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(54) **MODULAR MULTI-ENERGY  
THERMODYNAMIC DEVICE**

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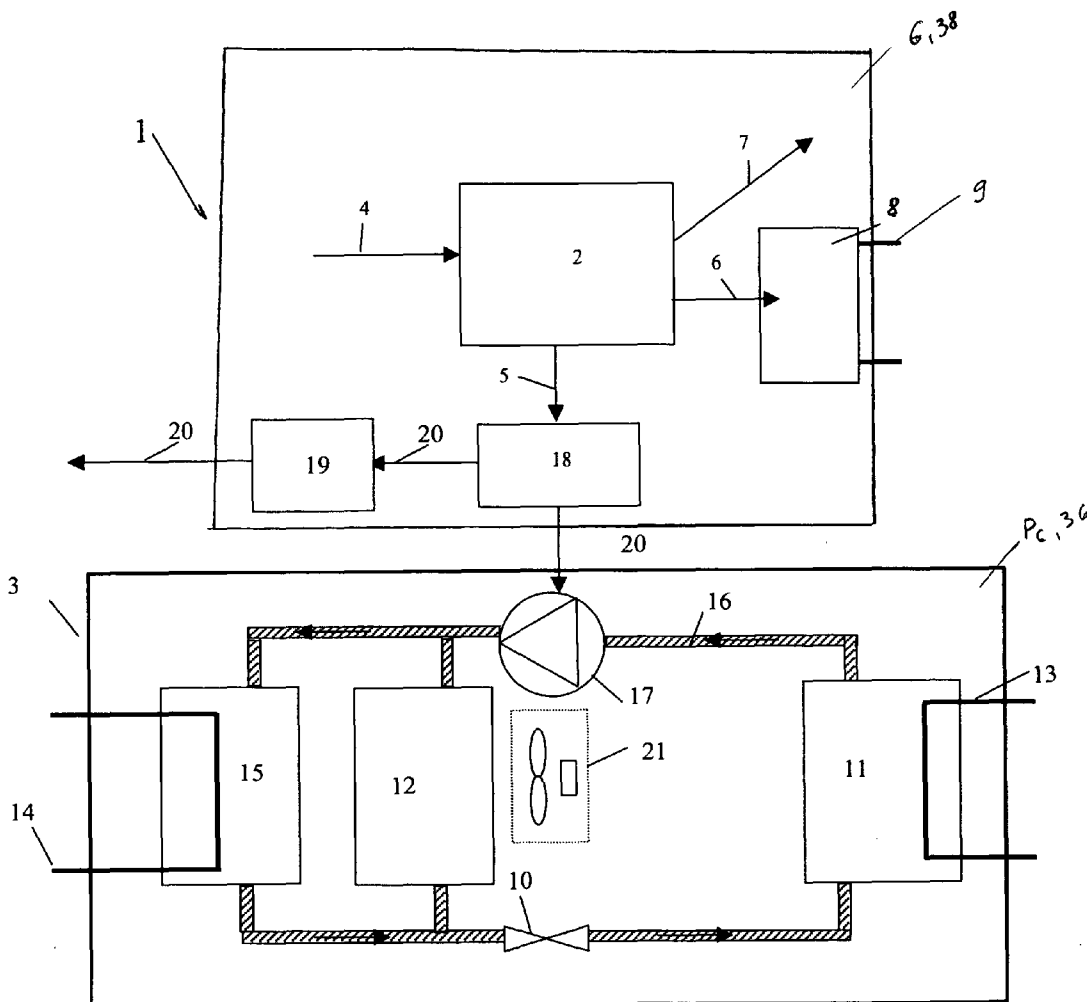
(57) **ABSTRACT**

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**Feb. 2, 2012**

A system for simultaneously producing electricity, water at a first temperature, water at a second temperature greater than the first temperature, and water at a third temperature greater than the second temperature. The system can also optionally simultaneously provide a refrigerating fluid at a first evaporation temperature, and the refrigerating fluid at a second evaporation temperature.



