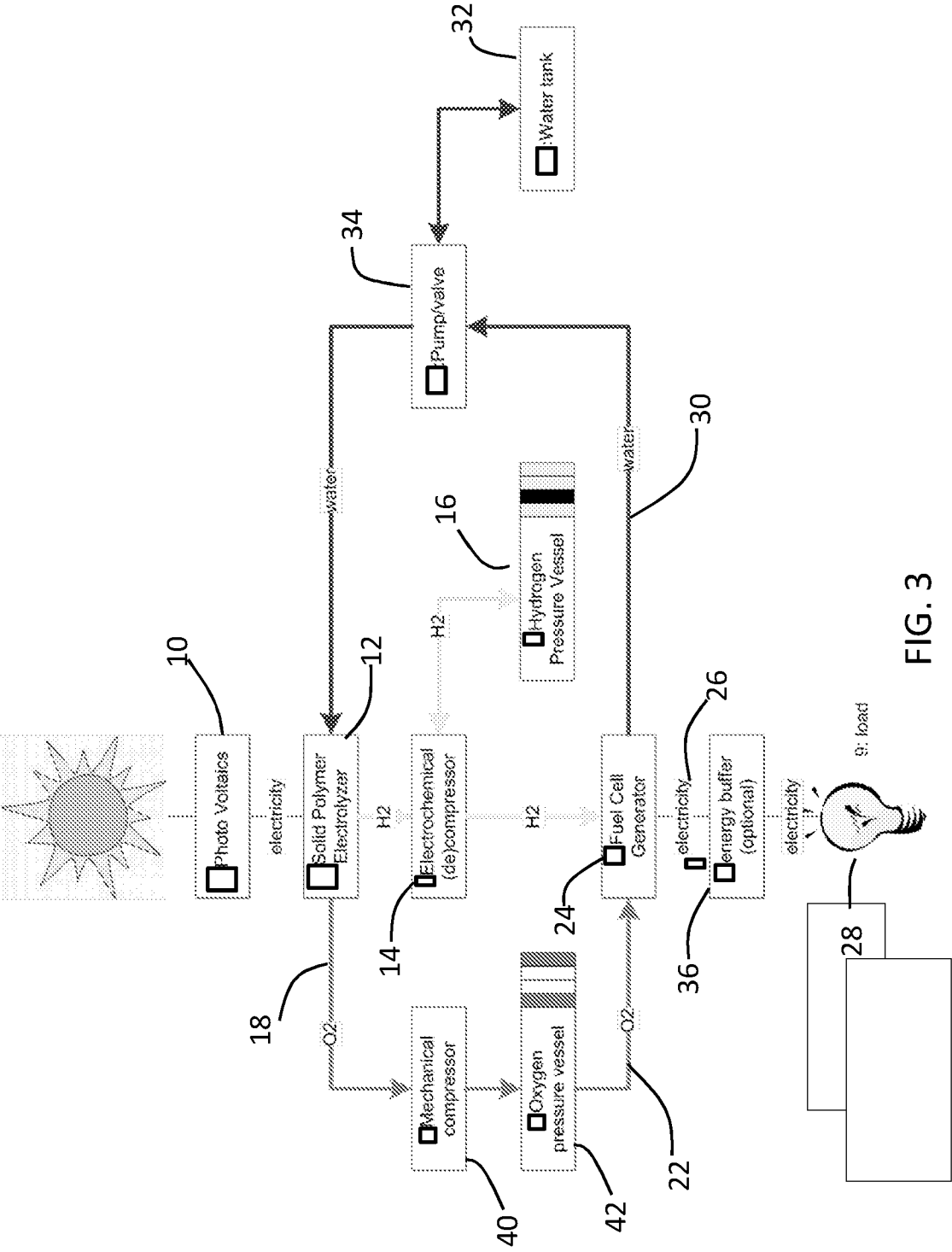


FIG. 3

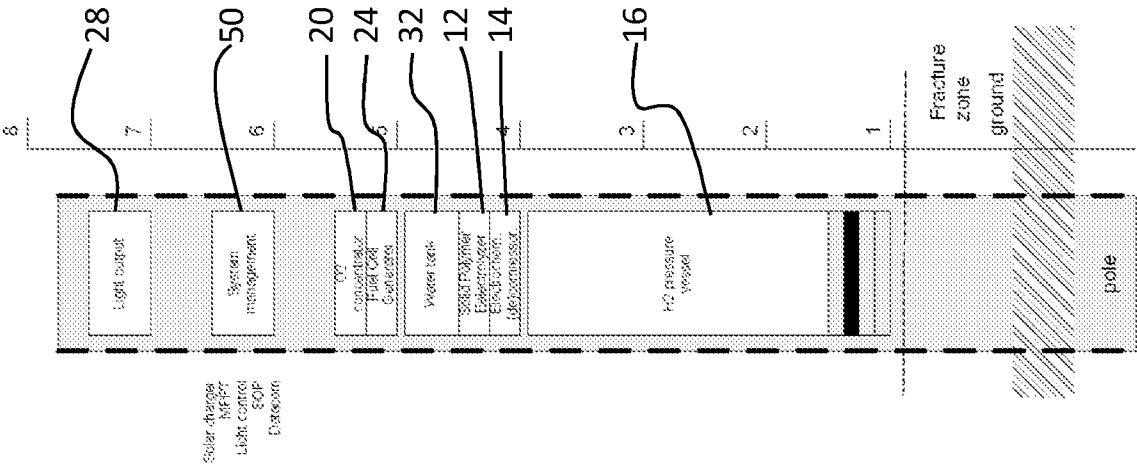


FIG. 4

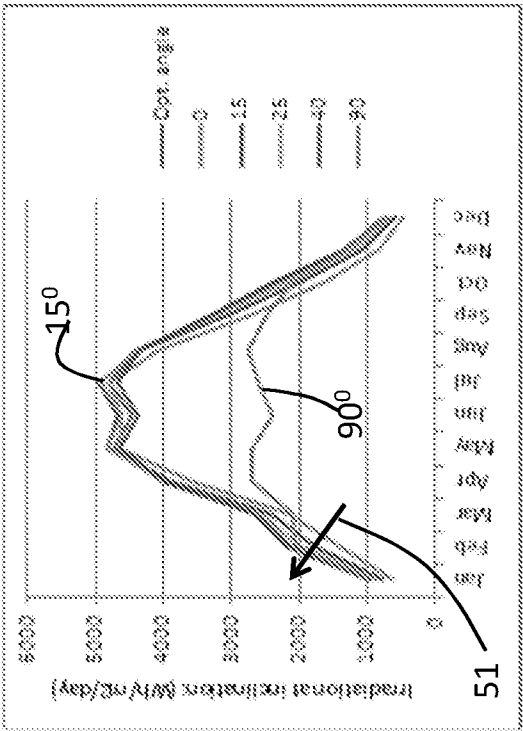


FIG. 5

