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(54) APPARATUS AND METHOD FOR PRODUCING SUSTAINABLE POWER AND HEAT

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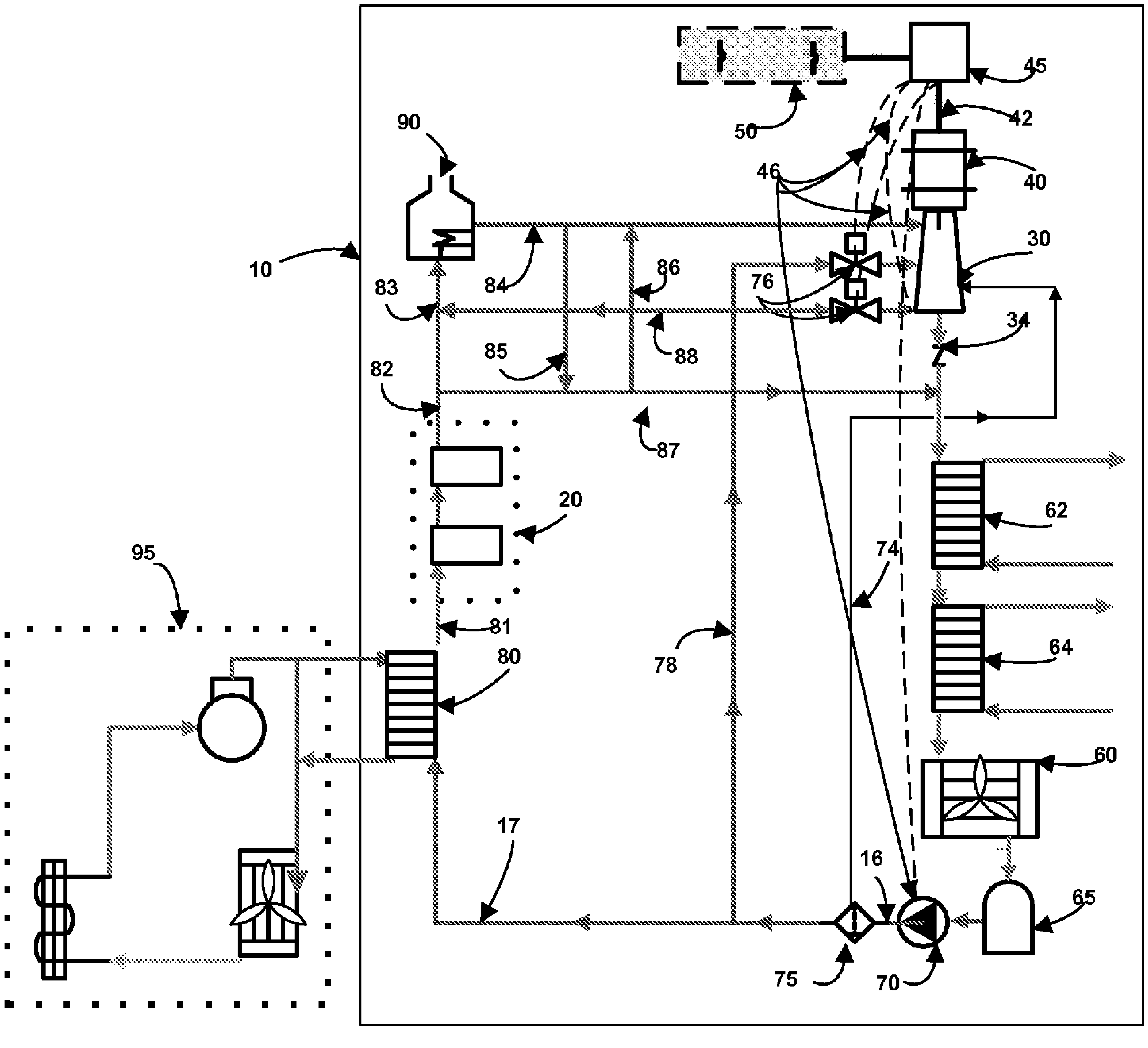
(57) ABSTRACT

An integrated system provides electricity and heat from solar, waste heat, biomass and fossil fuel energy. The system operates with a volatile organic working fluid that circulates in a variable speed heat engine type cycle, that is heated either to its boiling point, to a saturated state or above its boiling point, or to a superheated gas state, expanded through an expander, with working fluid injected therein such that the fluid exiting the expander is cooled in a condenser in thermal communication with a facility's domestic hot water, space heating or process heating systems, and circulated by a pump. Heat exchange loops define hot water production capability for use in a facility while a generator is coupled to the expander to produce electricity and is connected to the utility grid at fixed frequency and voltage in either a paralleling or island mode.