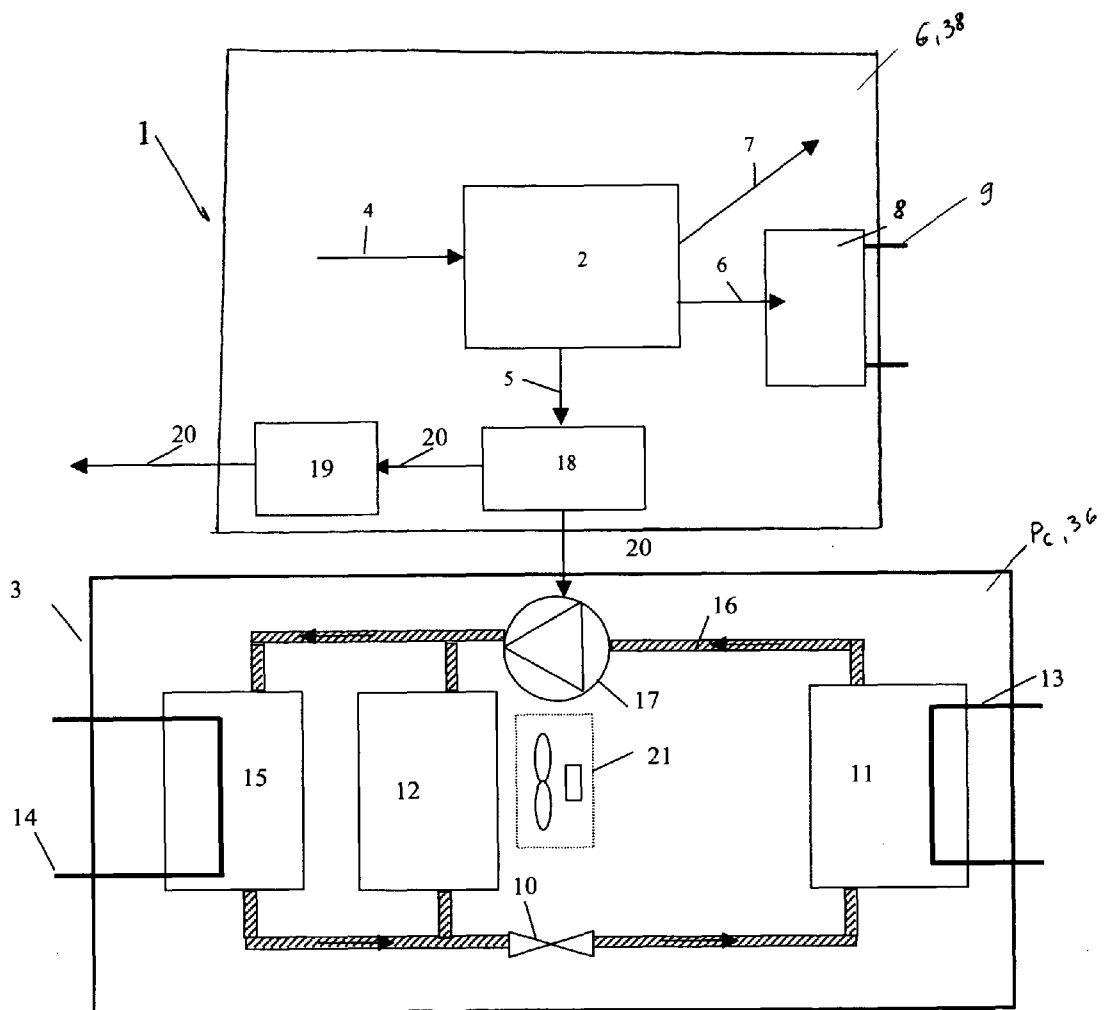


Figure 1

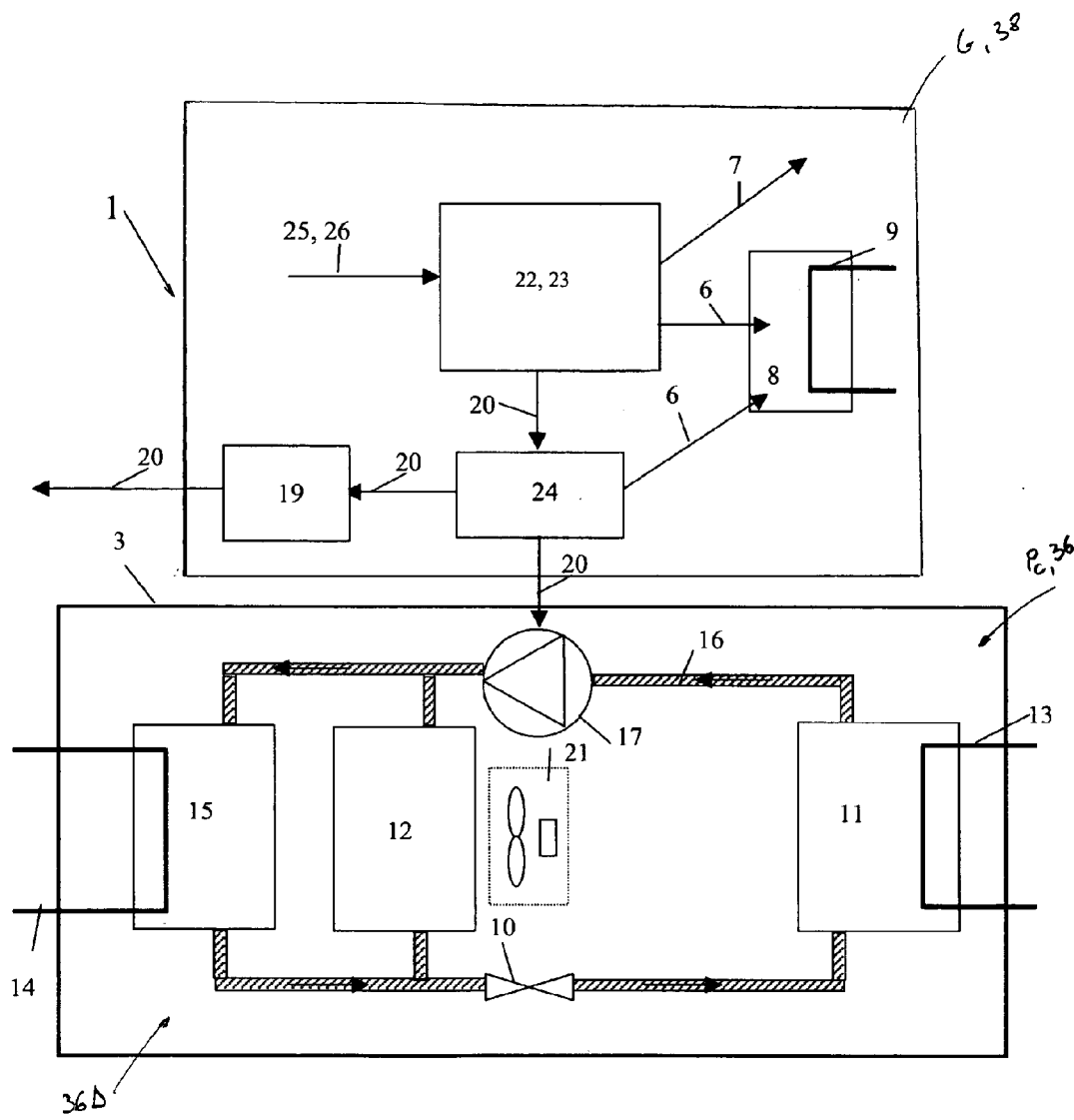


Figure 2

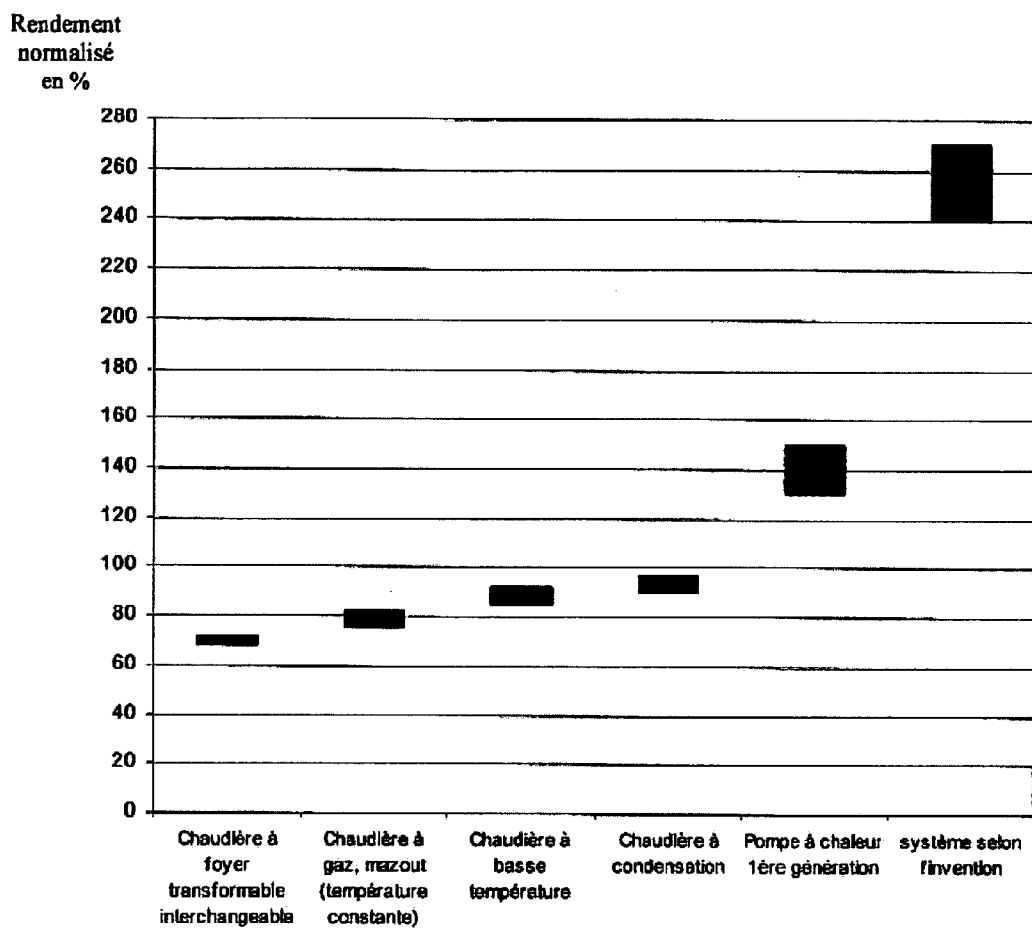


Figure 3

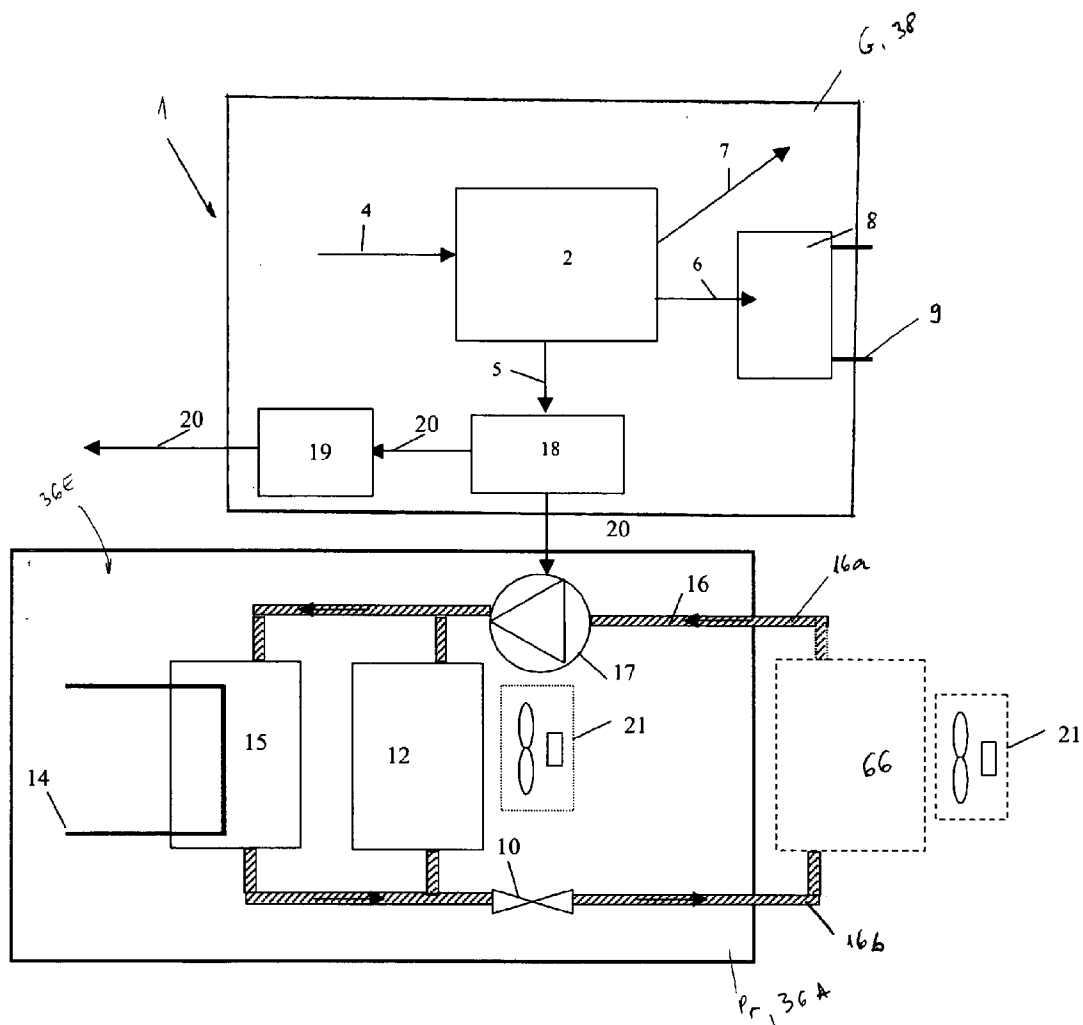


Figure 4



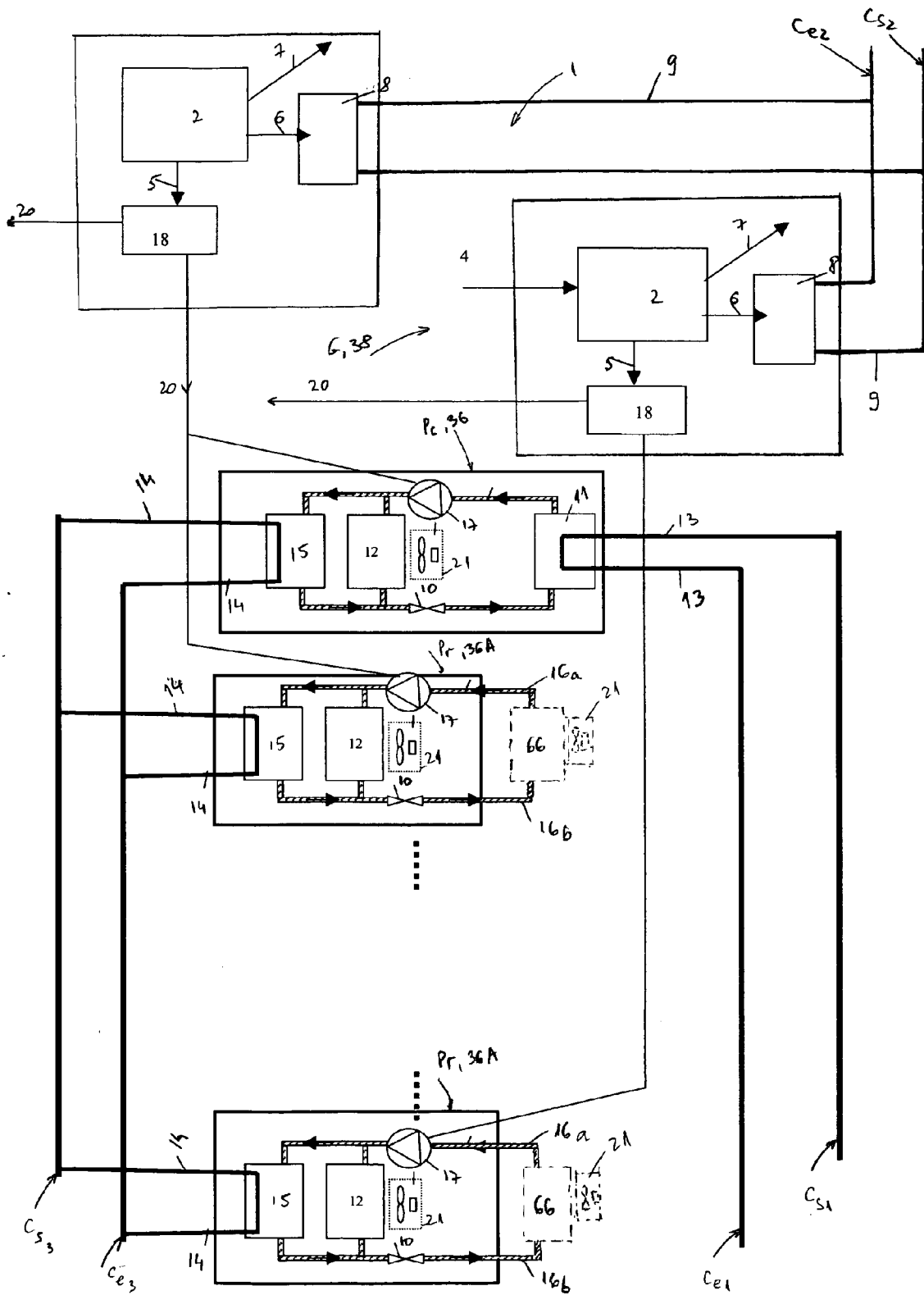


Fig 6

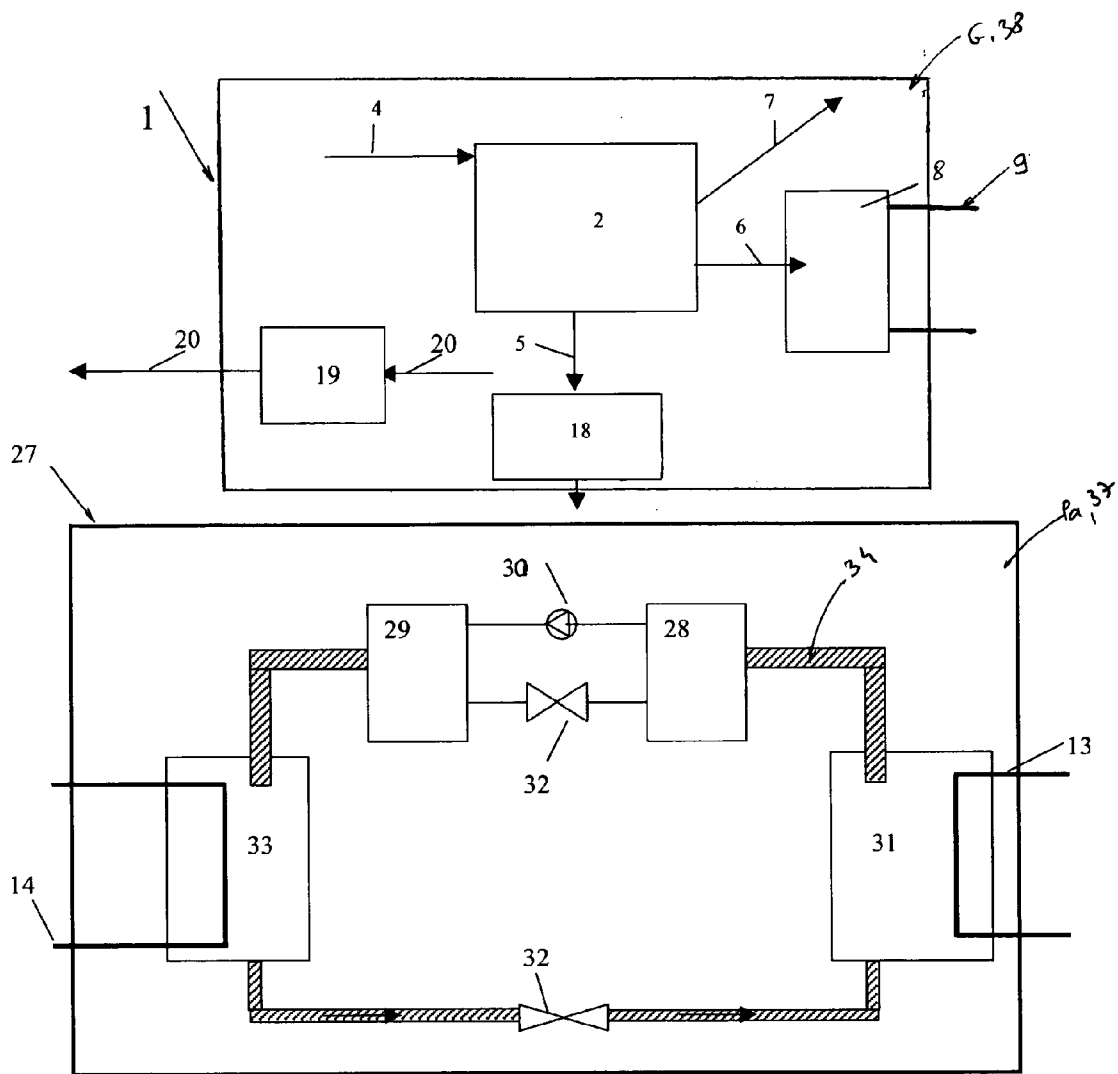


Fig. 7

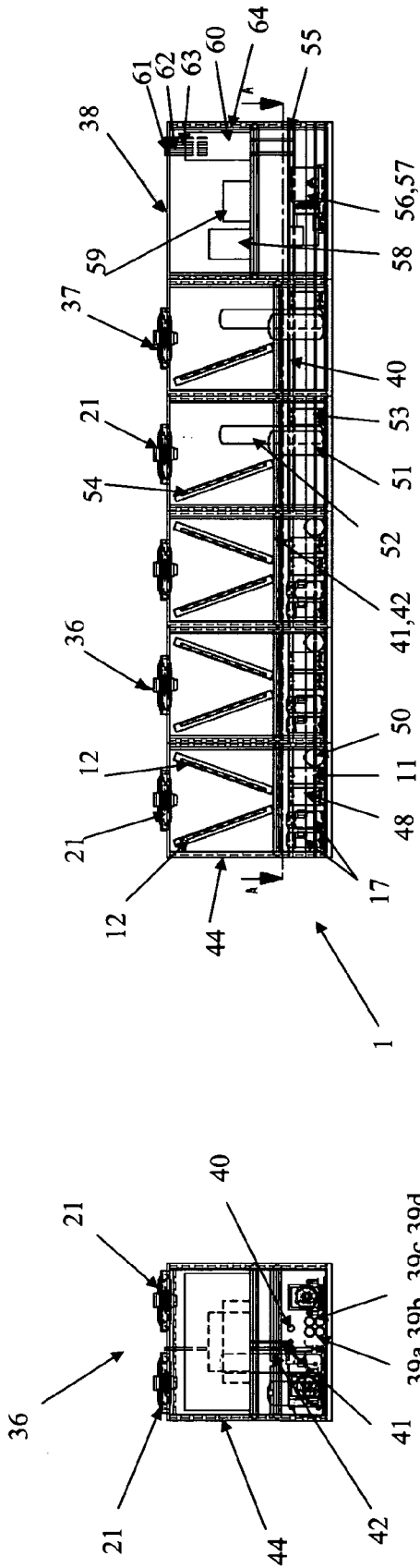


Fig. 8a

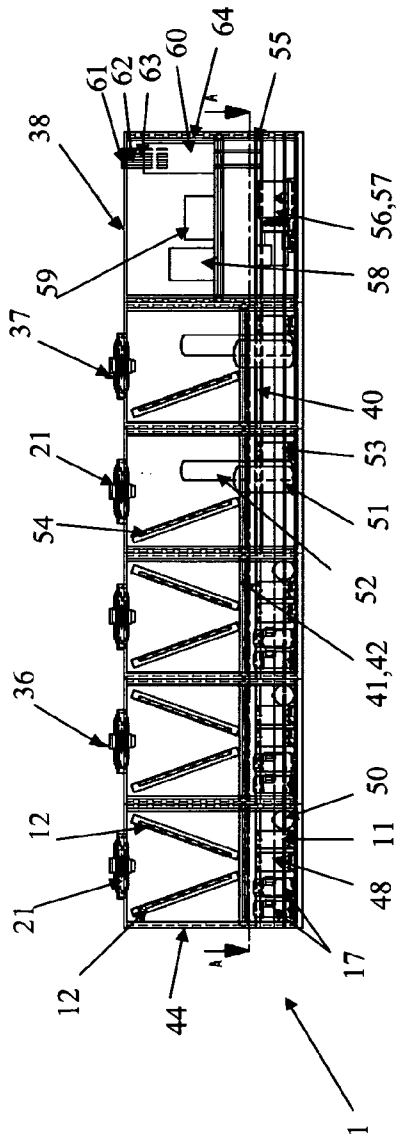


Fig. 8b

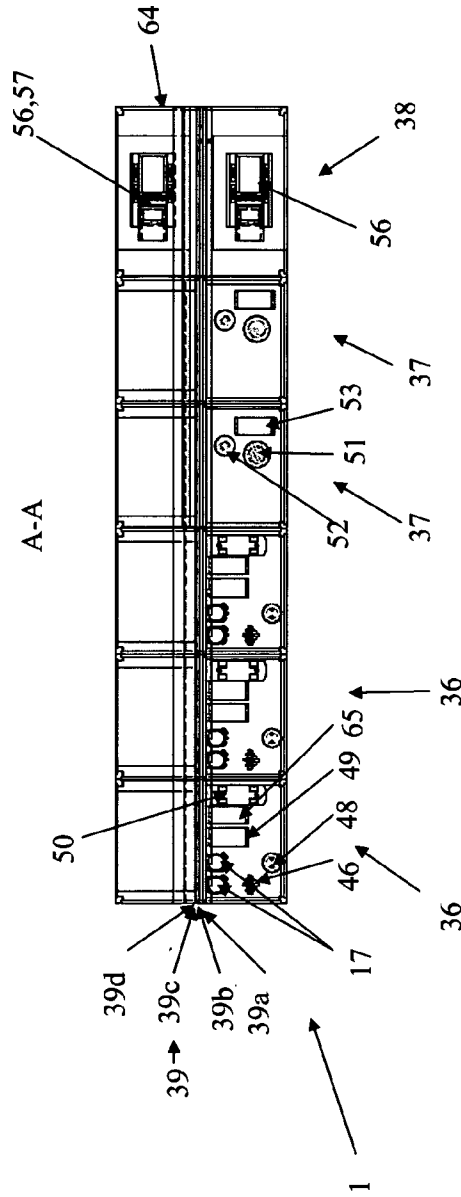


Fig. 8c

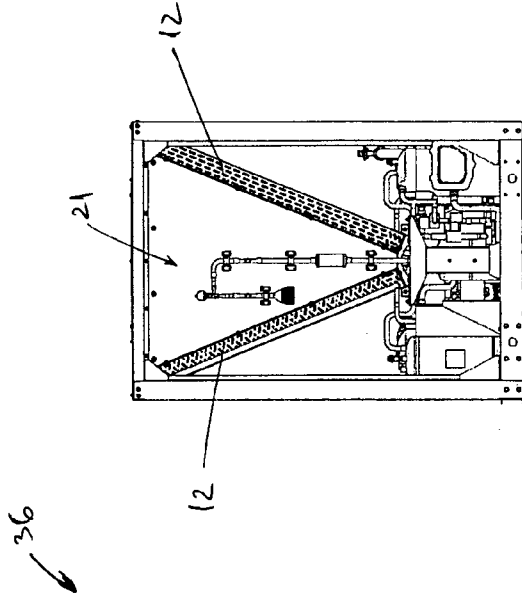


Fig. 9a

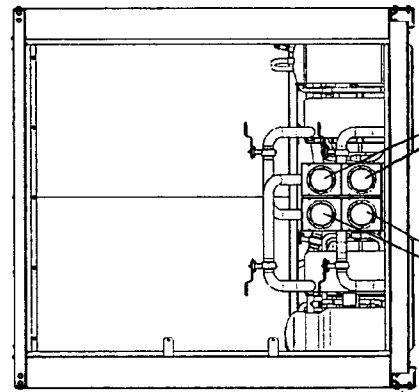


Fig. 9b

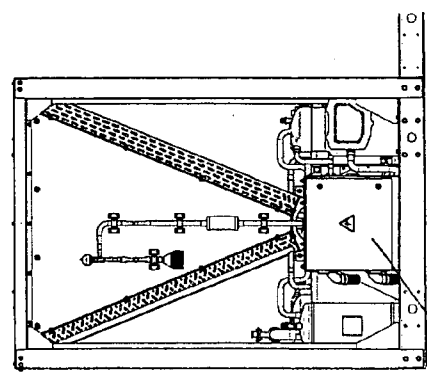


Fig. 9c

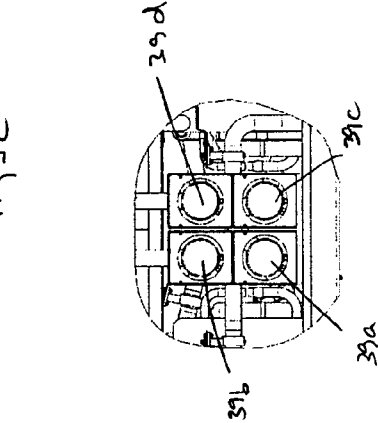


Fig. 9d

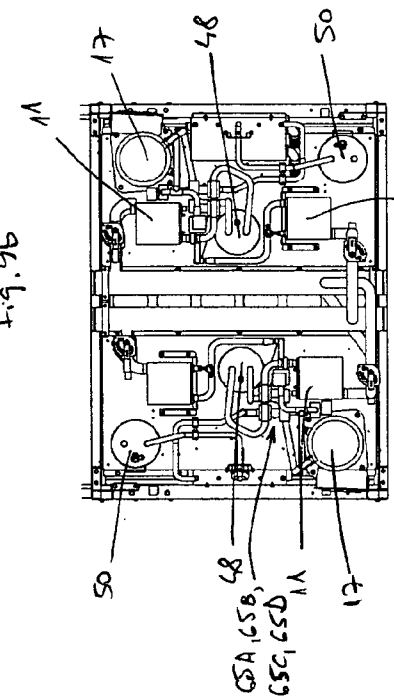


Fig. 9e

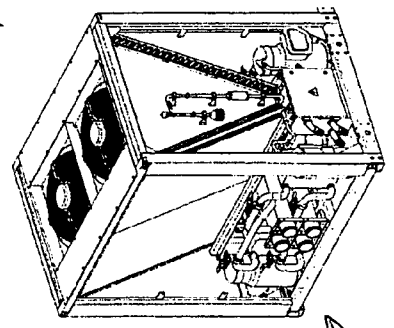


Fig. 9f

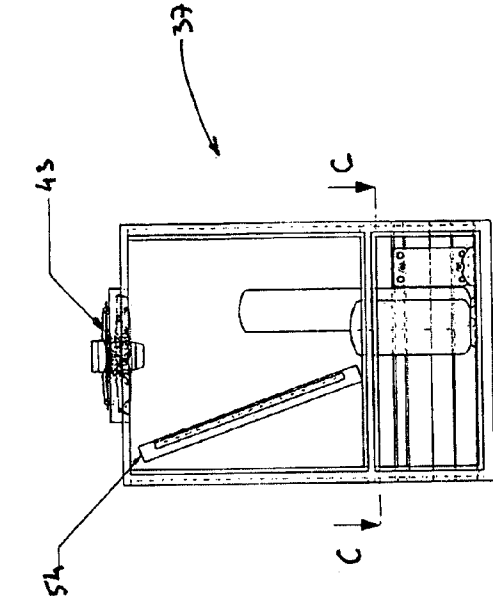


Fig. 10b

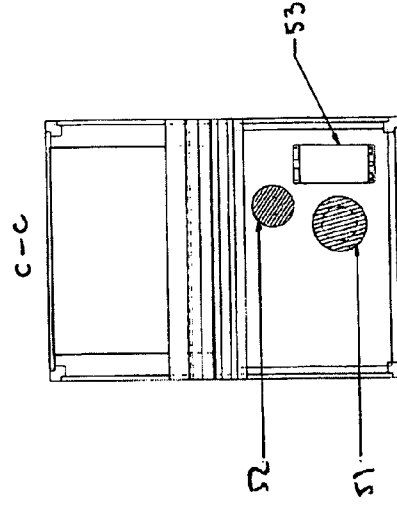


Fig. 10c

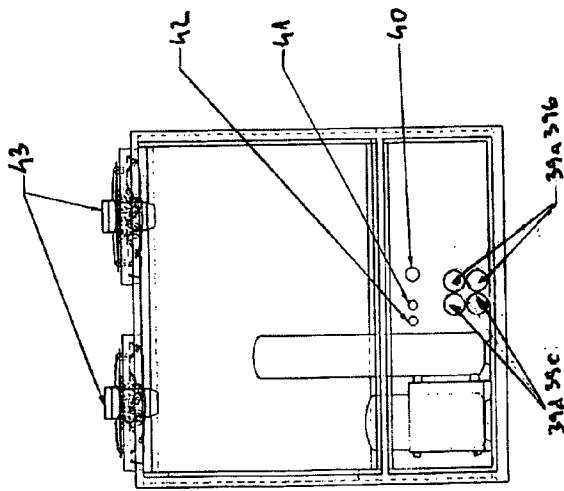


Fig. 10a



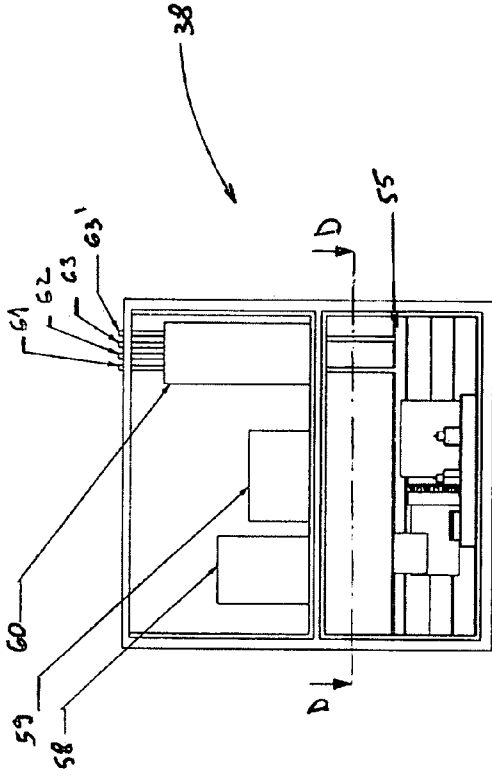


Fig. 11b

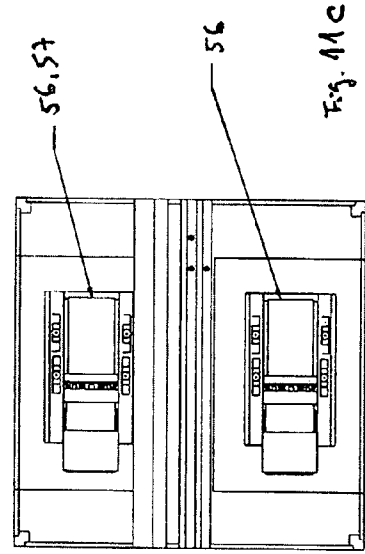


Fig. 11c

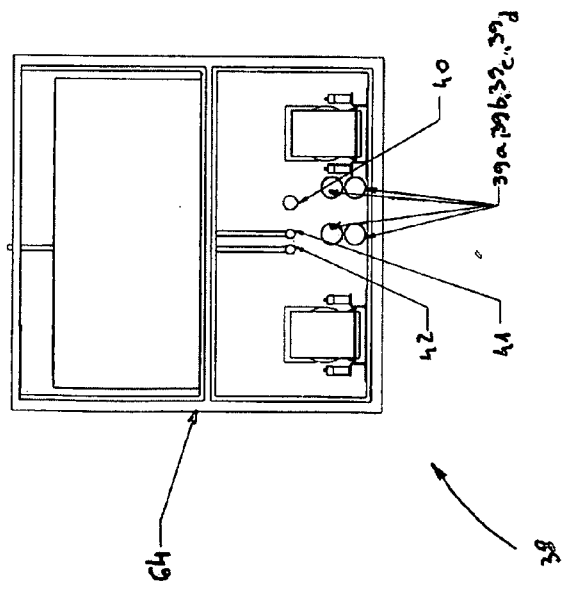