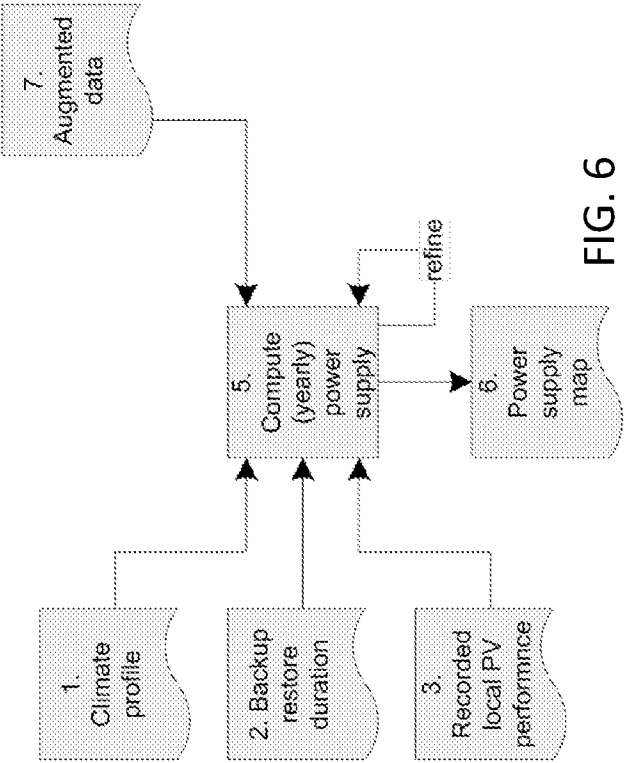


FIG. 6

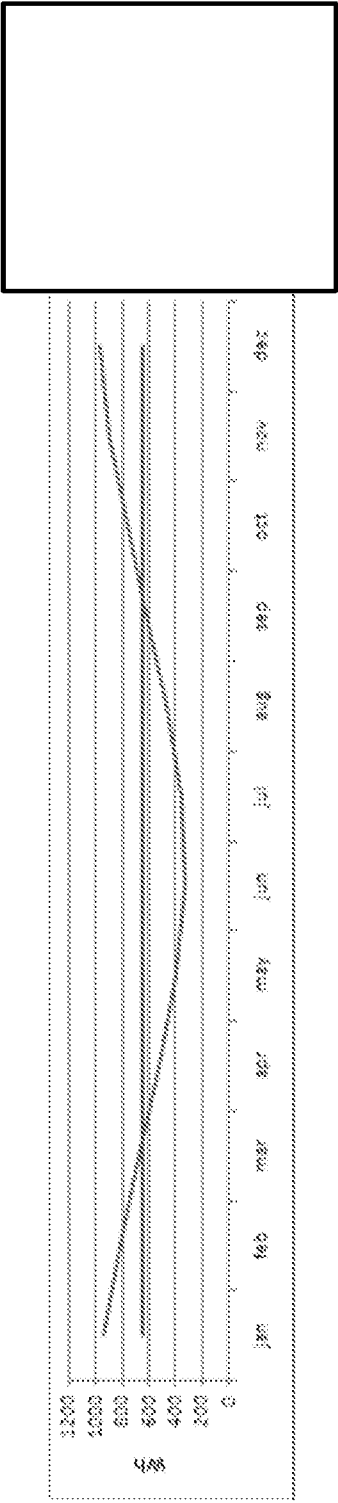


FIG. 7

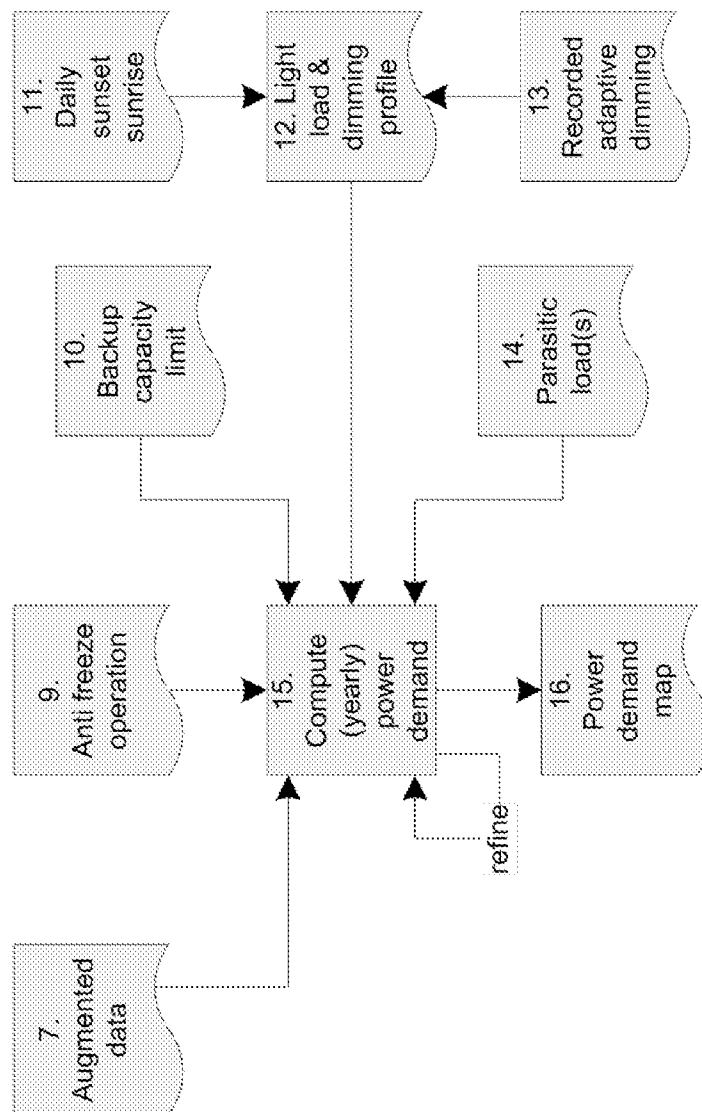


FIG. 8