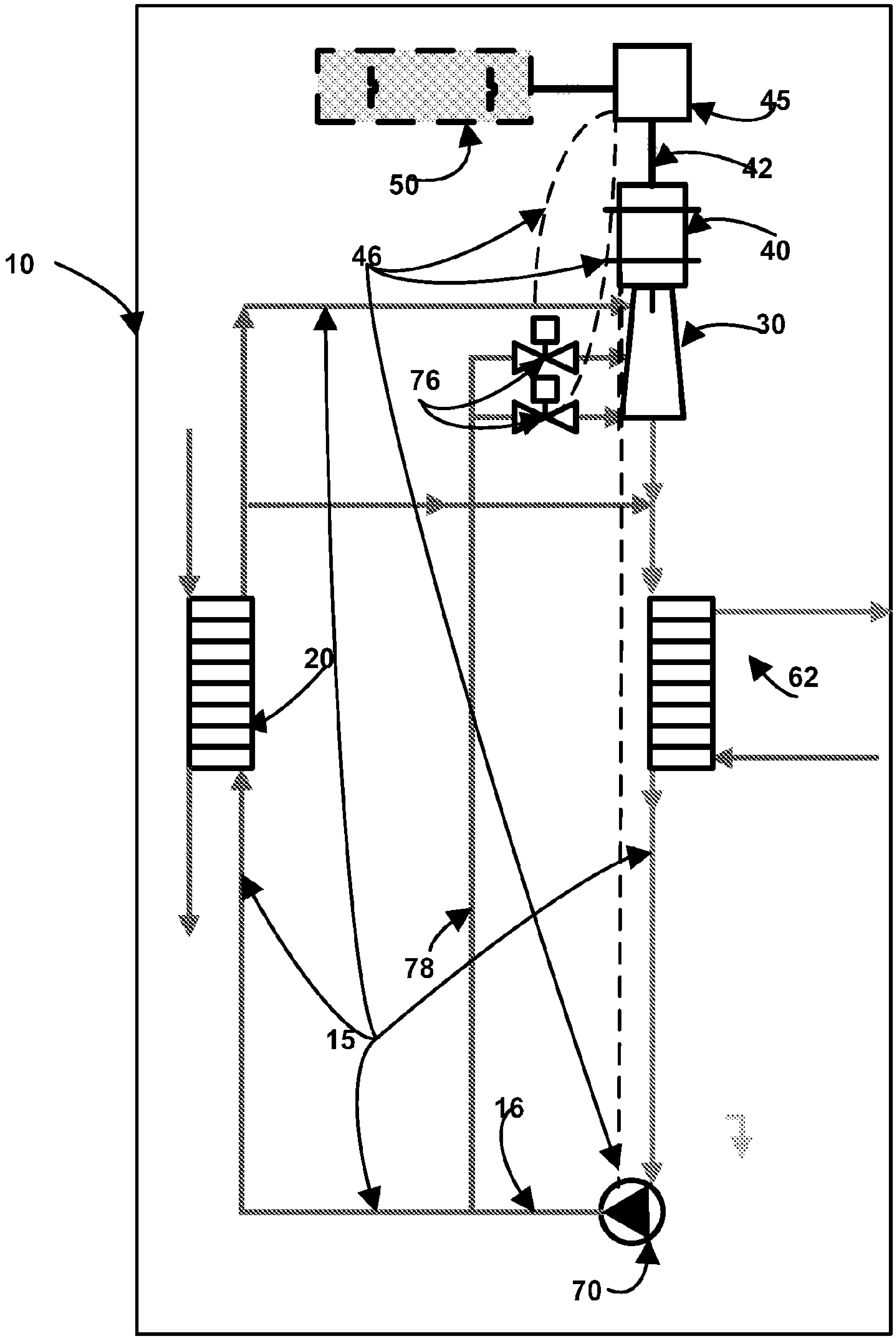


Figure 1

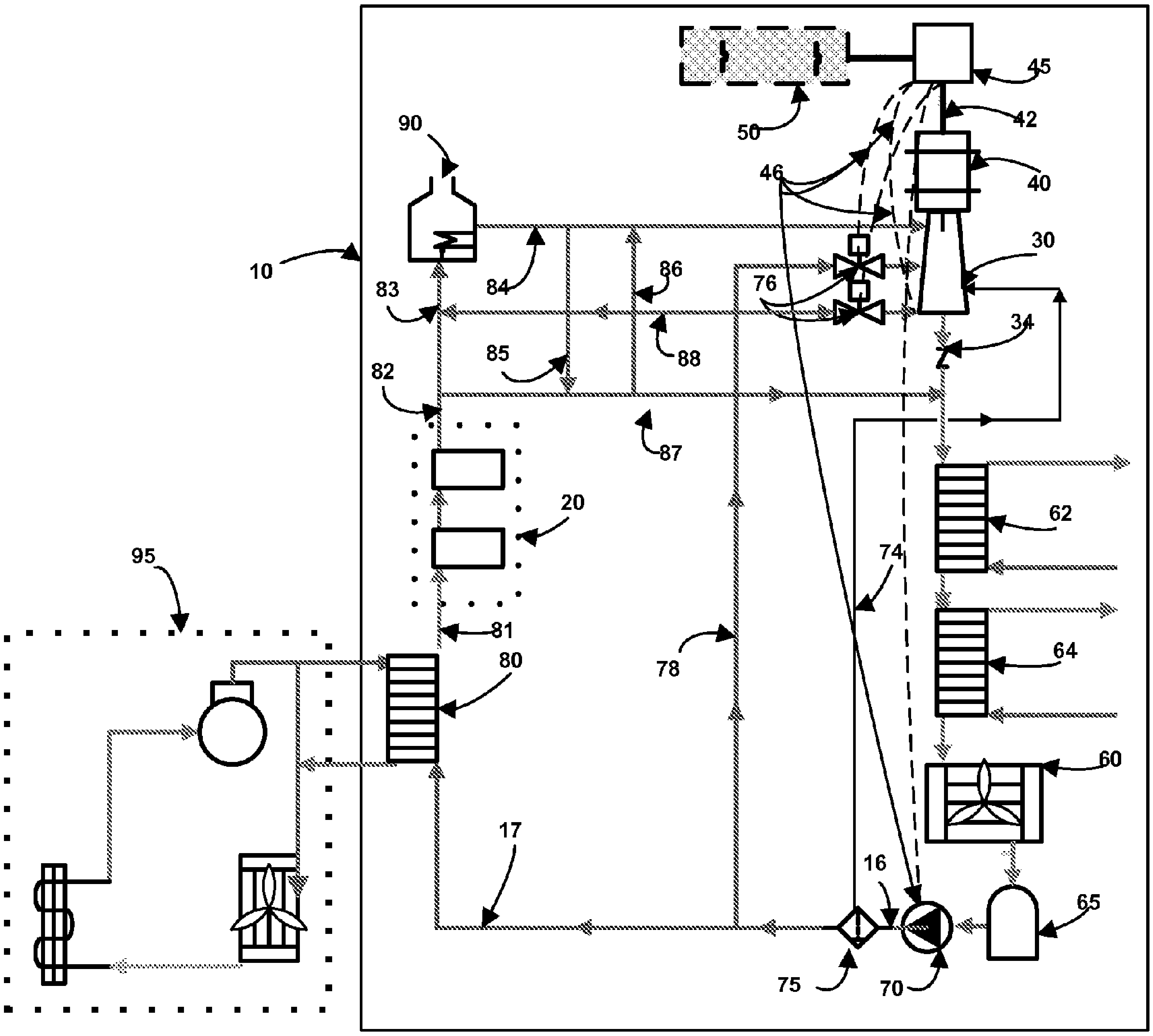

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Figure 2

APPARATUS AND METHOD FOR PRODUCING SUSTAINABLE POWER AND HEAT

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to the onsite production of heat and power from sustainable resources such as solar, waste heat and biomass system for the supply of electrical power, domestic hot water and space heating operating either in parallel or in isolation from the central grid, and more specifically, to a modular, scalable systems that enables maximum harvesting of solar energy, waste heat energy and heat from the combustion of fuel, to produce electrical power and useable heat in a closed loop heat engine cycle using a volatile organic working fluid in a system dynamically responsive to the source temperature, sink temperature, facility's electrical and thermal loads and ambient conditions.

[0002] In recent years, six major trends have emerged that are reshaping the energy industry. First, millions of consumers have experienced more frequent, more prolonged and more devastating electrical outages from failure of the central grid caused by more frequent, more severe and more costly hurricanes and storms and the increasing dependency of modern society on electrical devices including, computers, modems, televisions, and the like. Second, the cost of fossil fuel has spiked including gasoline, diesel fuel, natural gas and coal stimulated by the unprecedented demand for energy from emerging nations and the more severe storms. Third, the nearly universal acknowledgement of the detrimental impact caused by air pollution and specifically large fossil fuel plants in global warming. Fourth, the deregulation of the electrical industry has substantially reduced obstacles to interconnection by distributed generation resources. Fifth, substantial incentives from various governments spur more sustainable energy technologies. And, sixth, the increasing availability of real time pricing for all classes of electrical customers places a premium on technologies that can reduce grid electrical demand during high demand/high price situations.