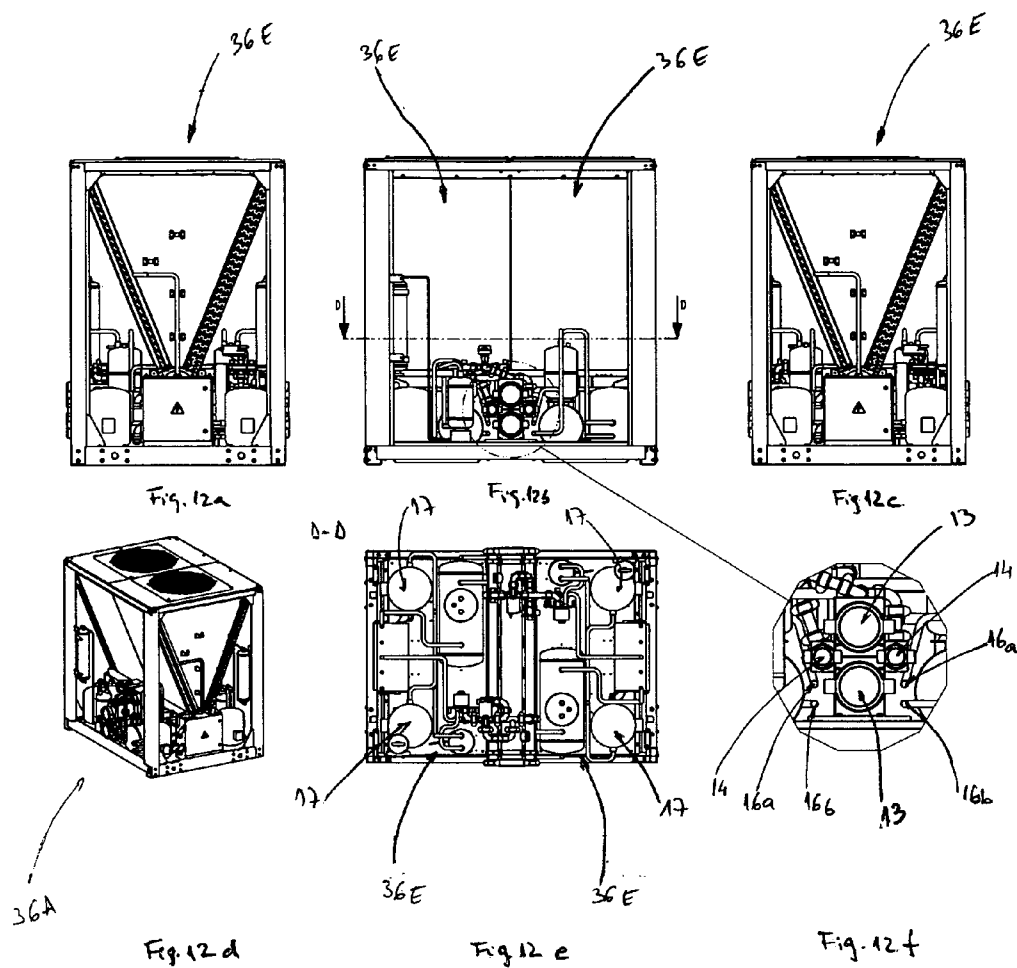
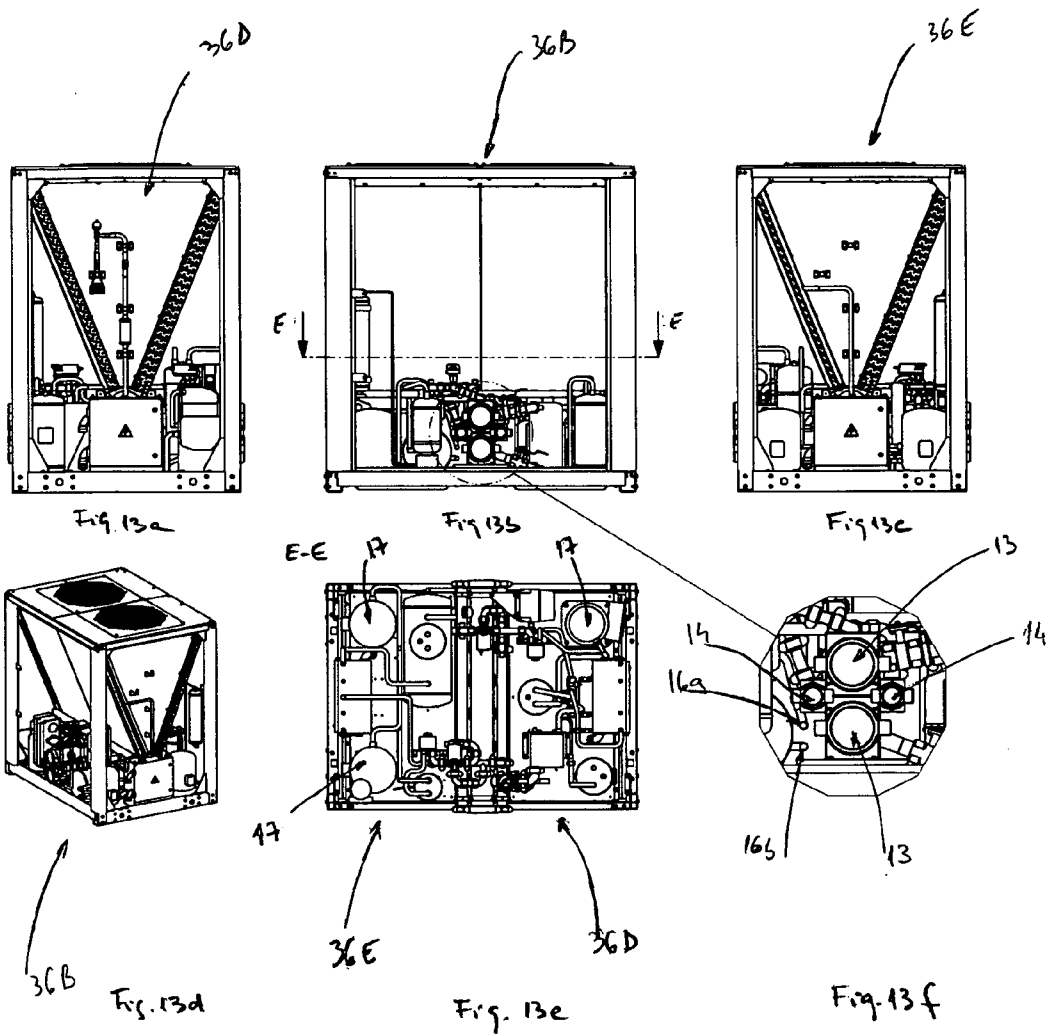


Fig. 11a





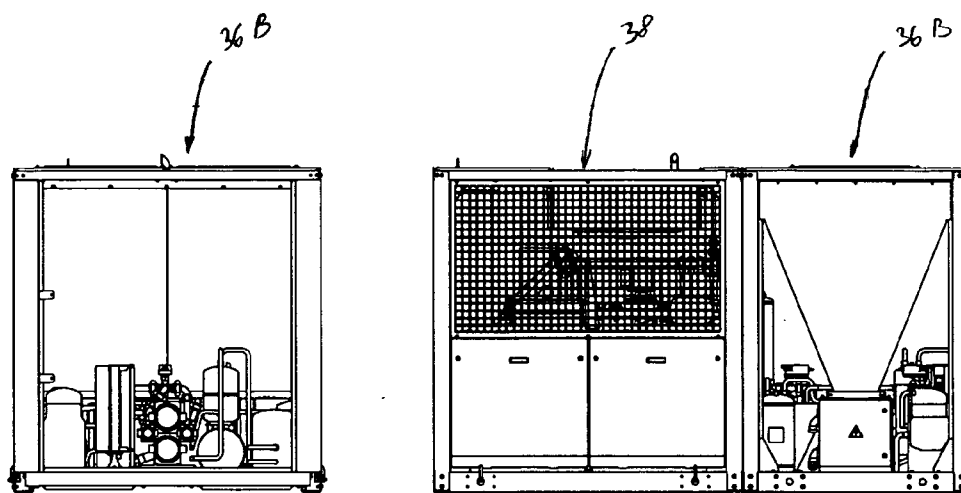


Fig. 14a

Fig. 14b

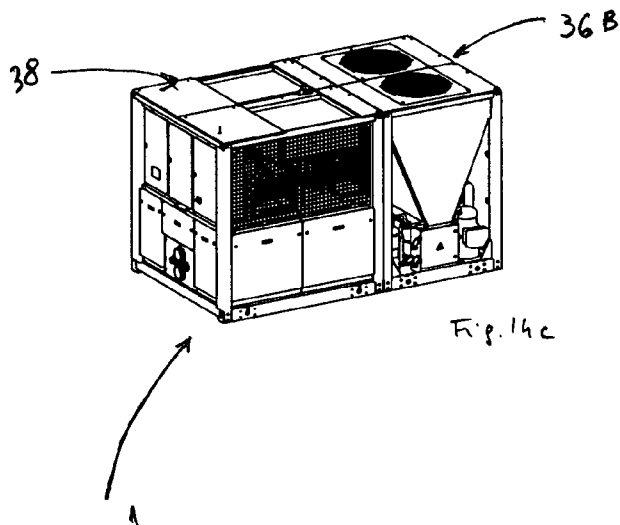


Fig. 14c

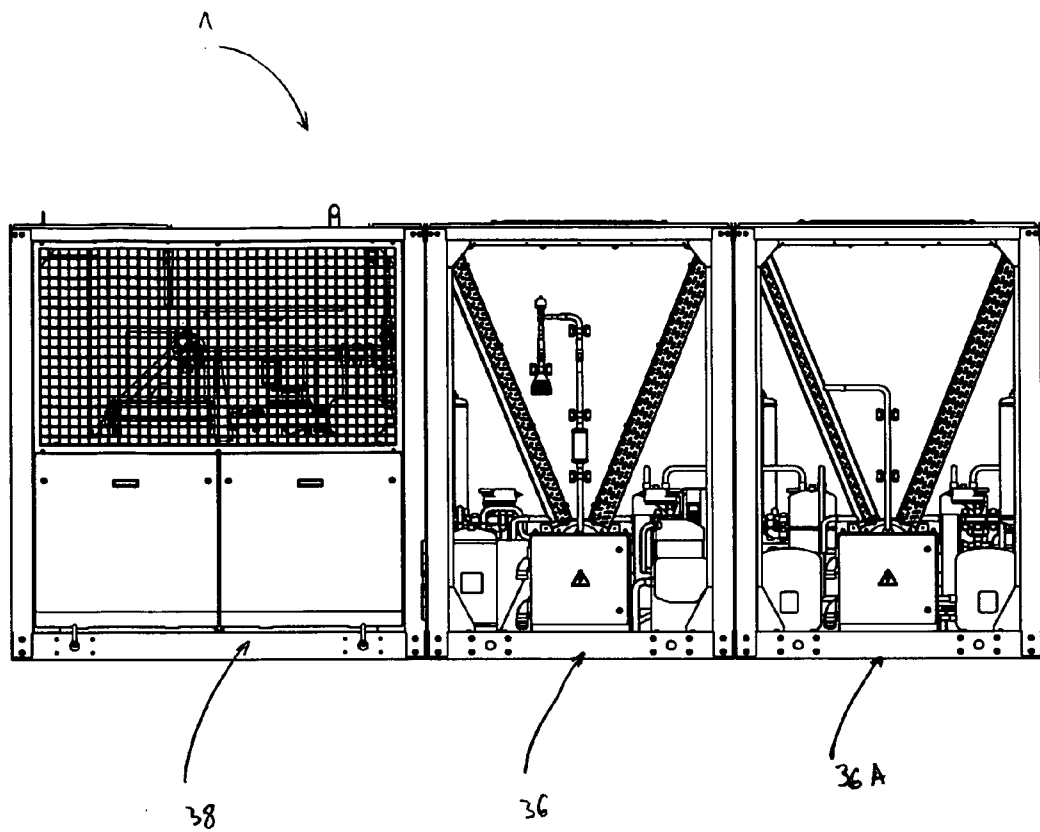


Fig. 15

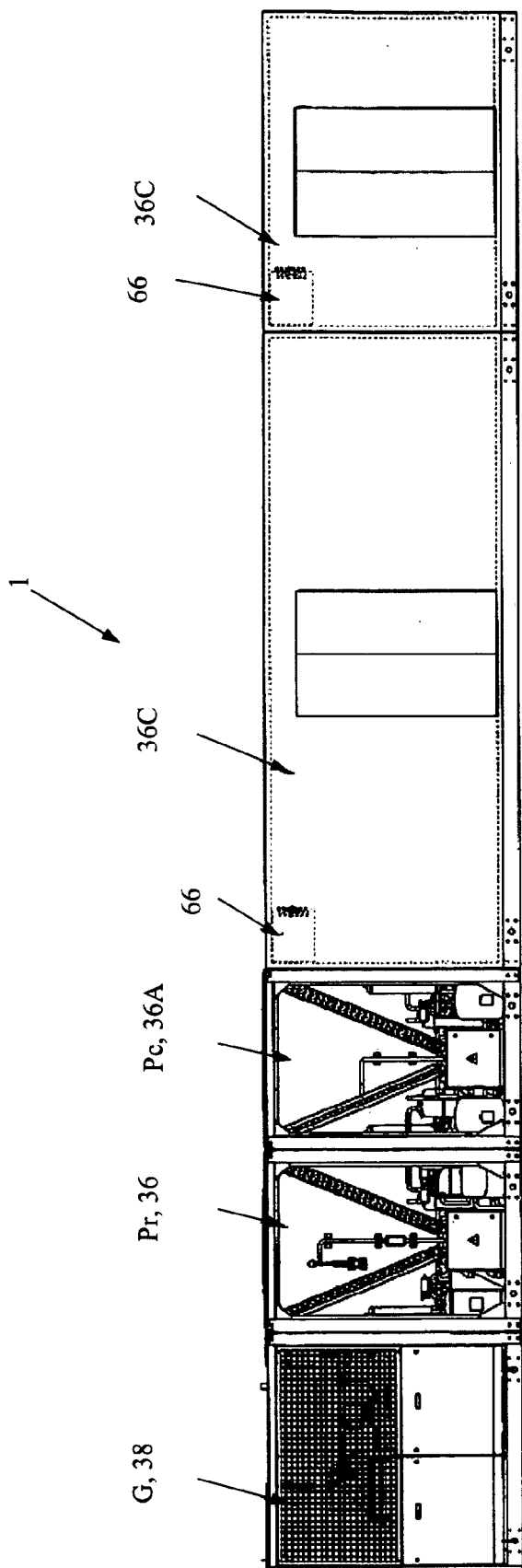


Fig. 16

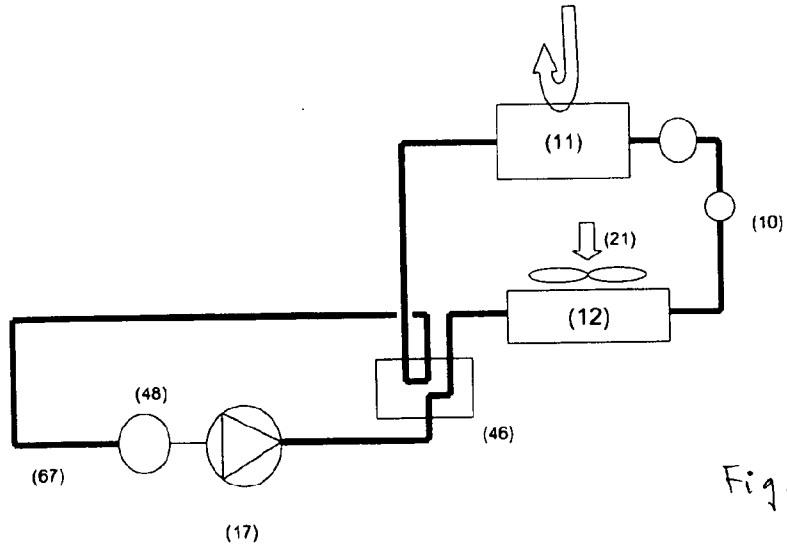


Fig. 17

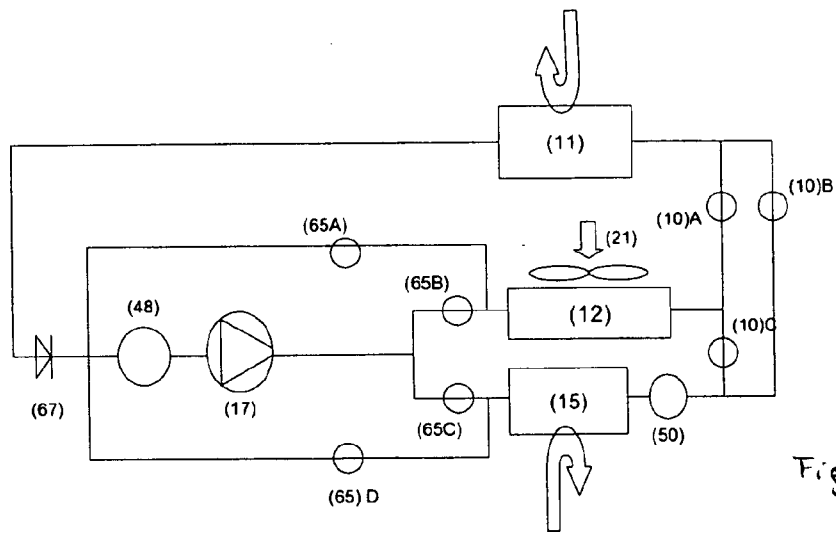


Fig. 18

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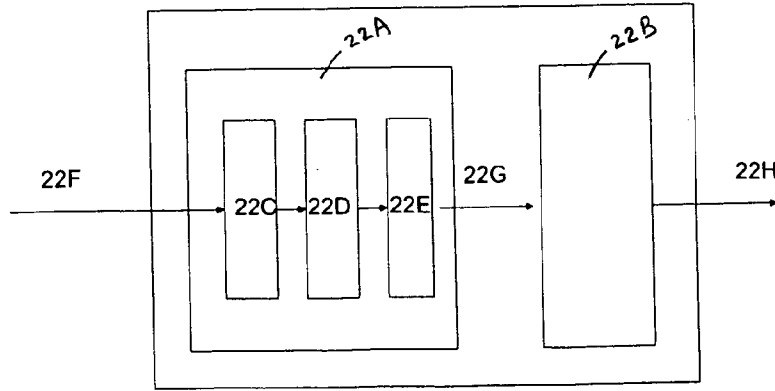


Fig. 19

## MODULAR MULTI-ENERGY THERMODYNAMIC DEVICE

### FIELD OF THE INVENTION

**[0001]** The invention concerns a system or device of modular design comprising at least one module generating electric current and one or more modules from the following types: heat or refrigeration pumps or mixed heat/refrigeration pump modules, enabling the simultaneous production of hot water, for example for heating buildings, very hot water, for example domestic hot water, cold water, for example for air conditioning, optionally refrigerating fluid, typically for refrigeration, and optionally electricity.