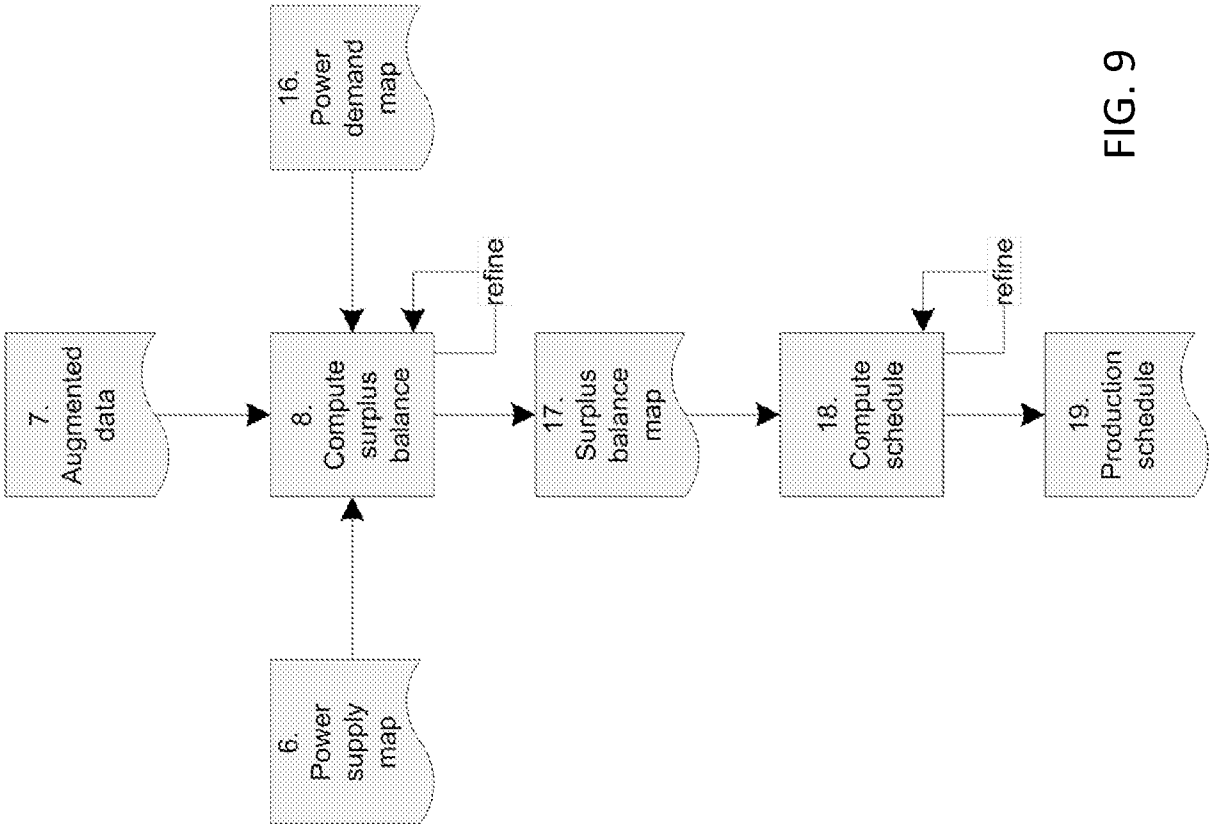


FIG. 9

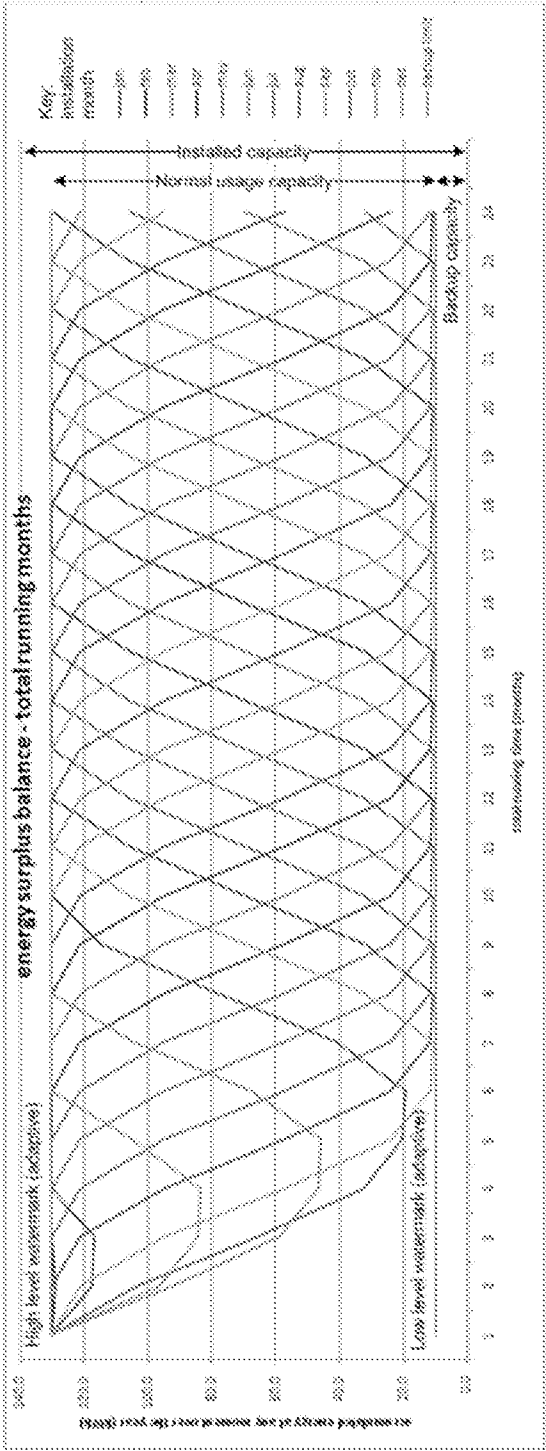


FIG. 10

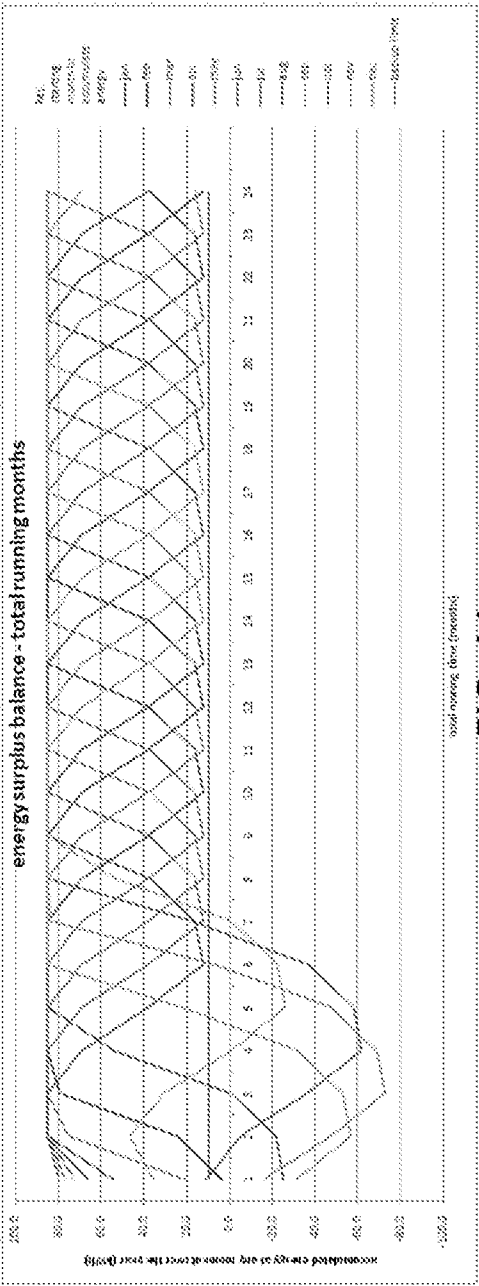


FIG. 11