### PRIOR ART

**[0002]** Systems are known composed of heat pumps actuated by internal combustion engines and using a steam-compression refrigeration cycle. The patent application EP 1 628 096 (LG Electronics Inc) describes such a system. These systems have been in common use in Japan for several years for air conditioning (cooling) in summer and heating in winter for buildings such as office premises or hotels, and the simultaneous production of domestic hot water. These systems are, the majority of the time, so-called direct expansion systems, that is to say they directly send a refrigerating fluid to individual internal units. These are generally installations of the VRV (variable refrigerant volume) or VRO (variable refrigerant output) type.

**[0003]** Such systems enable hot water to be produced, for example domestic hot water, by virtue of the use of the heat released by the combustion engine in operation. However, one of the major drawbacks of the systems is that the heat pump cannot function correctly by taking the necessary heat from the air when the external temperature is less than approximately 10° C. since this causes frosting of the evaporator. In practice, in winter, the heat of the engine is used to heat the evaporator in order to enable the thermodynamic system to continue to function with good efficiency when the external temperature is below 10° C. (down to approximately -20° C.), the drawback being in this case that water at very high temperature is no longer produced and the overall efficiency of the system becomes fairly low.

**[0004]** In addition, the document EP 1 628 096 enables only water at a single temperature to be supplied to the end user, the temperature of domestic hot water, and when the system is in air conditioning mode. In a variant, the system comprises several units, in particular interior units and exterior units, connected by refrigerating fluid pipes. In this case also, only one water temperature can be supplied by the system, this being domestic hot water supplied in air conditioning mode of the system.

**[0005]** To remedy this drawback, the system described in the document EP 2 085 721 of the applicant uses a cogeneration assembly connected to a heat pump designed so as to supply to the user, simultaneously, water at several different temperatures. However, the system described is designed for given refrigerating, heating and electrical capacity levels specific to a given application. The system is designed as a single indivisible assembly and because of this it allows no flexibility in design or use and must be completely resized for any new application.

**[0006]** Moreover, the existing systems have powers limited to maximum values of around 75 kW since they use car

engines of limited power and refrigeration components also not making it possible to function at higher powers.

**[0007]** Another drawback of the existing systems is that the sizing thereof must be adapted to the specific requirements of the user for water at different temperatures. However, these requirements, with regard to both the total quantity thereof and the distribution thereof over the various water temperatures, may vary according to the season or the lifestyle or in the course of a day. The systems according to the prior art firstly lack flexibility as to use thereof. Secondly, the correct sizing thereof according to the requirements of the user thereof in general requires made to measure design, or at least the possibility of selecting the appropriate system from a wide range of products of difference sizes.

**[0008]** The problem that the present invention sets out to solve is to remedy these drawbacks of the prior art.

### SUBJECT MATTER OF THE INVENTION

**[0009]** A first subject matter is a system (1) for simultaneously producing very hot water at temperature T2, hot water (14) at temperature T1 and/or cold water (13) at temperature T3, and electricity (20), and optionally also producing refrigerating fluid at evaporation temperature T4, and/or producing refrigerating fluid at evaporation temperature T5, and said system comprising at least one current-generating unit that comprises either a combustion engine (2) connected to an alternator (18) or a fuel cell (22), each of the current generators also comprising a heat exchanger (8) producing very hot water at temperature T2, and said system (1) or current generating unit optionally comprising one or more other current generators, selected from the group comprising a combustion engine (2) connected to an alternator (18), a fuel cell (22), a photovoltaic solar panel (23) or a wind turbine,

**[0010]** and said system (1) also comprising at least one heat pump (3), or a refrigeration unit and optionally an electric accumulator (19),

**[0011]** said heat pump or said refrigeration unit being (i) either of the steam compression type and then comprising at least one refrigerating fluid compressor (17), a first heat exchanger (11, 66) situated at the suction of the compressor (17) when the system (1) is in air conditioning mode, a pressure reducing valve (10), and second heat exchanger (12) placed at the discharge of the compressor (17) when the system (1) is in air conditioning mode, and optionally a third heat exchanger (15) situated at the discharge of the compressor (17) when the system (1) is in air conditioning mode and used for heating the hot water (14), (ii) or of the absorption type and then comprising an absorber (28), a circulation pump (30), a steam generator (29), a first heat exchanger (31) situated at the inlet of said absorber (28), a pressure reducing valve (32) and a second heat exchanger (33) situated at the outlet of said steam generator (29),

**[0012]** said system (1) being characterized in that

**[0013]** (a) the compressor (17) or the circulation pump (30) is driven by an electric motor, which may be supplied by one of said current generators, and in that

**[0014]** (b) said system (1) comprises at least one module Pc, Pa referred to as a "heat pump module" (36, 37) or at least one module Pr referred to as a "refrigeration module" (36A) or at least one module Pm (36B) referred to as "mixed: heat and refrigeration pump" comprising,

**[0015]** (b1) if it is a case of a compression heat pump module Pc (36), each at least one heat pump assembly comprising at least one refrigerating fluid compressor (17), said

first heat exchanger (11), said pressure reducing valve (10), said second heat exchanger (12) and optionally said third heat exchanger (15);

[0016] (b2) if it is a case of an absorption heat pump module Pa (37), each an absorber (28), said circulation pump (30), said steam generator (29), said first heat exchanger (31), said pressure reducing valve (32) and said second heat exchanger (33);

[0017] (b3) if it is a case of a refrigeration module Pr (36A), each at least one refrigeration unit comprising at least one refrigerating fluid compressor (17), said pressure reducing valve (10), said second heat exchanger (12) and optionally said third heat exchanger (15), as well as refrigerating fluid pipes (16a, 16b) intended to be connected to an air/water refrigerating fluid exchanger (66) external to the module Pr (36A);

[0018] (b4) if it is a case of a mixed module Pm (36B), two units, one of the heat pump type and the other of the refrigeration type, wherein

[0019] the unit of the heat pump type comprises at least one refrigerating fluid compressor (17), said first heat exchanger (11), said pressure reducing valve (10), said second heat exchanger (12) and optionally said third heat exchanger (15), and

[0020] the unit of the refrigeration type comprises at least one refrigerating fluid compressor (17), said pressure reducing valve (10), said second heat exchanger (12) and optionally said third heat exchanger (15) as well as refrigerating fluid pipes (16a, 16b) intended to be connected to an air/water refrigerating fluid exchanger (66) external the module Pm (36)

[0021] and in that said generating unit is included inside a generating module (G), said modules (G, Pc, Pa, Pr, Pm) each being provided with a frame and a unit forming an assembly interface produced so that said modules (G, Pc, Pa, Pr, Pm) can be assembled together, one after the other, and form a single unit.

[0022] System for simultaneously producing water at several temperatures, and optionally refrigerating fluid, means a system able to produce and supply to the user water and optionally refrigerating fluid at the specified temperatures via suitable manifolds that connect the single unit thus obtained to the plant of the user.

[0023] According to the invention, the number and type of modules is chosen according to the heating and/or refrigerating capacity and electrical power necessary for the functioning of the system to adapt it to a given application, as from the design thereof. Such a modular construction offers a broad pallet of design solutions for the system, by adapting the number and type of modules to each case of use. Moreover, the system also has flexibility in use since it takes account of a multiplicity of energies liable to supply the system, as well as a multiplicity of energy flows able to be produced by the system.

[0024] The system of the invention is modular in construction and makes it possible to connect together several complex modules, in particular cogeneration and thermodynamic, while simplifying the interfaces in order to obtain a unitary or single-piece assembly, preferably easily transportable by lorry. Thus the complexity of the design is concentrated inside the modules, the interfaces between modules being simplified to the maximum possible extent. The modules preferably have frames of identical height and width for connection to each other by suitable mechanical connection means.

[0025] This provides a standardization of the components, a reduction in the purchase costs of the components by increasing volumes, a reduction in the development time and a simplification of production.

[0026] A system will therefore be defined by choosing in an optimum fashion the modules that will be standardized, in particular through the internal functions thereof and the choice of interfaces in order to obtain a system corresponding to the requirements of the end user. The system of the invention responds to the requirements of applications such as:

1) Heating, Domestic Hot Water and Air Conditioning of Service or Residential Buildings:

[0027] This gives rise to a variable thermal requirement according the sizes of buildings, according to the insulation levels thereof, according to the types thereof (hospital, hotels, retirement homes or offices) and according to the location thereof (north or south Europe). The preferred fluid being water at temperature T1 (heating), T2 (domestic hot water) and T3 (air conditioning). For some applications, there may be simultaneously air conditioning and heating requirements in certain parts of the building.

2) Heating, Domestic Hot Water, Air Conditioning and Supply of Refrigeration Energy for Refrigeration Requirements for Supermarket Applications.

[0028] In addition to the points dealt with in the previous paragraph, there is added the requirement for refrigerating capacity in the form of refrigerating fluid at temperatures T4 and T5 in variable proportions according to the application.

3) Heating, Production of Electricity and Optionally Air Conditioning of Agricultural Greenhouses:

[0029] There are in this case major heating requirements in the form of hot water at temperatures T1 and T2 and often enjoying natural gas tariffs at a competitive cost. Any excess electricity may be resold.

4) Agricultural Biomass Plant Producing Biogas:

[0030] There is here local production of primary energy for covering heating and electricity requirements with resale of the surplus thereof. There is a requirement for hot water at temperatures T1 and T2. The excess electricity may be resold.

[0031] The various modules used by the system will be described and the capacity supplied to the system will be given by way of example hereinafter:

[0032] The cogeneration module (or generating module G) which enables heat capacity to be generated in the form of hot water at temperature T2 and electricity.

[0033] Internal functions of the module:

[0034] Each engine comprises one or two engines from the possible (non-limitative) choices of 2 liters and 4.6 liters.

[0035] The electric power can be used locally by the other modules or sent outside with the electrical network of the customer.

[0036] The thermal output is transferred by a regulated valve to the central water pipes for hot water T1 or very hot water T2 according to the respective requirements of the application.

[0037] 2-litre engine: up to 25 kW of electricity and simultaneously up to 35 kW of heating capacity at temperature T2.

[0038] 4.6-litre engine: up to 55 kW of electricity and simultaneously 80 kW of heating capacity at temperature T2.

**[0039]** Minimum outputs: one 2-litre engine: 25 kW electrical and 35 kW heat.

**[0040]** Maximum outputs: two 4.6 liter engines: 110 kW electrical and 160 kW heat,

**[0041]** The reversible heat pump module (Pc) that enables hot water to be produced at temperature T1 or cold water at temperature T3 using the compression refrigeration cycle,

**[0042]** Internal functions of the module: each module comprises two independent refrigeration units connected to the central water pipes, and a regulation system.

**[0043]** Each of the two units produces approximately 65 kW of cold water at temperature T3 or approximately 80 kW of hot water at temperature T1 (non-simultaneously).

**[0044]** Each module of this type produces: approximately 130 kW of cold water at temperature T3 or approximately 160 kW of hot water at temperature T1 (non-simultaneously).

**[0045]** The heat pump module with optional exchanger (Pc) simultaneously producing hot water at temperature T1 and cold water at temperature T3 using the compression refrigeration cycle.

**[0046]** Internal functions: Each module comprises two independent refrigeration units connected to the central water pipes, and a regulation system.

**[0047]** Each of the two units can produce approximately 65 kW of cold water at temperature T3 or approximately 80 kW of hot water at temperature T1 like the reversible heat pump module but it can also if necessary produce these two outputs simultaneously.

**[0048]** Each module of this type can therefore produce approximately 130 kW of cold water at temperature T3 or approximately 160 kW of hot water at temperature T1 like the reversible heat pump module but it can also if necessary produce these two outputs simultaneously, that is to say approximately 130 kW of refrigeration energy in the form of cold water at temperature T3 and approximately 160 kW of heat energy in the form of hot water at temperature T1.

**[0049]** The refrigeration module (Pr) producing refrigerating fluid at temperature T4 or T5 using the compression refrigeration cycle.

**[0050]** Internal functions: each module comprises two independent refrigeration units connected to the central refrigerating fluid pipes, and a regulation system.

**[0051]** Each of the two units can produce approximately 40 kW of refrigeration output in the form of refrigerating fluid at temperature T4 or approximately 20 kW of refrigerating fluid at temperature T5.

**[0052]** Each module of this type can therefore produce approximately 80 kW of refrigeration output in the form of refrigerating fluid at temperature T4 or approximately 40 kW of refrigerating fluid at temperature T5.

**[0053]** The mixed reversible heat/refrigeration pump module (Pm):

**[0054]** In addition, each of the above three modules (heat pump modules and refrigeration module) is composed of two independent units fulfilling the required function and it is therefore possible to have mixed modules comprising for example a reversible heat pump unit and a refrigeration unit (example in FIG. 13):

**[0055]** There is therefore production of hot water at temperature T1 (approximately 80 kW) or cold water at temperature T3 (approximately 65 kW) and simultaneously production of refrigerating fluid at temperature T4 (approximately 40 kW) or at temperature T5 (approximately 20 kW).

**[0056]** The absorption heat pump module (Pa): Production of hot water at temperature T1 using the absorption cycle. The heat output is approximately 35 kW.

**[0057]** Advantageously, said unit forming an assembly interface comprises: a mechanical interface, an electrical interface, and a fluid interface.

**[0058]** The system of the invention is modular in construction and comprises at least one electric current generator and one or more so-called "production" modules, each comprising one or two heat-pump or refrigeration units. System of modular construction means a system comprising at least two modules, each module comprising a frame forming a support for the components thereof, as well as means of mechanical electrical and fluid connection to the adjacent module. Preferably, the modules are produced so that, when connected, they have the same pattern at least in one dimension (for example the width of the module) and, even more advantageously, in two dimensions (width and height). A production module can comprise a heat-pump unit or a refrigeration unit. In an advantageous variant of the invention, a production module may comprise two units of the same type, for example two heat-pump units or two refrigeration units, on a common frame. In another advantageous variant of the invention, a production module is a mixed module, that is to say it comprises a heat-pump unit and refrigeration unit on a common frame.

**[0059]** The interfaces between modules are limited to the maximum possible extent and are of three types:

**[0060]** Mechanical interfaces: the modules have frames of identical heights and widths in order to connect to each other by means of suitable mechanical connection means.

**[0061]** Electrical and electronic interfaces: the regulation particular to each module makes it possible to limit the electronic interfaces (by communication bus mainly) and electrical interfaces (in particular the power cables of the compressors).

**[0062]** Fluid interfaces, in particular hydraulic and refrigerating fluid: they are situated at the same place for all the modules (preferably at the central part, such as the product shown in the drawings). They constitute the path for passage and transfer of the heat energy to the outside of the modular system of the invention.

**[0063]** Once these interfaces have been produced, the product is in the form of a single block or single unit transportable in a single piece for example by lorry.

**[0064]** Advantageously, up to six modules can be assembled together, including one or two cogeneration modules (one cogeneration module at each end of the machine).

**[0065]** The electrical and thermal outputs of the various modules of this single-piece unit are then added together. One megawatt is for example approached in terms of heat energy.

**[0066]** The electrical energy available will be used locally by the modules or returned to the outside to the customer network according to respective requirements.

**[0067]** The regulation of the unit will then be aimed at the total energy optimization of the machine.

**[0068]** Thus a system comprising six modules so defined advantageously fulfils the functions corresponding to the following applications:

**[0069]** 1) Heating, domestic hot water and air conditioning of service or residential buildings;

**[0070]** According to the respective power requirements firstly of air conditioning and heating (optionally simultaneous in a given proportion), secondly domestic hot water and

finally optional electrical backup, it will be possible to configure one or two generating units associated with heat pump modules possibly of a different type. This in order to adhere to requirements with a single machine.

[0071] 2) Heating, domestic hot water, air conditioning and supply of refrigeration energy for refrigeration requirements for supermarket applications.

[0072] The response to multiple requirements will rely on the refrigeration modules.

[0073] It will then be possible to have a unit composed of one or two cogeneration modules associated with one or more refrigeration modules themselves supplemented by heat pump modules. The assembly affording an adapted, coherent and single-piece response to a complex problem.

[0074] 3) Heating, production of electricity and optionally air conditioning of agricultural greenhouses:

[0075] The maximum cogeneration power associated with heat-pump modules will typically be found. The monobloc product avoids the use or construction of a technical room.

[0076] 4) Agricultural biomass plant producing biogas:

[0077] The available primary energy capacities are related to the size of the methanizers producing the biogas by biomass. This available power range is well suited to the cogeneration modules of the system of the invention.

[0078] The system 1 of the invention also comprises at least one refrigeration module 36A and optionally an electric accumulator 19, said module comprising at least one refrigeration unit that is of the steam compression type and then comprising at least one refrigerating fluid compressor 17, a pressure reducing valve 10, a heat exchanger 12 placed at the discharge of the compressor 17 and optionally a third heat exchanger 15 situated at the discharge of the compressor 17 when the system 1 is also used for heating hot water 14, the system also comprising refrigerating fluid pipes intended to be connected to an exchanger 66 of the refrigerating fluid/air type situated outside the module, or even outside the system typically, but not exclusively, in particular for foodstuff refrigeration applications. The exchanger 66 is essential to the functioning. It is however not situated physically in the module comprising the compressors. The exchanger 66 can be situated in a specific isothermal module forming part of the modular-design system (cold chamber role external the building for example). The exchanger 66 can also be situated at a distance from the modular-design system, in the enclosure of a building (application of the supermarket type for example). More particularly, according to the invention in this case

[0079] (a) the compressor 17 is driven by an electric motor, which may be supplied by one of said current generators, and

[0080] (b) said system 1 comprises at least one module Pr referred to as a "refrigeration module" each comprising at least one refrigerating fluid compressor 17, said pressure reducing valve 10, said heat exchanger 12 optionally said heat exchanger 15, and refrigerating fluid pipes (16a, 16b) intended to be connected to an exchanger 66 not being situated physically in the module, but being essential to the functioning thereof.

[0081] The current generator of the combustion engine type may be included in a so-called current generator module G; this module G may comprise one or several other current generators selected from combustion engines and fuel cells, or these other current generators may be integrated in a second current generating module. The current generating module or modules may advantageously comprise connections for connecting one or several external current sources such as

a photovoltaic solar panel 23, a wind turbine or an electrical network. Said current generators may be alternating current or direct current generators. In an advantageous embodiment, the first current generator is a combustion engine 2 connected to an alternator 18. In this case, the alternating current can supply said compressor 17 with alternating current (some of it being able to be introduced into an electrical network external to the system 1), or it may be transformed into direct current to supply said compressor 17 functioning under direct current and/or to recharge the electric accumulator 19. The same applies to the other current generators if they produce alternating current (such as a combustion engine, a wind turbine or a turbine). If one of the other current generators is a direct-current generator (for example the fuel cell 22 or the photovoltaic panel 23), this direct current may be used either directly by the compressor 17, if the latter functions under direct current, and/or by the electric accumulator 19, or be transformed into alternating current so as to be used by the compressor 17 functioning under alternating current, and/or be introduced into an electrical network external to the system 1.

[0082] Advantageously, said heat pump or refrigeration unit uses the steam compression refrigeration cycle.

[0083] The system according to the invention is highly advantageously designed so as to be able to be supplied by an external electrical network in order to cover, partly or wholly, the electrical requirements thereof, and so as to be able to send to said external electrical network at least some of the electrical energy produced by said system.

[0084] A second subject matter of the invention is a method of regulating a system according to the invention.

#### DESCRIPTION OF THE FIGURES

[0085] FIGS. 1 to 19 refer to the invention, particular embodiments of which they illustrate.

[0086] FIG. 1 shows an outline diagram of the system according to the invention, in the case where the alternating current generator is a combustion engine connected to an alternator and the heat pump uses the steam compression refrigeration cycle.

[0087] FIG. 2 shows an outline diagram of the system according to the invention, in the case where the alternating current generator is a photovoltaic solar panel or a fuel cell, connected to a DC to AC converter, and the heat pump uses the steam compression refrigeration cycle.

[0088] FIG. 3 presents the energy efficiency of the system according to the invention in the case of the heat pump compared with the efficiencies of various systems of the prior art.

[0089] FIG. 4 shows an outline diagram of the system according to the invention, in the case where the alternating current generator is a combustion engine connected to an alternator and the refrigeration module uses the steam compression refrigeration cycle.

[0090] FIG. 5 shows an outline diagram of a system of the invention according to a variant of the invention, the system comprising several current generating modules connected to several heat pump modules.

[0091] FIG. 6 shows an outline diagram of a system of the invention according to a variant of the invention, the system comprising several current generating modules connected to a heat pump module and to several refrigeration modules.

[0092] FIG. 7 shows an outline diagram of a system of the invention in the case where the alternating current generator

is a combustion engine connected to an alternator and the heat pump uses the absorption refrigeration cycle.

[0093] FIG. 8*a* is a side view, FIG. 8*b* a front view and FIG. 8*c* a view in section along the plane A-A in FIG. 8*b* of a system according to another variant of the invention wherein the system comprises a generating module connected to several heat pump modules of various types.

[0094] FIGS. 9*a* to 9*f* show different views of a compression heat pump module according to the invention comprising two heat pump units provided with the optional exchanger 15.

[0095] FIG. 10*a* is a side view, FIG. 10*b* a front view and FIG. 10*c* as view in section along the plane C-C in FIG. 10*b* of an absorption heat pump module according to the invention.

[0096] FIG. 11*a* is a side view, FIG. 11*b* a front view and FIG. 11*c* a view in section along the plane D-D of FIG. 11*b* of a generating module according to the invention.

[0097] FIGS. 12*a* to 12*f* show different views of a refrigeration module comprising two refrigeration units.

[0098] FIGS. 13*a* to 13*f* show different views of a mixed heat pump and refrigeration module.

[0099] FIGS. 14*a* to 14*c* show different views of an example of a system of the invention comprising a generating module and a mixed heat pump and refrigeration module.

[0100] FIG. 15 shows an example of a system comprising a generating module, a mixed heat pump and refrigeration module and a module of the refrigeration module type comprising two refrigeration units.

[0101] FIG. 16 shows an example of a system according to the invention comprising a generating module, a mixed heat pump and refrigeration module, of the refrigeration module type comprising two refrigeration units and two isothermal modules.

[0102] FIG. 17 shows an outline diagram of the compression heat pump unit designed according to a first operating mode.

[0103] FIG. 18 shows an outline diagram of the compression heat pump unit designed according to a second operating mode.

[0104] FIG. 19 shows an outline diagram of a fuel cell equipped with a reforming unit or reformer, said cell belonging to the generating module.

#### LIST OF REFERENCES

- [0105] 1 System according to the invention  
 [0106] 2 Combustion engine  
 [0107] 3 Heat pump  
 [0108] 4 Liquid or gaseous fuel inlet  
 [0109] 5 Mechanical energy produced by the engine  
 [0110] 6 Heat emitted by the alternating current generator in operation  
 [0111] 7 Energy losses  
 [0112] 8 Heat exchanger for the exchange of heat between the alternating current generator and very hot water  
 [0113] 9 Very hot water circuit  
 [0114] 10 Pressure reducing valve  
 [0115] 10A Pressure reducing valve A (optional circuit with exchanger 15)  
 [0116] 10B Pressure reducing valve B (optional circuit with exchanger 15)  
 [0117] 10C Pressure reducing valve C (optional circuit with exchanger 15)  
 [0118] 11 Water/refrigerating fluid heat exchanger (evaporator in air conditioning mode)  
 [0119] 12 Air/refrigerating fluid heat exchanger (evaporator in heating mode, and condenser in air conditioning mode)  
 [0120] 13 Water circuit—cold-water circuit when the heat pump is in air conditioning mode  
 [0121] 14 Hot-water circuit  
 [0122] 15 Refrigerating fluid/recovery water circuit heat exchanger  
 [0123] 16 Refrigerating fluid circuit  
 [0124] 16A Suction refrigerating fluid pipe  
 [0125] 16B Liquid refrigerating fluid pipe  
 [0126] 17 Compressor  
 [0127] 18 Alternator  
 [0128] 19 Electric accumulator  
 [0129] 20 Electrical energy  
 [0130] 21 Motor fan  
 [0131] 22 Fuel cell  
 [0132] 22A Reformer  
 [0133] 22B Cell core  
 [0134] 22C Reforming reactor  
 [0135] 22D Desulfurization unit  
 [0136] 22E WGS (water gas shift) unit.  
 [0137] 22F Fuel fluid (natural gas, biogas, etc)  
 [0138] 22G Hydrogen  
 [0139] 22H Electricity  
 [0140] 23 Photovoltaic solar panel  
 [0141] 24 DC to AC converter  
 [0142] 25 Solar energy  
 [0143] 26 Fuel (for fuel cell)  
 [0144] 27 Heat pump using the absorption cycle  
 [0145] 28 Absorber  
 [0146] 29 Generator  
 [0147] 30 Circulation pump  
 [0148] 31 Evaporator of the absorption cycle  
 [0149] 32 Pressure reducing valve for the absorption cycle  
 [0150] 33 Condenser of the absorption cycle  
 [0151] 34 Refrigerating fluid  
 [0152] 35 Absorber  
 [0153] 36 Compression heat pump module  
 [0154] 36A Refrigeration module  
 [0155] 36B Mixed module: heat pump and refrigeration  
 [0156] 36C Isothermal module  
 [0157] 36D Heat pump unit  
 [0158] 36E Refrigeration unit  
 [0159] 37 Absorption heat pump module  
 [0160] 38 Current-generation module  
 [0161] 39*a, b*, Collectors connecting the water exchangers  
 [0162] *c, d*,  
 [0163] 40 Gas pipes connecting the absorption heat pump modules  
 [0164] 41 Power cable  
 [0165] 42 Regulation cable  
 [0166] 44 Heat pump module frame  
 [0167] 46 4-way valve  
 [0168] 47 Refrigeration compressor  
 [0169] 48 Liquid anti-knock bottle  
 [0170] 50 Liquid reservoir  
 [0171] 51 Absorber  
 [0172] 52 Generator  
 [0173] 53 Refrigerating fluid/absorption-cycle water plate exchanger  
 [0174] 54 Refrigerating fluid/absorption-cycle air plate exchanger  
 [0175] 55 Fuel inlet

- [0176] 56 Thermal engine unit and alternator thereof
- [0177] 57 Fuel cell and inverter unit thereof
- [0178] 58 Connection of external thermal sources
- [0179] 59 Exchanger for exchange of heat between the current generator and very hot water
- [0180] 60 Global system power and regulation cubicle
- [0181] 61 Power cable for energy feed coming from photovoltaic power
- [0182] 62 Power cable for electrical network feed
- [0183] 63 Power cable for sending electrical energy to the network
- [0184] 64 Current-generating module frame
- [0185] 65A, 65B Two-way refrigeration valves
- [0186] 65C, 65D
- [0187] 66 Refrigerating fluid/air exchanger
- [0188] 67 Non-return valve on refrigerating fluid circuit
- [0189] 68 Regulation box
- [0190] Pc Compression heat pump module
- [0191] Pa Absorption heat pump module
- [0192] Pr Refrigeration module
- [0193] Pm Mixed module: refrigeration and heat pump
- [0194] G Current-generating module
- [0195] Ce1, Ce2, Customer inlet manifold
- [0196] Ce3
- [0197] Cs1, Cs2, Customer outlet manifold
- [0198] Cs3

## DESCRIPTION OF THE INVENTION

## Definitions

- [0199] In the present document, the following meanings should be understood:
- [0200] Thermodynamic system of the refrigeration or heat pump type: device comprising a compressor and several exchangers in which a specific transfer fluid flows, usually referred to as refrigerating fluid, said device absorbing thermal energy at a first temperature and restoring thermal energy at a second temperature, the second temperature being higher than the first.
- [0201] Geothermal loop: set of pipes placed in the ground typically in a vertical or horizontal position and intended to exchange heat between the heating or cooling system and the ground.
- [0202] Heat exchanger: device intended to transfer heat between several circuits.
- [0203] Transfer fluid: heat-transfer fluid used for transferring heat; the classic examples are refrigerating fluid, water or, glycolated water, sometimes referred to as brine.
- [0204] Thermal source or source: by convention, the terms source and thermal load refer to the heating mode. The source is the medium from which heat is extracted in heating mode. This extraction of heat takes place with certain physical characteristics such as the thermal inertia or the available power that characterize the source. It should be noted that the term source is improper in cooling mode since therein heat issuing from the building is in fact discharged.
- [0205] Thermal load or load: the load is the medium where the heat is discharged in heating mode. This discharge of heat takes place with certain physical characteristics such as the thermal inertia or the available power that characterize the load, and likewise the load is the place where the heat is withdrawn in cooling mode.
- [0206] COP or coefficient of performance: the COP or coefficient of performance of a system in heating mode is

defined as the ratio between the available heating capacity to the electrical power consumed by the system. In the system according to the invention, "electrical equivalent" COP means the COP that the plant would have if electricity were used in place of gas or biofuel.

[0207] Alternating-current generator: device that generates alternating current either directly or by means of an additional converter that transforms the direct current generated into alternating current.

[0208] Combustion engine: an engine which, by combustion, transforms the chemical energy contained in a fuel into mechanical energy.

[0209] Internal combustion engine: combustion engine where the combustion of the fuel producing the energy necessary for functioning takes place in the engine itself typically in a combustion chamber.

[0210] Photovoltaic solar panel: electrical direct-current generator consisting of a set of photovoltaic cells connected together electrically.

[0211] Thermal solar collector: device in which the temperature of a solid, liquid or gaseous medium is increased by total or partial absorption of solar radiation.

[0212] Fuel cell: device producing electricity by means of oxidation, on one electrode, of a reducing fuel (for example hydrogen) coupled to the reduction on the other electrode of an oxidant, such as oxygen from the air.

## Detailed Description

[0213] The combustion engine 2 of the system according to the invention is preferably an internal combustion engine; it forms part of the current-generating module G. It is preferably supplied with natural gas. According to requirements, it may also be supplied with other gaseous or liquid fuels such as petrol, fuel oil, kerosene, alcohol, or biofuels such as vegetable oils, bioethanol or biogas.

[0214] It may be a case of other types of combustion engine, such as external combustion engines such as Stirling engines. The alternator 18 connected to the combustion engine also forms part of the generator G.

[0215] The fuel cell 22 of the system according to the invention may be any type of fuel cell known to persons skilled in the art, typically, but not exclusively, operating at temperatures below 200° C., but which may in certain cases reach a temperature of 800° C. to 1000° C. (for example a fuel cell of the "solid oxide" type) and supplied with a suitable fuel, such as hydrogen, methane or other hydrocarbon mixture such as petrol or fuel oil. The fuel cell is composed at a minimum of a cell core 22B supplied with hydrogen (the case of fuel cell cores based on proton exchange membranes) or supplied by the plurality of hydrocarbon fuels already cited (the case of high-temperature cell cores of the solid oxide type). If the cell of the type based on proton exchange membranes and hydrogen is not directly available, then the fuel cell 22 is then composed of a reformer 22A and a cell core 22B. The role of the reformer is to extract the hydrogen necessary to the cell core from more chemically complex fuels already cited, such as natural gas, methane, biogas or other hydrocarbon mixture. The hydrogen thus extracted supplies the cell core based on proton exchange membranes.

[0216] An example of functioning of a fuel cell 22 with reformer 22A is illustrated in FIG. 19 and will be described below. The fuel 22F (which may be natural gas, biogas, etc) undergoes in the reformer 22A a series of transformations aimed at extracting hydrogen 22G therefrom, while limiting

the level of impurities (typically sulfur) and carbon monoxide. For this purpose, the fuel first of all passes through a reforming reactor which, following the addition of water, will extract hydrogen therefrom. In the case of methane, for example, the chemical reaction is of the type  $\text{CH}_4 + 2\text{H}_2\text{O} = \text{CO}_2 + 4\text{H}_2$ . The role of the unit 22D is to reduce the sulfur content, since sulfur may affect the behavior of the cell core 22B. The unit 22E for its part effects the so-called "water gas shift" transformation, which reduces the carbon monoxide content of the mixture, which may also affect the behavior of the cell core. The chemical reaction in this unit is of the type:  $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$ .

[0217] The photovoltaic solar panels 23 of the system according to the invention may be any type of panel known to persons skilled in the art, in particular the semiconductor constituting the photovoltaic cells may, non-limitatively, be amorphous, polycrystalline or monocrystalline silicon, a semiconductor organic material or a combination of these. A plurality of photovoltaic solar panels may be used.

[0218] In preferred embodiments, the system according to the invention is reversible, namely it may function in a mode favoring heating by the supply of hot water at temperature T1 ("heating mode") or in a mode favoring the cooling by the supply of cold water at temperature T3 ("air conditioning mode"). To do this, a cycle-reversal four-way valve 46 (FIG. 8C) is installed on the refrigerating fluid circuit 16. It is also possible to have non-reversible systems, in particular for certain refrigeration applications. When the system is provided with the optional exchanger 15, it is then possible to simultaneously supply hot water at temperature T1 and cold water at temperature T3 in variable proportions for each in order to meet the requirements of use. The cycle-reversal four-way valve 46 is then replaced by four two-way refrigeration valves 65A, B, C, D. The pressure reducing valve 10 is then supplemented by two additional pressure reducing valves, meaning that the circuit comprises three pressure reducing valves: 10A, 10B, 10C.

[0219] In the case where the heat pump 3 is reversible, the heat exchangers 11 and 12 are reversible exchangers. It should be noted that we have chosen to describe in detail the functioning of the system according to the invention in air conditioning mode. When the heat pump functions in heating mode, the water circuit 13 becomes a hot-water circuit.

[0220] In addition, the heat exchanger 11 is preferably a plate exchanger.

[0221] With reference to FIG. 1, the heat pump 3 of the system 1 according to the invention is a module Pc 36 that comprises

[0222] one or two sealed closed circuits in which a transfer fluid flows, such as a refrigerating fluid 16,

[0223] at least one compressor 17 per circuit driven by an electric motor,

[0224] a pressure reducing valve 10,

[0225] a first heat exchanger 11, situated at the suction of the compressor 17 when the system is functioning in air conditioning mode,

[0226] a second heat exchanger 12, situated at the discharge from the compressor 17 when the system is functioning in air conditioning mode,

[0227] an optional third heat exchanger 15, situated at the discharge from the compressor 17 when the system is in simultaneous air conditioning and heating mode by recovery of heat.

[0228] These components are arranged inside a frame, not shown in FIG. 1.

[0229] According to the invention also, the compressor 17 is driven by an electric motor. This electric motor may be supplied electrically by the first current generator and/or by one or more of the other current generators, or by the electrical network, according to the choice made by the global system regulation method chosen. It is possible to use a DC or AC motor. Using an electric motor for operating the compressor 17 (and in particular not driving the compressor 17 directly (mechanically) by the combustion engine 2) has the advantage of being able to use hermetic compressors, thus avoiding the risks of leakage relating to the use of open compressors. In a particular embodiment, the compressor 17 is driven by an electric motor supplied electrically by a combustion engine 2, the necessary electricity being generated by the alternator 18 driven by said combustion engine 2.

[0230] For the reasons mentioned above, the compressor of the heat pump is preferably a hermetic compressor. Hermetic compressor means a compressor composed of a closed casing, in general a welded steel envelope, inside which there are a compression unit for compressing the refrigerating fluid and a motor that drives the compression unit. It is however also possible to use semi-hermetic compressors in which it is possible to have access to certain internal components during maintenance or any repairs.

[0231] The heat pump 3 of the system 1 according to the invention can be provided with a third heat exchanger 15. This exchanger is preferably (like the second heat exchanger 11) a plate exchanger.

[0232] The heat pump 3 of the system 1 according to the invention allows the use of all types of thermal loads known to persons skilled in the art for heating and air conditioning, such as refreshing heating floors or fan convectors. The loads may also be air processing units for the dehumidification of swimming pools and the treatment of fresh air in premises, or water circuits in industrial processes requiring the use of hot water and/or cold water.

[0233] In a variant of the invention, the heat pump 3 of the system 1 according to the invention may be a heat pump of the air/water type, that is to say a heat pump using external air and/or extracted air as the heat source in heating mode or a heat pump of the water/water type, that is to say a heat pump using a water circuit in the external ground as the heat source in heating mode. An advantageous thermal source for the heat pump 3 is a geothermal loop.

[0234] The heat exchangers on the source and on the load are adapted to the type of heat pump and to the type of application according to criteria well known to persons skilled in the art.

[0235] With reference to FIG. 4, the refrigeration unit according to the invention is a module Pr 36A that comprises:

[0236] at least one circuit in which a transfer fluid such as a refrigerating fluid 16 circulates; the circuit is closed and sealed after final installation of the exchanger 11 (in the factory or on the end site),

[0237] at least one compressor 17 driven by an electric motor,

[0238] a pressure reducing valve 10,

[0239] suction refrigerating fluid pipes 16a and liquid pipes 16b intended to be connected to a heat exchanger 66 by the refrigeration circuit, situated at the suction of the compressor 17. This exchanger is not situated in the module Pr 36A comprising the compressors 17. It may be situated in an

isothermal module 36C, as shown in FIG. 16, or may be situated outside a modular unit according to the invention (typically in a building close to the modular unit). This exchanger makes it possible to close the circuit and is necessary to the functioning of the system. A module may comprise two circuits independent from the refrigeration point of view, and therefore two exchangers 66. Each of these exchangers may be situated in an isothermal module 36C or outside the modular unit as described above.

[0240] a second heat exchanger 12 situated at the discharge of the compressor 17.

[0241] These components are arranged inside a frame, not shown in FIG. 4.

[0242] According to the invention also, the compressor 17 is driven by an electric motor. This electric motor may be supplied electrically by the first current generator and/or by one or more of the other current generators, or the electrical network, according to the choice made by the global system regulation method chosen. It is possible to use a DC or AC motor. Using an electric motor for operating the compressor 17 (and in particular not driving the compressor 17 directly (mechanically) by the combustion engine 2) has the advantage of being able to use hermetic compressors, thus avoiding the risks of leakage relating to the use of open compressors. In a particular embodiment, the compressor 17 is driven by an electric motor supplied electrically by a combustion engine 2, the necessary electricity being generated by the alternator 18 driven by said combustion engine 2.