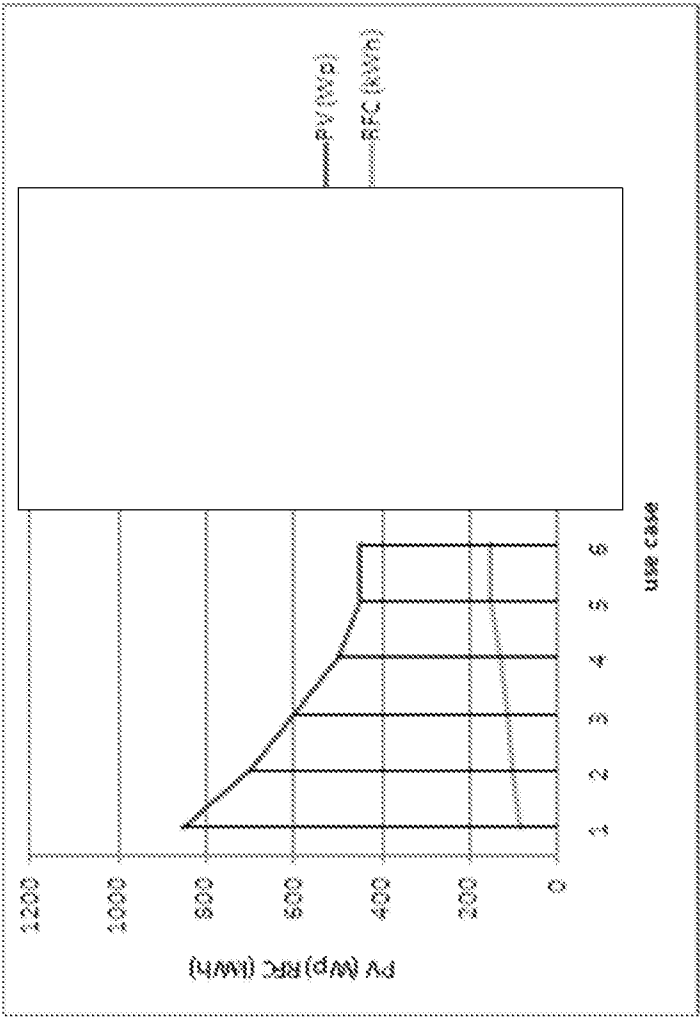


FIG. 12

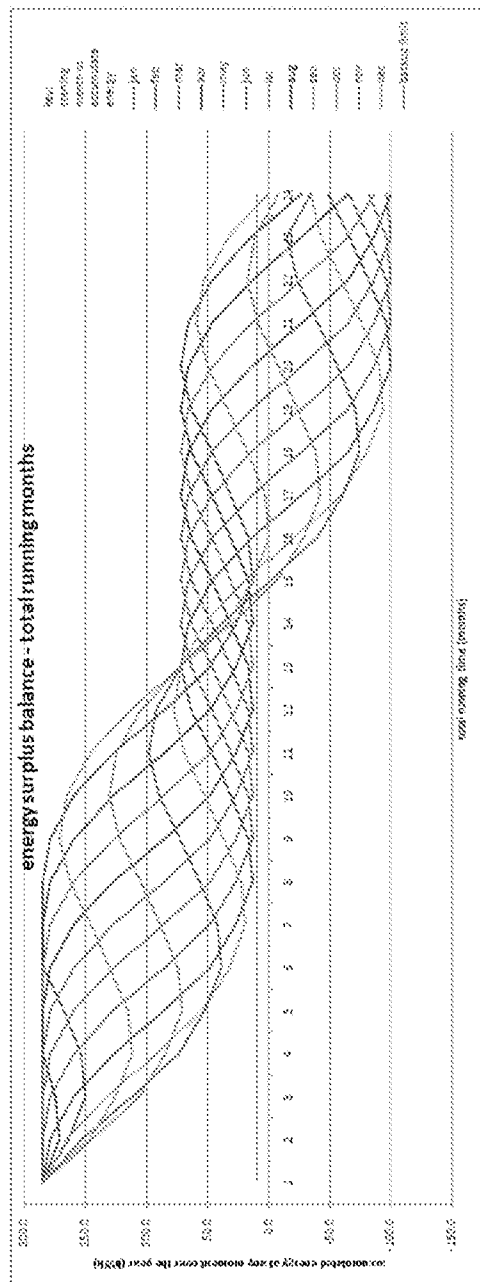


FIG. 13

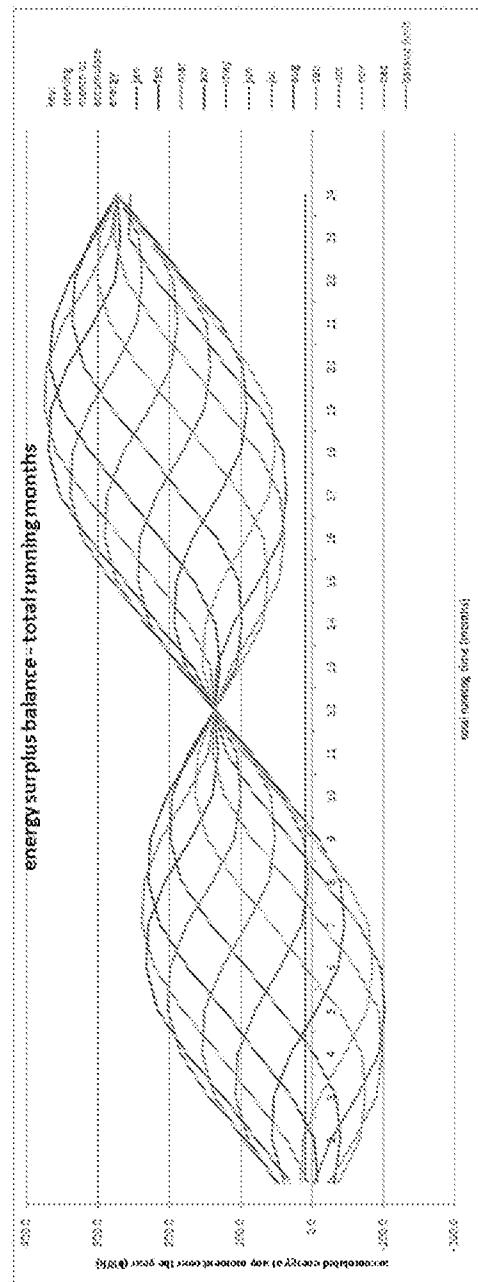