[0243] For the reasons mentioned above, the compressor of the heat pump is preferably a hermetic compressor. Hermetic compressor means a compressor composed of a closed casing, in general a welded steel envelope, inside which there are a compression unit for compressing the refrigerating fluid and a motor that drives the compression unit, it is however also possible to use semi-hermetic compressors in which it is possible to have access to certain internal components during maintenance or any repairs.

[0244] The compressor 17 typically, but not exclusively, has a consumed electric power of 10 to 30 kW depending on the models and the operating conditions of the compressor (rotation speed, suction pressure and discharge pressure). The refrigerating capacity will vary from 5 to 80 kW according to the operating conditions. However, in order to increase the available refrigeration capacity, it is preferred to use two compressors 17 connected in parallel and, in this case, the set of two compressors will have a doubled refrigeration capacity and consumed electric power.

[0245] The refrigeration unit of the system according to the invention can be provided with a third heat exchanger 15. This exchanger is preferably a plate exchanger.

[0246] In the present invention, the refrigerating fluid is preferably chosen from hydrofluorocarbons HFCs (for example R134A, R407C, R404A and R4110A) which are the most usual. It can also be envisaged using hydrocarbons, more particularly propane, as the refrigerating fluid. It is also possible to use CO<sub>2</sub>.

[0247] A preferred refrigerating fluid for the system of the present invention is R134A or 410A for the heat pump. A preferred refrigerating fluid for the system of the present invention is typically but not exclusively R404A for the refrigeration unit. However, the functioning of the present invention is not limited to the choice of one of the existing fluids on the market, and other fluids can be envisaged.

[0248] The heat pump 3 of the system 1 according to the invention allows the use of all types of thermal load known to persons skilled in the art for heating and air conditioning, such as refreshing heating floors or fan convectors. The loads may also be air processing units for the dehumidification of swimming pools and the treatment of fresh air in premises, or water circuits industrial processes requiring the use of hot water and/or cold water.

[0249] In a variant of the invention, the heat pump 3 of the system 1 according to the invention may be a heat pump of the air/water type, that is to say a heat pump using external air and/or extracted air as the heat source in heating mode or a heat pump of the water/water type, that is to say a heat pump using a water circuit in the external ground as the heat source in heating mode. An advantageous thermal source for the heat pump 3 is a geothermal loop.

[0250] The refrigeration unit 36A of the system 1 according to the invention comprises an air/air refrigeration circuit, that is to say the air is cooled to a so-called mean refrigeration temperature T4 typically enabling fresh foodstuffs to be preserved (cheese, milk, etc) or is cooled to a lower temperature T5 referred to as a low refrigeration temperature typically enabling frozen food to be preserved. The heat captured is typically discharged into the external air by means of the compressor 17 and the refrigerating fluid/air exchanger 12.

[0251] The heat exchangers on the source and on the load are suited to the type of refrigeration unit and the type of application according to the criteria generally known to persons skilled in the art.

[0252] Optionally, the system 36A can be provided with a heat exchanger 15 for delivering hot water at temperature T1.

[0253] In a particular embodiment, as seen more clearly in FIG. 7, the system 1 also comprises a heat pump of modular construction using the absorption cycle 27, and at least one electric accumulator 19. The module Pa 37 of said heat pump comprises an absorber 28, a generator 29, a circulation pump 30, an evaporator 31 situated at the inlet of the absorber, a suitable pressure reducing valve 32 and a condenser 33 placed at the output of the generator, a refrigerating fluid 34 and an absorbent 35. This system forms a second subject matter of the invention. The heat pump using the absorption cycle 27 is based on a reduction in the solubility of a gas in the refrigerating fluid when the temperature increases. Advantageously, the absorbent/refrigerating fluid flow pairs are respectively the ammonia/water pair and the water/lithium bromide pair. The refrigerating fluid is absorbed in a deg C solution of the absorber 28, and the solution enriched with refrigerating fluid is transferred to the generator 29 by means of the circulation pump 30. The solution is heated therein, which causes the separation of the refrigerating fluid and an increase in the pressure and temperature. The refrigerating fluid flows towards the condenser 33, where it condenses, discharging heat. It then passes through a pressure reducing system 32 and reaches the evaporator 31, where it evaporates, absorbing heat. It then rejoins the absorber 28, and the cycle recommences.

[0254] The heat pumps using the absorption cycle are known per se. They are less used since they are more expensive than heat pumps using the mechanical steam compression refrigeration cycle. However, heat pumps using the absorption cycle require only a little electrical power, mainly for the auxiliary components and regulation. The major part of the energy necessary for the absorption cycle is thermal and comes typically from the combustion of fossil energy in

a burner. In the system according to the invention, the heat pump using the absorption cycle 27 can be supplied with thermal energy by any suitable source, in particular by the heat generated by one of the combustion engines 2, by the fuel cell 22 or by a thermal solar collector.

[0255] In an advantageous embodiment of the invention, the system 1 comprises a generating module connected to a heat pump module; said system simultaneously allows:

[0256] cooling of water by the heat pump 3 to a temperature T3,

[0257] the heating of water by the heat pump 3 to a temperature T1,

[0258] the production of very hot water at a temperature T2 by recovering thermal energy given off by the current generator (which may be a combustion engine 2 connected to alternator 18) during operation,

[0259] the production of electricity.

[0260] The system 1 according to this embodiment of the invention also allows the production of only one or of two or three elements chosen from cold water, hot water, very hot water and electricity.

[0261] The cold water has a temperature T3 typically between  $-8^{\circ}$  C. and  $+15^{\circ}$  C. (the case of water with glycol added) or between  $4^{\circ}$  C. and  $15^{\circ}$  C. (the case of water). This temperature is preferably between  $5^{\circ}$  C. and  $9^{\circ}$  C.

[0262] The so-called hot water produced by the heat pump 3 has a temperature T1 typically between  $20^{\circ}$  C. and  $60^{\circ}$  C., and preferably between  $30^{\circ}$  C. and  $60^{\circ}$  C.

[0263] The so-called very hot water (typically domestic hot water) reaches a temperature  $T2 > T1$  typically between  $40^{\circ}$  C. and  $75^{\circ}$  C., and preferably  $55^{\circ}$  C. and  $75^{\circ}$  C.

[0264] In another embodiment of the invention, the system 1 comprises a generating module connected to a refrigeration module; said system allows simultaneously:

[0265] the supply of refrigerating fluid at the thermodynamic conditions (evaporation temperature T4 or T5) enabling, after connection to a refrigerating fluid/air exchanger 66, very cold air to be supplied for refrigeration applications;

[0266] optionally the heating of water to temperature T1;

[0267] the production of very hot water at a temperature T2 by recovering thermal energy given off by the current generator (which may be a combustion engine 2 connected to an alternator 18) during operation,

[0268] the production of electricity.

[0269] A system 1 comprising one or more heat pump and refrigeration modules according to the invention, therefore makes it possible to provide:

[0270] the production of elements from among cold water, hot water, very hot water or refrigerating fluid at the thermodynamic conditions of medium-temperature refrigeration, refrigerating fluid at the thermodynamic conditions of low-temperature refrigeration and electricity;

[0271] the cold water has a temperature T3 typically between  $-8^{\circ}$  C. and  $+15^{\circ}$  C. (the case of water with glycol added) or between  $4^{\circ}$  C. and  $15^{\circ}$  C. (the case of water). This temperature is preferably between  $5^{\circ}$  C. and  $9^{\circ}$  C.;

[0272] the so-called hot water produced by the heat pump 3 has a temperature T1 typically between  $20^{\circ}$  C. and  $60^{\circ}$  C., and preferably between  $30^{\circ}$  C. and  $60^{\circ}$  C.;

[0273] the so-called very hot water (typically domestic hot water) reaches a temperature  $T2 > T1$  typically between  $40^{\circ}$  C. and  $75^{\circ}$  C., and preferably  $55^{\circ}$  C. and  $75^{\circ}$  C.;

[0274] the refrigerating fluid to the thermodynamic conditions of medium-average temperature refrigeration has an evaporation temperature T4 typically between  $-15^{\circ}$  C. and  $5^{\circ}$  C. and preferably between  $-10^{\circ}$  C. and  $-5^{\circ}$  C.;

[0275] the refrigerating fluid to the thermodynamic conditions of low-temperature refrigeration has an evaporation temperature T5 typically between  $-40^{\circ}$  C. and  $-25^{\circ}$  C. and preferably between  $-35^{\circ}$  C. and  $-30^{\circ}$  C.

[0276] When the current generator is a combustion engine, possibly associated with an alternator, the heat is recovered both on the cooling circuit of the combustion engine 2 and on the exhaust gases of the engine.

[0277] When the electric current generator is a fuel cell 22, optionally associated with a DC to AC converter, the heat is recovered on the cooling circuit of the fuel cell 22 to which a heat exchange circuit placed on the current converter is optionally added.

[0278] When the electric current generator is a photovoltaic solar panel 23, possibly associated with a DC to AC converter, the heat is advantageously recovered by a heat exchange circuit placed under the photovoltaic cells, and/or by a heat exchange circuit placed on the current converter. This has a more favorable energy efficiency than the use of an electric element for heating the water.

[0279] The so-called cold water is obtained at a temperature  $T3 < T1$  typically between  $-8^{\circ}$  C. and  $+15^{\circ}$  C. (the case of water with glycol added) or between  $4^{\circ}$  C. and  $15^{\circ}$  C. (the case of water). This temperature is preferably between  $5^{\circ}$  C. and  $9^{\circ}$  C.

[0280] In an advantageous embodiment, T1 is between  $20^{\circ}$  C. and  $60^{\circ}$  C.,  $T2 > T1$  is between  $40^{\circ}$  C. and  $75^{\circ}$  C., and  $T3 < T1$  is between  $-5^{\circ}$  C. and  $+15^{\circ}$  C.

[0281]  $T4 < T3$  is between  $-15^{\circ}$  C. and  $5^{\circ}$  C.

[0282] T5 is between  $-45^{\circ}$  C. and  $-25^{\circ}$  C.

[0283] The system 1 according to the invention is also provided with a regulation system, preferably electronic (not shown, preferably situated in a so-called power and regulation cubicle which for its part is preferably situated in the generating module G 38). This regulation system can function with several set points, thus making it possible to trigger the functioning of the system according to the invention according to the requirements for cold water at temperature T3, and/or hot water at temperature T1 and/or very hot water at temperature T2, or refrigerating fluid at temperatures T4 or T5, and to make the choice to optionally return some of the electrical energy generated by the system to the external electrical network. It will be described in greater detail below.

[0284] With reference to FIG. 1, the engine 2 is supplied with fuel by means of an inlet 4.

[0285] Typically, approximately 32% to 37% of the energy supplied to the combustion engine in the form of fuel is recovered in the form of mechanical energy 5 in order to drive the alternator 18 and produce electricity 20. This makes it possible to supply the compressor 17 of the heat pump 3 with the electricity 20 thus produced. Any surplus of electricity produced by the alternator 18 in the case of a partial load or a sizing for this purpose can be used for recharging the electric accumulator 19 or be re-injected onto the network.

[0286] In addition, the electricity produced by the alternating current generator is used for operating the electrical and/or electronic elements of the system according to the invention, such as solenoid valves, one or more powered fans 21 associated with the heat exchanger 12, and the electronic regulation system. Moreover, some of the electricity pro-

duced by the AC generator can be used for supplying electrical apparatus or devices situated outside the system according to the invention, such as lighting for example.

[0287] Typically when the AC generator is a combustion engine 2, approximately 40% to 60% of the energy supplied to said engine 2 is recovered in the form of heat energy 6 for heating domestic hot water. The rest of the energy (typically between 3% and 25%) being dissipated in the form of losses 7.

[0288] Still with reference to FIG. 1, and considering the air condition mode, the heat pump 3 the compressor 17 of which is supplied with electricity 20 produced by the alternating current generator supplies cold water 13, with an "air conditioning" COP of between 2.9 and 3.5. The system also simultaneously supplies hot water 14, with a heating COP of between 3 and 5.

[0289] In addition, when the AC generator is a combustion engine 2, at least one heat exchanger 8 placed on the combustion engine 2 recovers the heat 6 emitted by the engine 2.

[0290] Preferably at least one heat exchanger (not shown) is placed on the exhaust gas circuit of the engine, and at least one second heat exchanger is placed on the liquid-cooling circuit of the engine 2.

[0291] According to the invention, the system 1 is modular in design and comprises at least one electric current generating module G 38 and one or more (N) production modules P each comprising one or two heat pump units 36D or refrigeration units 36E. The electric current generating module may comprise at least one combustion engine 2.

[0292] According to this modular embodiment, each of the N heat pump Pc modules and/or refrigeration modules Pr (i.e. of the steam compression type) of the system 1 according to the invention comprises

[0293] a sealed closed circuit in which the transfer fluid circulates, such as a refrigerating fluid 16,

[0294] a compressor 17 driven by an electric motor,

[0295] a pressure reducing valve 10,

[0296] in the case of heat pump units Pc, a first heat exchanger 11, preferably of the plate type, situated at the suction of the compressor 17 when the system is functioning in air conditioning mode,

[0297] a second heat exchanger 12, situated at the discharge of the compressor 17 when the system is functioning in air conditioning mode,

[0298] optionally a third heat exchanger 15, preferably a plate exchanger,

[0299] in the case of refrigeration units Pr, a heat exchanger 66 that can be situated in a specific isothermal module forming part of the modular-design system or may be situated at a distance from the modular-design system, in the enclosure of a building.

[0300] These components are arranged inside a frame.

[0301] The heat pump modules Pc are preferably identical, in particular with regard to the essential components and sizing thereof. This makes it possible to manufacture them in mass production. This also facilitates maintenance and repair thereof, since it is simply possible to exchange a defective module with a module in operating condition and repair the defective module without its being connected to the system 1.

[0302] In general terms, in the context of the present invention, the heat pump module Pc comprises two compression heat pump units 36D, or the mixed module Pm comprises a heat pump unit 36D and a refrigeration unit 36D or the refrigeration module 36A comprises two refrigeration units 36E.

These modules are produced in the form of a frame, said frame having manifold pipes, optionally a fuel feed pipe, and electric power and regulation cables passing through them. Said frame is also provided with means of connecting the various pipes and cables to the system. By way of example, the dimensions of such a so-called production module frame are: length 1700 mm, width 2200 mm, height 2420 mm.

[0303] The frame typically encloses

[0304] at least one compressor, advantageously of the variable power type,

[0305] at least one reversible battery in V formation,

[0306] at least one fan,

[0307] at least one plate exchanger,

[0308] auxiliary components of a heat pump or refrigeration unit of a known type, such as a four-way valve, two-way refrigeration valves, and one or more refrigeration pressure reducing valves,

[0309] a liquid reservoir intended to contain refrigerating liquid.

[0310] In general terms, in the context of the present invention, the absorption heat pump module Pa can be produced in the form of a frame, said frame having manifold pipes, a fuel inlet pipe and electrical power and regulation cables passing through it. Said frame is also provided with means of connecting the various pipes and cables to the system. Said frame typically contains at least the following elements:

[0311] a refrigerating fluid/water exchanger,

[0312] a generator,

[0313] an absorber,

[0314] a refrigerating fluid/water plate exchanger,

[0315] and other auxiliary components of an absorption heat pump, such as: a pump, pressure reducing valves.

[0316] In general terms, in the context of the present invention, the current module G can be produced in the form of a frame, said frame having a fuel inlet pipe and power and regulation cables passing through it. Said frame is also provided with means of connecting the various pipes and cables to the system. Said frame typically contains at least one current generator of the thermal engine type connected to the alternator thereof or a fuel cell, an exchanger for exchanging heat between the current generator or generators and the very hot water, and a global power and regulation cubicle for the system; optionally, other current generating sources, such as a fuel cell and optionally the alternator thereof, or other external thermal sources (such as connection to thermal solar collectors) can be arranged in the same frame of the current generating module. By way of example, but without this being essential, the dimensions of such a generating module frame are: length 2300 mm, width 2300 mm, height 2420 mm.

[0317] In general terms, in the context of the present invention, the combustion engine 2 is preferably an engine adapted for natural gas. It may for example be an engine with a cubic capacity of 2 liters to 4.6 liters of a normal type as used in certain motor vehicles with petrol or diesel industrial vehicles, but specifically adapted for use with natural gas. In a preferred variant embodiment of the current generating module, a combination of two engines 2 is used, with identical or different cubic capacities, according to the requirement of the user.

[0318] It is advantageous to provide in the system 1 at least one connection for an external heat transfer fluid that provides thermal energy, coming for example from a thermal solar collector or a geothermal loop; this connection is advanta-

geously made at generation level since this simplifies both the design and regulation of the system 1.

[0319] In general terms, in the context of the present invention, a single electric current generator is advantageously used, but this depends on the energy sizing of the system. It is possible to use two electric current generators, preferably arranged in the same generating module G; one of these two generators is advantageously a combustion engine 2. It is possible to use two combustion engines 2, either in the same current generating module or in two separate modules. It is preferred to integrate them in the same module since this makes it possible to share certain components such as the lubrication and/or cooling circuits.

[0320] The use of two combustion engines 2 optimizes use thereof according to the requirements for hot water, very hot water, cold water and generated electric current. By way of example, if the two engines are petrol or natural gas engines, and the energy requirement that they must supply is fairly low, it may be preferable, for the purpose of preserving the service life of the engines or optimizing the COP thereof, to use only one of the two engines, whereas in the case where the two combustion engines 2 are diesel engines, it may be preferable to use both under partial load rather than one at full load. The existence of two engines therefore increases the flexibility of use of the system 1 and moreover provides redundancy in the event of engine breakdown. It is obviously possible also to use more than two engines.

[0321] In an advantageous embodiment, use is made of engines of a normal type developed for mass production cars, since this provides a highly advantageous purchase price and reliable maintenance.

[0322] In a particular embodiment, which may be combined with all the other embodiments, the alternators are put in contact with a heat exchanger in order to recover at least some of the thermal energy in which part of the electrical energy is transformed, knowing that the energy efficiency of an alternator is always less than 100%. This heat exchanger then heats a heat transfer liquid that is entered into a heat pump circuit.

[0323] It is also possible to combine in a module firstly a generator composed of a combustion engine and an alternator with another generator of the fuel cell type. It is thus possible to take advantage of the particularities of each of the generators: lower price for combustion engines, silence in operation and higher energy efficiency for fuel cells.

[0324] Finally, when the price of fuel cells has decreased or for particular applications (industrial sites having available unprocessed hydrogen), two generators of the fuel cell type will be installed.

[0325] FIG. 5 illustrates a particular embodiment comprising two cogeneration units, which may be integrated in the same generating module G, connected to a plurality of heat pump modules of the steam compression Pc type. The various heat pump modules are connected together by customer inlet manifolds Ce1, Ce3 and by customer outlet manifolds Cs1, Cs3. Customer inlet pipes Ce2 and customer outlet pipes Cs2 are provided at the very hot water circuit 9. FIGS. 8a to 8c illustrate better an example embodiment of a system comprising several compression heat modules 36, in this case three modules, connected to two absorption heat pump modules 37, which are for their part connected to a current generating modules 38. These modules 36, 37, 38 are illustrated individually in FIGS. 9a to 9f, 10a, b, c and 11a, b, c. In the side view in FIG. 8a a frame 44 of the heat pump module 36 or 37

can be seen, which has four manifolds 39a, 39b, 39c, 39d passing through it, the diameter of the manifolds being able to be adapted to the water flows necessary for the application, by power cables 41 and regulation cables 42. The frame 44 forms a housing open on the sides so that it can have the fluid manifolds and electric cables passing through it, or even possibly have gas pipes 40 passing through it if required (for example in order to connect a distant absorption heat pump module 37 to the generating module 39 passing through a compression heat pump module 36). The collector 39a is a collector for the entry and the collector 39b a collector for the exit of fluid. The other two collectors 39c for entry and 39d for exit are intended for the recovery of heat in air conditioning mode; they are then connected to the third optional heat exchanger 15 present in this variant in the compression heat pump module 36, and functioning on the same principle as the exchanger 15 of the module Pc. In a variant, a third recovery heat exchanger (not shown) may also be present in the absorption heat pump module 37.

[0326] As mentioned above, the generating module 38 is also produced in the form of a frame 64, forming a housing open on the side so that it can have the fluid manifolds and electric cables passing through it.

[0327] As can be seen more clearly in FIGS. 9a to 9f and in FIGS. 8b and 8c, a compression heat pump module 36 comprises, inside the frame 44 thereof, two heat pump units each comprising a fan 21, a refrigerating fluid/air exchanger 12, a four-way valve 46, a refrigeration compressor 17, a liquid anti-knock bottle 48, a refrigerating fluid/water plate exchanger 11, a liquid reservoir 50 and optionally a refrigerating fluid/recovery water plate exchanger 15, the context of this option, the four-way valve is replaced by four two-way refrigeration valves 65A, 65B, 65C, 65D (FIG. 9e), the functioning of which will be described below. An absorption heat pump module 37 comprises, inside a frame 44, and as can be seen more clearly in FIGS. 8a to 8c and 6b and 6c, a fan 21, a refrigerating fluid/air exchanger 54, an absorber 51, a generator 52 and a refrigerating fluid/water plate exchanger 53. These modules 36, 37 function on the same principle as the modules Pc and Pa, as described previously.

[0328] The operating principle of a steam compression heat pump unit that composes a heat pump module Pc 36 will now be described in more detail with reference to FIGS. 17 and 18.

[0329] FIG. 17 shows schematically a heat pump unit according to a first embodiment of the invention, in particular a reversible heat pump with a four-way valve 46. The functioning thereof in heating and cooling modes will be described hereinafter.

[0330] When the heat pump unit of FIG. 17 is functioning in heating mode, the regulation of the machine will satisfy the heating capacity requirement by regulating the power of the refrigeration compressor so as to comply with the hot water temperature T1. Thus all the available heat is discharged to the water of the heating system through the exchanger 11. The four-way valve 46 connects the discharge pipe of the compressor to the exchanger 11. The pressure reducing valve 10 regulates the flow of refrigerating fluid in order to maintain superheating of this fluid when it leaves the exchanger 12. The four-way valve 46 connects the exchanger 12 to the suction pipe of the compressor 17. The regulation loop concerns the temperature T1 of hot water leaving the exchanger 11.

[0331] When the heat pump unit of FIG. 17 is functioning in cooling mode, regulation of the machine will satisfy the

refrigerating capacity requirement by regulating the power of the refrigeration compressor in order to comply with the cold water temperature T3. All the heat available is then discharged to the external air through the exchanger 12. The pressure reducing valve 10 regulates the flow of fluid when it leaves the exchanger 11. The four-way valve 46 connects the discharge pipe of the compressor 17 to the exchanger 12. The pressure reducing valve 10 regulates the flow of refrigerating fluid to maintain superheating of this fluid when it leaves the exchanger 11. The four-way valve 46 connects the exchanger 11 to the suction pipe of the compressor 17. The regulation loop concerns the temperature T3 of cold water leaving the exchanger 11.

[0332] FIG. 18 shows schematically a heat pump unit according a second embodiment of the invention, in particular a reversible heat pump with a recovery exchanger 15 and four two-way refrigeration valves (or solenoid valves) 65A, 65B, 65C, 65D. The functioning thereof according to the six possible operating modes thereof will be described below.

[0333] When the heat pump unit of FIG. 18 is functioning in cooling mode, the machine will satisfy the refrigerating capacity requirement by regulating the power of the refrigeration compressor 17 in order to comply with the cold-water temperature T3. All the available heat is then discharged to the external air through the exchanger 12. The solenoid valve 65B is open, all the other solenoids valves being closed. The pressure reducing valve 10A regulates the flow of refrigerating fluid in order to maintain superheating of this fluid when it leaves the exchanger 11. The pressure reducing valves 10B and 10C are closed. The regulation loop concerns the temperature T3 of cold water leaving the exchanger 11.

[0334] When the heat pump unit of FIG. 18 is functioning in cooling and heat recovery mode, regulation of the machine will satisfy the refrigerating capacity requirement by regulating the power of the refrigeration compressor in order to comply with the cold-water temperature T3. The available heat is sent to the water recovery circuit by means of the exchanger 15. The solenoid valve 65C is open, all the other solenoid valves being closed. The pressure reducing valve 10B regulates the flow of refrigerating fluid in order to maintain superheating of this fluid when it leaves the exchanger 11. The pressure reducing valves 10A and 10C are closed. The regulation loop concerns the temperature T3 of cold water leaving the exchanger 11.

[0335] When the heat pump unit of FIG. 18 is functioning in cooling mode, with recovery of heat and discharge of heat unused, the regulation of the machine will satisfy the refrigerating capacity required by regulating the power of the refrigeration compressor in order to comply with the cold-water temperature T3. The available heat is sent to the water recovery circuit by means of the exchanger 15. If the quantity of heat available is greater than requirements, then the excess is sent to the exchanger 12. The solenoid valves 65B and 65C are open, all the other solenoid valves being closed. The pressure reducing valves 10A and 10B regulate together the flow of refrigerating fluid in order to maintain superheating of this fluid when it leaves the exchanger 11. The pressure reducing valve 10C is closed. Two parallel regulation loops are in operation: a first concerning the temperature T3 of cold water leaving the exchanger 11 and a second that controls the temperature T1 of hot water leaving the exchanger 15.

[0336] When the heat pump unit of FIG. 18 is functioning in heating mode, regulation of the machine will satisfy the heating capacity requirement by regulating the power of the

refrigeration compressor in order to comply with the hot-water temperature T1. The available heat extracted from the air by means of the exchanger 12 is sent to the water recovery circuit by means of the exchanger 15. The solenoid valves 65A and 65C are open, all the other solenoid valves being closed. The pressure reducing valve 10C regulates together the flow of refrigerating fluid in order to maintain superheating of this fluid when it leaves the exchanger 12. The pressure reducing valves 10A and 10B are closed. The regulation loop concerns the temperature T1 of the hot water leaving the exchanger 15.

[0337] When the heat pump assembly of FIG. 18 is functioning in heating and heat recovery mode, regulation of the machine will satisfy the refrigerating capacity requirement in order to comply with the cold-water temperature T3 (exchanger 11). In addition, the regulation of the machine will satisfy the heating capacity requirement by regulating the power of the refrigeration compressor in order to comply with the hot-water temperature T1 (exchanger 15). The complementary capacity is extracted from the air by means of the exchanger 12. The solenoid valves 65A and 65C are open, all the other solenoid valves being closed. The pressure reducing valve 10C regulates the refrigerating fluid flow in order to maintain superheating of this fluid when it leaves the exchanger 12. The pressure reducing valve 10B regulates the refrigerating fluid flow in order to maintain superheating of this fluid when it leaves the exchanger 11. The pressure reducing valve 10A is closed. Two parallel regulation loops are in operation again: a first concerning the hot-water temperature T1 leaving the exchanger 15 and a second concerning the cold water temperature T3 leaving the exchanger 11.

[0338] When the heat pump unit of FIG. 18 is functioning in defrosting mode, the machine will extract heat at the recovery circuit by means of the heat exchanger 15. This heat will be sent to the exchanger 12 in order to defrost it. The solenoid valves 65B and 65D are open, the other solenoid valves being closed. The pressure reducing valve 10C controls the superheating of the refrigerating fluid leaving the exchanger 15, the other pressure reducing valves being closed. Regulation of the machine launches the defrosting and stops it on the basis of the information given by the pressure and temperature sensors of the circuit.

[0339] As illustrated in FIGS. 11a, 11b and 8b and 8c, the current generating module 38 has a frame 64, provided with a fuel inlet 55 communicating with the pipe 40 of the module 37. The frame 64 comprises at least one current generator, which may be a combustion engine and the current generator 56 thereof, or a fuel cell with the inverter 57 thereof. A connection of the external thermal sources 58 may be provided for thermal solar collectors or other hot-water sources. An exchanger 59 is provided for effecting the exchange of heat between the current generator and the very hot water. The frame 64 also contains a global power and regulation cubicle for the system 60, said cubicle being provided with connections to power cabling 61 for feeding energy coming from a photovoltaic panel, cabling 62 for feed from the external electrical network and power cabling 63 for sending electrical energy to the external electrical network. In a variant, cabling 63' can connect the cubicle 60 to the feed of an auxiliary energy source such as coming from a wind turbine, a turbine or the like.

[0340] FIG. 6 illustrates another particular embodiment comprising two generating modules G, 38 connected to a heat pump of the steam compression type Pc, 36 and to a plurality

of refrigeration modules Pr, 36A. The various refrigeration modules Pr are connected together and connected to the heat pump module Pc by customer inlet manifolds Ce3 and by customer outlet manifolds Cs3. The water flows in the modular exchangers are balanced in this case by means of balancing valves of the system.

[0341] FIGS. 12a to 12f illustrate better an example embodiment of a refrigeration module 36A comprising two refrigeration units 36E on a common frame. More particularly the detail view 12f illustrates to an enlarged scale the inlet and outlet connection pipes to the cold water circuit 13, the inlet and outlet connection pipes to the hot water circuit 14, and the four refrigerating fluid pipes, including two for suction 16A and two for liquid 16B, for connecting the two refrigeration units 36E to a refrigerating fluid/air exchanger 66 situated at a distance, being external to the module 36A. FIGS. 12a and 12b are front and rear views of the refrigeration module 36E, FIG. 12b illustrates a side view of a refrigeration module 36A comprising two refrigeration units 36E, FIG. 12d is a perspective view of the refrigeration module 36A and FIG. 12e is a view in section of the module 36A produced with the plane D-D of FIG. 12b. As can be seen in these figures, the refrigeration module 36A comprising two refrigeration units 36E has total symmetry vertically, which makes it possible to arrange all the components of the two refrigeration units advantageously on a common frame of the module.

[0342] FIGS. 13a to 13f illustrate better an example embodiment of a mixed module 36B comprising a refrigeration unit 36E and a heat pump unit 36D on a common frame. More particularly the detail view 13f illustrates to an enlarged scale the inlet and outlet connection pipes to the cold water circuit 13, the inlet and outlet connection pipes to the hot water circuit 14, and the two refrigerating fluid pipes, including one suction 16A and one liquid 16B, for connecting the refrigeration units 36E to a refrigerating fluid/air exchanger 66 situated at a distance, being external to the module 36A. FIGS. 13a and 13b are front and rear views of the mixed module 36B, FIG. 13b illustrates a side view of a mixed module 36B, FIG. 13d is a perspective view of the mixed module 36B and FIG. 13e is a view in section produced with the plane E-E of FIG. 13b.

[0343] FIGS. 14a to 14c illustrate better an example embodiment of a system of the invention comprising a generating module 38 connected to a mixed module 36B comprising a refrigeration unit 36E and a heat pump unit 36D on a common frame. FIG. 14a is a side view of the unit, FIG. 14b is a front view of the unit and FIG. 14c is a perspective view of the generating module unit 38 and mixed module 36B.

[0344] FIG. 15 is a front view illustrating an example embodiment of a system of the invention comprising a generating module 38 connected to a compression heat pump module 36 and to a refrigeration module 36A.

[0345] FIG. 16 illustrates an example embodiment of a system of the invention comprising a generating module 38 connected to a compression heat pump module 36, to a refrigeration module 36A, connected to a first isothermal module 36C comprising an evaporator 66 and to a second isothermal module comprising an evaporator 66.

[0346] The main advantages of the system according to the invention compared with the systems of the prior art are:

[0347] a multi-energy supply or one with several energy sources, typically electricity/natural gas or fuel oil,

[0348] functioning as far as a temperature of  $-20^{\circ}$  C. with good efficiency,

[0349] a COP on total primary energy superior to 1.5, even when the external temperature is low,

[0350] integration of the functions within the same modular unit for simultaneous fluid supply applications (water or refrigerating fluid) at temperatures ranging from  $-45^{\circ}$  C. to  $+75^{\circ}$  C.

[0351] As can be seen in FIG. 3, the system according to the invention has an efficiency superior to that of the systems of the prior art, even recent, such as condensation gas boilers.

[0352] This good efficiency is obtained by the recovery of heat within the system:

[0353] Firstly, the recovery in the heat pump units by means of the third heat exchanger 15, placed in the refrigerating fluid circuit.

[0354] Secondly the recovery of heat in the current generators of the combustion engine or fuel cell type.

[0355] This good efficiency is also obtained by means of the selection of high-performance components: for example generously sized exchangers, combustion engines with a compression ratio optimized for the fuel used, modern variable-speed fans provided with electronic switching motors.

[0356] A total power of 60 to 900 kW is typically obtained by means of the modular structure of the system according to the invention, complying with the geometric dimensions of a lorry of standard size in Europe (maximum length of the load: 13 meters).

[0357] It is moreover entirely possible to achieve all the features described in the invention, for powers covering the range from 20 to 150 kW, with dimensions allowing passage through a door, i.e. 890 mm wide and 1800 mm high. The features described comprise a possibility of obtaining simultaneously water at three different temperatures T1, T2 and T3 as well as refrigerating fluid at temperatures T4 and T5.

[0358] In a particular embodiment, the steam compression heat pump module comprises two heat pump units each comprising a compressor (typically spiral compressors, also referred to as scroll compressors), a fan, a V-formation reversible air/refrigerating fluid exchanger (referred to as a "battery") and two water/circuit refrigerating fluid exchangers (including an optional one for the heat recovery circuit). The embodiment will be illustrated below by examples.

[0359] In air/water mode, the heat pump module can function in heating mode alone or air conditioning alone with possible recovery on an independent circuit. Thus, in winter, the battery on the air is in evaporator mode, while the plate exchanger functions in condenser mode. For the production of hot water at temperature T1, additional heat may if necessary come from the heat recovered on the cooling circuit of the combustion engine and on the exhaust fumes thereof.

[0360] It is also possible to recover the heat from the engine at very hot temperature T2. In summer, the battery on the external air functions in condenser mode, whereas the plate exchanger functions in evaporator mode. This allows the production of cold water, and offers the possibility of also providing hot water at temperature T2 on an independent circuit by virtue of the recovery on the cooling circuit of the combustion engine and on the exhaust gases thereof.

[0361] In heating mode alone, the heat pump heats the water partly, and the recovery of heat on the cooling of the combustion engine and the exhaust gases thereof provides if necessary the additional heat, in order to supply for example water at a typical temperature of  $45^{\circ}$  C.

[0362] In air conditioning mode, the heat pump module cools the cold water, for example to a temperature of 7° C., whereas independently it is possible to generate hot or very hot water by recovering the heat generated by the electrical energy generating module (combustion engine), according to the requirements of the consumer.

[0363] In water/water mode, the system can produce simultaneously hot water for heating and cold water for air conditioning, both in summer and in winter. Then the batteries on the external air are no longer used, but only the reversible plate exchangers: one functions in condenser mode to produce hot water, the other functions in evaporator mode to produce cold water. The recovery of heat on the electrical energy generating module is used for additional heat on the production of hot or even very hot water (domestic water).

[0364] In an advantageous embodiment, which can be implemented with all the other embodiments and variants thereof, the system 1 is controlled by at least one computer machine comprising at least one microprocessor and at least one data entry interface. Data are entered in the microprocessor of said computer machine by means of said data entry interface.

[0365] The invention also concerns a method of regulating a system 1 according to the invention. This regulation mode is described here.

[0366] In a first step (a), at least one so-called “basic data item” is entered in said microprocessor. These basic data are typically entered in the processor either at the initial programming thereof in the factory, or when the system 1 is commissioned on the site of the user (parameterizing of the regulation for the given installation) or again by the user over the course of time during the use of the system 1 (level-one parameterizing to take account of basic changes, for example the cost of the energy).

[0367] These basic data concern the technical features of the modules and the components and consumables thereof. They are selected from the group formed by:

[0368] (da1) the unit cost of the fuel of each combustion engine 2, fuel cell 22 and absorption heat pump used in the system 1;

[0369] (da2) the energy content of each fuel;

[0370] (da3) the CO<sub>2</sub> impact of each fuel per unit of mass;

[0371] (da4) the energy efficiency of each combustion engine 2 according to the load and rotation speed thereof, which makes it possible to determine the quantity of CO<sub>2</sub> discharged per unit of mechanical power produced by this combustion engine 2;

[0372] (da5) the nominal power at full load of each combustion engine 2 according to the rotation speed thereof;

[0373] (da6) the thermal output percentage recovered on the cooling circuit of the engine and the thermal output percentage recovered on the exhaust gases, which makes it possible to determine the quantity of CO<sub>2</sub> discharged per unit of thermal output produced by the combustion engine 2,

[0374] (da7) the unit cost of the electrical energy supplied by the external network (instantaneous cost, change thereof as a function of time, and change thereof as a function of the power level demanded);

[0375] (da8) the service life of each generator (mainly of the combustion engine 2 and fuel cell 22) according to the load thereof;

[0376] (da9) the maintenance cost for each generator (mainly the combustion engine 2 and fuel cell 22) according to the number of operating hours;

[0377] (da10) the cost of dismantling and replacing each generator (mainly the combustion engine 2 and fuel cell 22);

[0378] (da11) the service life, maintenance cost and cost of dismantling and replacing each type of heat pump (using the steam compression cycle or using the absorption cycle);

[0379] (da12) the efficiency of the alternator as a function of the electrical power that it supplies, which makes it possible to determine the mechanical power demanded of the combustion engine 2 for an electrical power supplied;

[0380] (da13) the efficiency of the fuel cell 22 as a function of the load thereof when it is not equipped with a reformer (the typical but not exclusive case of a cell of the PEM type—Proton Exchange Membrane supplied by hydrogen), or the efficiency of the fuel cell as a function of the load thereof when it is equipped with a reformer (the typical case of a PEM cell supplied by a fuel other than hydrogen);

[0381] (da14) the efficiency of the inverter of the fuel cell 22 or photovoltaic solar panels 23 when such exist;

[0382] (da15) the electrical consumption and the fluid flow (typically glycol) of the circulation pump of the solar collectors;

[0383] (da16) the unit selling price of the electrical energy supplied to the external network,

[0384] (such as the instantaneous price, the change thereof as a function of time and the change thereof as a function of the power level demanded).

[0385] In an advantageous embodiment, there are entered for each type of heat pump the performance tables giving the refrigerating capacity supplied, the heating capacity supplied, the electrical power consumed, and the quantity of fuel consumed if applicable (the case of the absorption heat pump) within the operating range thereof. These performance tables are defined in fact by the water temperatures of each circuit (T1, T2 and T3, T4 and T5), the fluid flow of the associated exchangers, and the input temperature of the ambient air. The regulation mode may provide that any functioning with one or more of these parameters outside the operating range defined is prohibited.

[0386] In an advantageous embodiment, there are entered, for each compressor used in the steam compression heat pumps, by way of supplementary control, the following basic data:

[0387] the performance tables giving the refrigerating capacity supplied,

[0388] the heating capacity supplied,

[0389] the electrical power consumed as a function of the suction pressure and delivery pressure of the compressor for a given refrigerating fluid.

[0390] These data enable the above performance tables to be crosschecked. They can also be used as basic data for determining, for the complete system, the refrigerating and heating capacities supplied as well as the electrical power consumed by the steam compression heat pumps. These data include, for each compressor, the volumetric flow level (expressed typically as a percentage) at which it functions (typically 10% to 100%).