FIG. 14

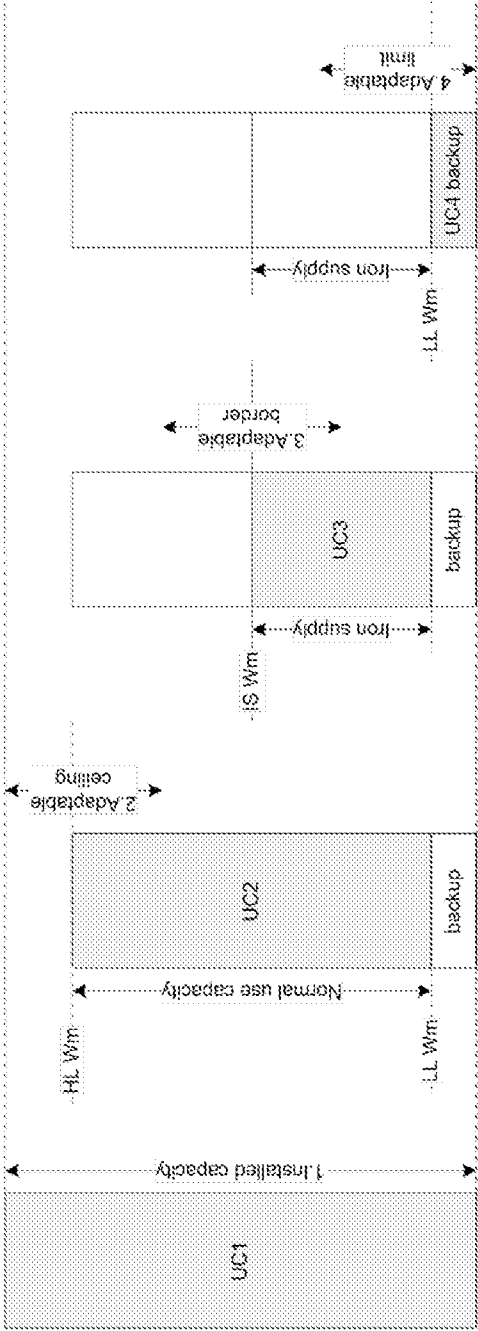


FIG. 15

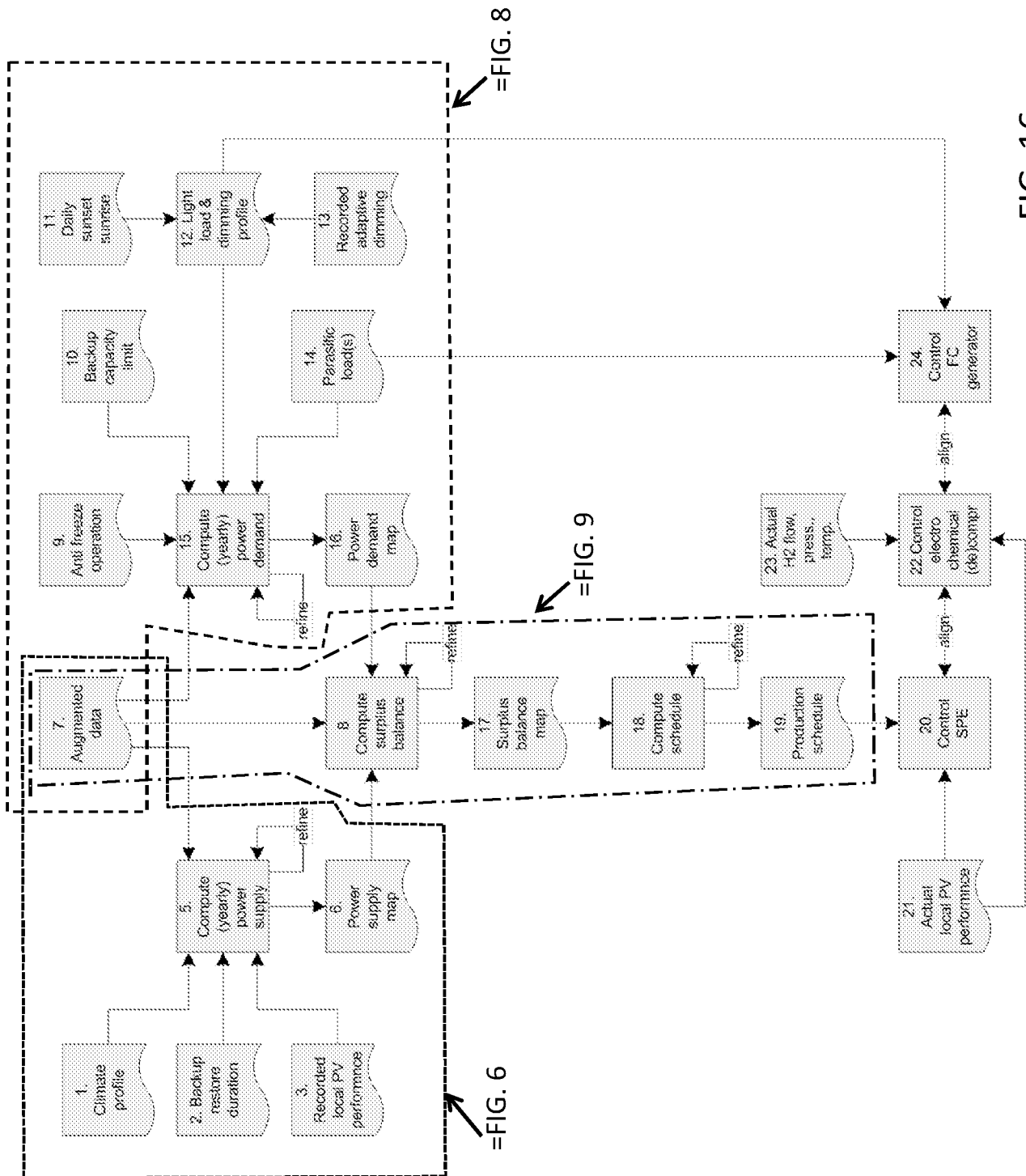


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/058965

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/00 H01M16/00 H02J3/38
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

28 April 2014

Date of mailing of the international search report

12/05/2014

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Rother, Stefan

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/058965

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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