[0391] In a second step (b), at least one so-called “instantaneous data item” is entered. These instantaneous data are typically entered in the microprocessor during functioning thereof by the measuring equipment that the various components of the system 1 have, or by a device external to the system 1 (for example by an electrical contact of the “peak day cancellation of the electrical system”, by an Ethernet network, etc) communicating some of these data to the plant.

[0392] This at least one instantaneous data item is selected from the group formed by:

[0393] (db1) the instantaneous electrical power produced by each current generator present: alternator 18, fuel cell 22, photovoltaic solar panel 23;

[0394] (db2) the rotation speed of each combustion engine 2;

[0395] (db3) the instantaneous fuel consumption of the plant (explosion engine and absorption heat pump);

[0396] (db4) the temperature of the fluid recovering the thermal energy from the combustion engine 2 (in particular the thermal energy contained in the cooling circuit and in the exhaust gases);

[0397] (db5) the instantaneous electrical power consumed by the system 1 from the network, obtained by direct measurement;

[0398] (db6) the instantaneous power supplied to the network by the system 1, obtained by direct measurement;

[0399] (db7) the current, voltage or instantaneous electrical power produced by the photovoltaic solar panel 23 (if such panel is present);

[0400] (db8) the instantaneous temperature T1;

[0401] (db9) the instantaneous temperature T2;

[0402] (db10) the instantaneous temperature T3;

[0403] (db11) the instantaneous temperature T4;

[0404] (db12) the instantaneous temperature T5;

[0405] (db13) the temperature of the ambient air;

[0406] (db14) the number of operating hours of each electric current generator (mainly combustion engine 2 and fuel cell 22);

[0407] (db15) the number of operating hours of each heat pump circuit in the plant (steam compression or absorption type).

[0408] If one of the instantaneous temperatures T1, T2 or T3 is selected (data db8, db9, db10), it is advantageous to select all three.

[0409] In a third step (c), at least one so-called "target data item" is defined, to which a so-called "target value" is allocated, said target data item being selected from the group formed by:

[0410] (dc1) the temperature T1 and the change thereof as a function of parameters such as the external temperature or the energy cost (the ideal comfort may give way to economically acceptable comfort);

[0411] (dc2) the temperature T2 and the change thereof as a function of parameters such as the external temperature or the energy cost;

[0412] (dc3) the temperature T3 and the change thereof as a function of parameters such as the external temperature or the energy cost;

[0413] (dc4) the temperature T4 and the change thereof as a function of parameters such as the required temperature in the external refrigerated enclosure or the energy cost;

[0414] (dc5) the temperature T5 and the change thereof as a function of parameters such as the required temperature in the external refrigerated enclosure or the energy cost;

[0415] (dc6) the global COP as being the maximum global COP for the system 1, this point being correlated with the minimum global CO<sub>2</sub> impact of the system 1;

[0416] (dc7) the energy cost as being the minimum energy cost of the system 1;

[0417] (dc8) the total operating cost as being the total minimum operating cost of the system 1.

[0418] Whatever the target data item or items chosen, there may in addition be a supplementary target data item such as the minimum electric power to be supplied to the network (in the case of operation as an emergency generator for example).

[0419] Said at least one target data item and the associated target value thereof are entered in the microprocessor.

[0420] In a fourth step (d), the system 1 is regulated by means of said computer machine so as, for each of the selected target data, to achieve the target value or values determined, said regulation being effected by comparing the current value of the selected target data item, which is determined from time to time or regularly or continuously, taking into account the basic data selected as well as the instantaneous data selected, and adjusting at least one so-called "adjustment data item" selected from the group formed by

[0421] (dd1) the type and number of current generators in operation and the electrical power supplied by each of said generators (advantageously by selecting the generators according to the features thereof vis-a-vis the selected target data);

[0422] (dd2) the allocation of the electrical powers supplied by the generator or generators respectively to the plant and to the network external to the system 1;

[0423] (dd3) the type and number of heat pumps and/or refrigeration units in operation;

[0424] (dd4) in the case of steam compression heat pumps and/or refrigeration units, adjustment of the volumetric flow (expressed as a percentage) imposed by the regulation on the compressors in order to optimize the system 1

[0425] so as, for each target data item selected, to bring its current value close to the target value.

[0426] In the case where several target data are selected, the regulation method may comprise a weighting algorithm for determining a target parameter from the target values.

[0427] Three examples for such a regulation method are given here:

[0428] 1) If the target data item is the maximum global COP of the system 1, or the minimum CO<sub>2</sub> impact thereof (data item dc4), it will be sought among other things to follow the following rules:

[0429] it will be sought to operate the current generators in the maximum efficiency region thereof (at full load for example for a combustion engine 2 operating on natural gas);

[0430] it will be sought to recover the maximum calorific thermal discharge of the combustion engine 2. For example, if the requirements of the plant site for very hot water are less than the production of the combustion engine 2, this heat production will be totaled with the hot water supplied by the heat pump modules;

[0431] it will be sought to operate all the heat pump modules under partial load rather than to stop some of them so as to reduce the load on each exchanger and thus provide more effective functioning from an energy point of view.

[0432] 2) if the priority target data item is the energy cost as being the minimum energy cost of the system 1 (data item dc5), the approach is similar to the optimization of the previous example but the parameterisable coefficients for each type of energy become the following:

[0433] Purchase cost of each energy external to the system 1 (typical electrical energy issuing from the network or energy of the fossil fuel or biogas fuel type) at the time of use. (For example, the cost of the electrical energy may vary according to the period of the year but may also as a function of consumption thresholds in the day or in the year: this

threshold or thresholds being related to the electrical subscription of the plant in question. These weightings may of course change in the course of the life of the plant and are therefore parameterisable in the context of the global regulation method for the system).

**[0434]** The price of any resale to the electrical energy network that may if necessary be produced by the generating module or modules of the device (this price may also vary, according to rules in general similar to those that apply to the purchase cost of the electrical energy).

**[0435]** The taking into account of the change in target data such as the temperatures T1, T2, T3 and the possible change therein as a function of the energy costs.

**[0436]** It will be sought to regulate the data listed at (d) (data dd1 to dd4) in order to obtain a minimum cost taking account of the energies sold and purchased.

**[0437]** 3) If the priority data item is the total operating cost (data item dc6) as being the minimum total operating cost of the system 1, the approach is similar to the previous optimization but also takes into account:

**[0438]** the service lives of each generator (data item da8),

**[0439]** the maintenance costs (data item da9),

**[0440]** the cost of dismantling and replacing each generator (data item da10),

**[0441]** the cost of dismantling and replacing each type of heat pump (data item da11).

**[0442]** Particular importance is thus granted to the service life of certain critical components such as the combustion engines or fuel cells.

**[0443]** The system according to the invention can be used advantageously in balneotherapy or thalassotherapy equipment, in shared housing, for heating swimming pools, in hospitals or medical establishments, in hotels or tourist accommodation.

**[0444]** The system may also be used advantageously in agricultural applications where there is a need for heating capacity, and possibly refrigerating capacity, or even both simultaneously. The primary fuel of the system could then be natural gas or biogas but it could also be biogas issuing from any biomass that is available, or even optionally generated on the actual site of the application. A first series of applications preferably concerns agricultural greenhouses using for example natural gas as the primary fuel,

**[0445]** A second series of applications concerns methanization units, the system of the invention then using the biogas produced on site.

**[0446]** The system according to the invention is also used in industrial processes requiring the simultaneous heating and cooling of water, used at different points in the process. This is the case for example with certain food processes.

**[0447]** The system according to the invention is also used in industrial processes requiring the cooling of air to medium and low refrigeration temperatures used at different points in the process. This is the case for example with certain food processes, in particular in applications of the supermarket type.

**[0448]** Another advantage of the system according to the invention is the flexibility of design and flexibility of use thereof. The flexibility of use continuously affords an optimum choice of the type or types of energy used and/or supplied, according to external parameters and target parameters (objectives), by means of a suitable regulation method.

**[0449]** The flexibility of design allows optimization of the device according to the foreseeable requirements of the user,

in particular in terms of thermal capacity, and requirements for different water temperatures. This optimization is made in particular by the choice of the type and number of heat pump modules, and by the choice of the type and number of the electrical generating module.

**[0450]** The flexibility of design takes account among other things of the following parameters:

**[0451]** a) Requirements for heating capacity and refrigerating capacity and simultaneous heating capacity and refrigerating capacity of the site concerned throughout the year. These parameters will have a direct impact on quantity of heat pump modules concerned and on the choice of the cycle employed.

**[0452]** b) Potential requirement for an electrical generator on the plant (as a solution of backup for the network for example). The generating module or modules that can be integrated in the device, combined with the flexibility of use of the device, meet this requirement. The choice of the generating module or modules will depend among other things on: the power necessary for supplying the device; the existence of expensive electrical thresholds on the site (for example purchase of a transformer, consumption thresholds) that it will then be advantageous not to cross, characteristics of the site (existence of renewable energy of the wind or photovoltaic type), the required noise level or the required efficiency (advantage of the fuel cell).

**[0453]** c) Familiarity of the users with one or other of the heat pump device cycles (compression or absorption) and the refrigeration cycle.

**[0454]** d) CO<sub>2</sub> impact: importance of the CO<sub>2</sub> impact of the plant in question (conformity with a label of the HQE (High Environment Quality) type for example) and valorization of the CO<sub>2</sub> impact of the electrical energy of the network.

**[0455]** e) Finally of course, and for all the modules, the optimum configuration will depend on the initial purchase cost and the operating costs (taking account of the energy consumption and maintenance).

**[0456]** It can be noted that the device offers a combination of design solutions for adapting effectively to each case.

**[0457]** The flexibility of use takes account in particular of the multiplicity of energies able to supply the various components of the system 1 according to the invention, as well as the multiplicity of energy flows able to be produced by the system 1. All the above modules are supplied by one or more of the following energies: fossil filets (in particular natural gas, liquefied petroleum gas, diesel oil, petrol), biofuels, hydrogen and electric current. The heat pump modules may have recourse typically to the following two conventional cycles: the mechanical steam compression refrigeration cycle and the absorption cycle. The conventional water systems connected to the heat pumps can be supplemented in the device by a water system issuing from thermal solar collectors. The electricity generating modules can have recourse to various technologies of the thermal engine and alternator type, photovoltaic solar panel 23, wind turbine, turbine or fuel cell.

**[0458]** The flexibility of use is made possible by virtue of the global regulation method for all the modules of the device (heat pump and electrical generators), which takes optimum account among other things of the following target parameters (objectives):

**[0459]** (i) Priority given to the COP of the installation. Parameterisable coefficients will make it possible to express the various energies external to the device (for example the

electricity from the network, the thermal energy from the solar collectors and the photovoltaic electrical energy) in terms of primary energy and CO<sub>2</sub> impact in order to give a global view of the COP of the multi energy device. The global regulation of the device will take account, in the global optimization, of the efficiency of each type of generating module. Thus, and among other operating rules:

**[0460]** It will be sought to operate the current generators in the maximum efficiency zone thereof (at full load for example for a thermal engine functioning with natural gas);

**[0461]** The maximum heat discharge of the thermal engine will be recovered. For example, if the requirements of the plant site for very hot water are less than the production of the thermal engine, this heat production will be totaled with the hot water supplied by the heat pump modules;

**[0462]** It will be sought to operate all the heat pump modules under partial load rather than to stop some in order to reduce the load on each exchanger and thus to afford functioning that is more effective in terms of energy.

**[0463]** (ii) Priority given to the energy operating cost of the plant:

**[0464]** The approach is similar to the previous optimization but the parameterisable coefficients for each type of energy become as follows:

**[0465]** Purchase cost of each energy external to the device (typically electrical energy issuing from the network or energy of the fossil fuel or biogas type) at the moment of use. For example, the electrical energy cost may vary according to the time of year but also according to the consumption thresholds in the day or in the year, this threshold or thresholds being related to the electrical subscription of the plant in question. The weightings may of course change over the life of the plant and are therefore parameterisable in the context of the global regulation method of the device.

**[0466]** Price of any resale to the electrical energy network may if necessary be produced by the generating module or modules of the device. This price may also vary, according to rules in general similar to those that apply to the purchase cost of the electrical energy.

**[0467]** (iii) Priority given to the total operating cost of the plant (in particular the energy cost, the maintenance cost, which includes in particular the dismantling cost and the replacement cost). Particular importance is thus accorded to the service life of certain critical components such as the combustion engines 2 or the fuel cell 22.

**[0468]** The result of the above is that it is by virtue of its modular design, the very wide temperature range available for respective power ranges for each temperature sized on use, finally combined with the global regulation thereof, which knows precisely the functioning and performances of each of these modules, that the device allows optimization of functioning, which is at the same time global, suited to the complexity of the problems encountered and to changes therein.

#### EXAMPLES

**[0469]** The example embodiments that follow illustrate certain embodiments of the invention. They do not limit the invention.

**[0470]** In these examples, use is made of two types of thermal engine for automobiles adapted to function with natural gas: one engine with a cubic capacity of 2.0 liters manufactured by Volkswagen and another with a cubic capacity of 4.6 liters, manufactured by MAN.

**[0471]** Five different electric current generating modules (module G) were manufactured:

**[0472]** (a) 2.0 liter engine alone, (b) 4.6 liter engine alone, (c) two 2.0 liter engines, (d) two 4.6 liter engines, (e) one 2.0 liter engine and one 4.6 liter engine.

**[0473]** A single heat pump module model (module P) was manufactured, which comprised among other things:

**[0474]** two spiral compressors (also referred to as scroll compressors) functioning with R410a fluid, including one with variable power (digital control);

**[0475]** two fans;

**[0476]** two reversible batteries in V formation;

**[0477]** four dual-circuit reversible-plate exchangers (including two for the optional recovery circuit).

**[0478]** These P modules, according to the use thereof, can also comprise a buffer tank, an expansion tank, a circulator, and refrigeration and hydraulic valves. The auxiliary components are supplied by the external electrical network. The compressors are supplied either with the electrical energy generating by the module, or by the external electrical network.

1-16. (canceled)

17. A system configured to simultaneously produce electricity, water at a first temperature, water at a second temperature greater than the first temperature, and water at a third temperature greater than the second temperature, the system comprising:

a current-generating module configured to simultaneously produce the electricity and the water at the third temperature, the current-generating module including an energy producing device operatively connected to a first heat exchanger which is configured to produce the water at the third temperature; and

a unit in communication with the current-generating module and configured to receive a portion of the electricity produced by the current generation module and thereby simultaneously produce the water at the first temperature and water the second temperature.

18. The system of claim 17, wherein:

the first temperature is in a range between one of -8° C. and +15° C. and 4° C. and 15° C.;

the second temperature is in a range between 20° C. and 60° C.; and

the third temperature is in a range between 40° C. and 75° C.

19. The system of claim 17, wherein:

the first temperature is in a range between 5° C. and 9° C.;

the second temperature is in a range between 30° C. and 60° C.; and

the third temperature is in a range between 55° C. and 75° C.

20. The system of claim 17, wherein the energy producing device comprises at least one of a fuel cell and solar panel operatively connected to a DC-to-AC converter.

21. The system of claim 20, wherein the fuel cell comprises:

a reformer which transforms fuel received by the fuel cell to extract hydrogen therefrom; and

a cell core which receives the hydrogen extracted by the reformer and uses the hydrogen to produce electricity.

22. The system of claim 17, wherein the energy producing device comprises an combustion engine operatively connected to an alternator.

23. The system of claim 17, wherein the unit comprises a heat pump unit configured to operate under a steam compression refrigeration cycle, the heat pump unit including a fluid circuit through which a fluid flows, a fluid compressor, a second heat exchanger situated at a suction of the fluid compressor when the system is functioning in an air conditioning mode, a third heat exchanger situated at a discharge of the fluid compressor when the system is functioning in an air conditioning mode, and a fourth heat exchanger situated at the discharge of the fluid compressor when the system is in a simultaneous air conditioning and heating mode.

24. The system of claim 23, wherein the fluid compressor comprises a hermetic fluid compressor.

25. The system of claim 23, wherein the heat pump unit further comprises a pressure reduction valve provided at the fluid circuit.

26. The system of claim 17, wherein the unit comprises a refrigerator unit configured to operate under a steam compression refrigeration cycle, the refrigerator unit including a fluid circuit through which a fluid flows, a compressor driven by an electric motor and in communication with the fluid circuit, a pressure reducing valve in communication with the fluid circuit, a second heat exchanger provided at a discharge of the compressor and in communication with the fluid circuit, and a third heat exchanger provided at the discharge of the compressor and in communication with the fluid circuit.

27. The system of claim 26, further comprising;

a fourth heat exchanger provided at the suction of the compressor outside of the refrigerator unit and in communication with the fluid circuit.

28. The system of claim 17, wherein the unit comprises a heat pump unit configured to operate under an absorption cycle, the heat pump unit including an absorber, a steam generator, a circulation pump, an evaporator provided at an inlet of the absorber, a pressure reducing valve provided at an output of the steam generator, a condenser each provided at the output of the steam generator, and a refrigerating fluid which flows through the heat pump unit.

29. A system configured to simultaneously produce electricity, water at a first temperature, water at a second temperature greater than the first temperature, and water at a third temperature greater than the second temperature, the system comprising:

a current-generating module configured to produce the electricity, the generating module including a first heat exchanger configured to produce the water at the third temperature, and an electric accumulator operatively connected to the alternator; and

a unit in communication with the current-generating module and configured to receive electricity produced by the current generation unit, the unit comprising a plurality of second heat exchangers configured to produce the water at the first temperature and the water at the second temperature.

30. The system of claim 29, wherein the unit comprises one of:

a heat pump unit, the heat pump unit including a refrigerating fluid circuit through which a refrigerating fluid

flows, a fluid compressor, a pressure reducing valve and the plurality of second heat exchangers; and  
a refrigerator unit, the refrigerator unit including a refrigerating fluid circuit through which a refrigerating fluid flows, a fluid compressor driven by an electric motor and in communication with the refrigerating fluid circuit, a pressure reducing valve in communication with the refrigerating fluid circuit, and the plurality of second heat exchangers.

31. The system of claim 30, wherein:

the first temperature is in a range between 5° C. and 9° C.;  
the second temperature is in a range between 30° C. and 60° C.; and

the third temperature is in a range between 55° C. and 75° C.

32. The system of claim 30, wherein the system is also configured to simultaneously heat the refrigerating fluid at a first evaporation temperature and at a second evaporation temperature greater than the first evaporation temperature.

33. The system of claim 30, further comprising;

a third heat exchanger provided outside of the refrigerator unit and in communication with the refrigerating fluid circuit.

34. A system configured to simultaneously produce electricity, water at a first temperature, water at a second temperature greater than the first temperature, and water at a third temperature greater than the second temperature, the system comprising:

a plurality of current-generating modules collectively configured to produce the electricity and the water at the third temperature, each current-generating module including a first heat exchanger configured to produce the water at the third temperature; and

a plurality of units in communication with the current-generating modules and configured to receive electricity produced by the current generation modules, each unit comprising a plurality of second heat exchangers collectively configured to produce the water at the first temperature and water at the second temperature.

35. The system of claim 34, wherein each unit comprises one of:

a heat pump unit, the heat pump unit including a refrigerating fluid circuit through which a refrigerating fluid flows, a fluid compressor, a pressure reducing valve and the plurality of second heat exchangers; and

a refrigerator unit, the refrigerator unit including a refrigerating fluid circuit through which a refrigerating fluid flows, a fluid compressor driven by an electric motor and in communication with the refrigerating fluid circuit, a pressure reducing valve in communication with the refrigerating fluid circuit, and the plurality of second heat exchangers.

36. The system of claim 34, wherein the energy producing device comprises one of:

at least one of a fuel cell and solar panel operatively connected to a DC-to-AC converter; and

an combustion engine operatively connected to an alternator.

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