[0003] Although there is an abundance of solar energy received by the Earth, its intensity at the Earth's surface is actually very low and varying with the time of day, time of year and the conditions of the Earth's atmosphere. Conventional heat engine cycles have been analyzed based on the on the ideal heat engine cycle Carnot disclosed in 1824 which postulates an infinite heat source and an infinite heat sink. In such hypothesized system, the efficiency of the power systems is determined by:

[0004] (i) the temperatures of the available heat source and sink;

[0005] (ii) the selection of the state points, thereby describing the adopted thermodynamic cycle;

[0006] (iii) the behavior of the working fluid used;

[0007] (iv) the irreversibility's in the mechanical systems involved; and,

[0008] (v) the temperature and pressure limitations of the materials used in the devices.

[0009] In a similar fashion the more practical Rankine and its associated organic Rankine cycles (ORCs) also assume infinite source and sink temperature and requires the evaporation and typically superheating of the working fluid in the heating device before entering the expander.

DESCRIPTION OF THE PRIOR ART

[0010] In 1977, S. S. Wilson & M. S. Radwan in "Appropriate Thermodynamics for Heat Engine Analysis and Design" disclosed a modified organic heat engine cycle, called the trilateral flash cycle (TFCs) based on the matching and optimization of heat source and sink, cycle, working fluid, expander and load characteristics which heats the liquid working fluid only to the point of boiling, saturation, and expands the heated high pressure saturated working fluid using positive displacement expanders in a cycle that optimizes the amount of the finite heat energy recoverable and electricity produced from a finite heat source. All previous disclosed closed loop heat engine systems utilizing a volatile organic working fluid were designed to operate in one of the two distinct modes, super heated, (ORC) or saturated liquid, (TFC) and did not contemplate the advantages or the ability to dynamically switch between the two modes in response to changing fuel load and operating conditions. Clearly, it is desirable to overcome the limitations and deficiencies of the ORC and TFC to provide a method which dynamical adjusts the heating of the working liquid only up to its boiling point, TFC or beyond its boiling point, ORC depending on the fuel, load, and ambient conditions.

[0011] During the expansion of volatile organic working fluid in an expander, almost invariably the working fluid leaves the expander in the superheated state and has to be cooled in the condenser or requires a recuperator heat exchanger to transfer the heat to preheat the relatively high pressure liquid. Everything else being equal the greater the superheat in the exhausted working fluid exiting the expander, the lower the efficiency of the mechanical/electrical generating heat engine cycle. Clearly dispensing with the need for a recuperator and producing more electrical energy from the same thermal energy is desirable through the injection of relatively high pressure liquid into the expansion volume of the expander and modulating the mass flow of the injected liquid such that the combined mass flow of the working fluid exits the expander in a saturated state and produces more net power.

[0012] Combined heat and power (CHP) systems using internal combustion engines, turbines, micro turbines, and fuel cells have been known for some time as a way to improve overall efficiency by an order of magnitude in energy production systems. In a typical CHP system, heat and electricity are produced from a combustion process engine that drives an electric generator, as well as heat water, or air. Although historically CHP systems tend to be rather large, because of the six forces outline above, micro CHP systems consuming fossil fuel are emerging technologies. Because of the dramatic increase in power outages and fossil fuel prices, there is a huge market for dispatchable, sustainable energy systems.

[0013] In view of the limitations of the existing art, the present invention fulfills the long felt need to optimize the production of electricity and heat in response to the varying availability of solar energy, waste heat and the varying load requirements of the facility, to dynamically optimize the electric power production by operating the system with a superheated working fluid entering the expander as in a Carnot or Rankine cycles or with a saturated liquid entering the expander in the trilateral flash cycle and minimizing the superheat of the working fluid exiting the expander and to provide a more reliable and secure source of electricity and heat not subject to the numerous power outages of central grid systems. The above and other objects and advantages of the present invention will become apparent from the following specifications, drawings and claims. It will be understood that the particular embodiments of the invention are shown by way of illustration only and not as limitation of the invention. The principle features of this invention may be employed in various embodiments without departing from the scope of the invention.

[0014] While the above-described systems fulfill their respective, particular objectives and requirements, the aforementioned systems do not describe a system that uses beneficial portions of the Rankine and Carnot cycles to produce electricity and heat at minimal amounts of energy. Therefore, a need exists for a new and improved apparatus and method for producing sustainable power and heat that in its structure allows for multiple fuels to generate heat. The present invention substantially fulfills this need. Further, the present invention substantially departs from the conventional concepts and designs of the prior art.

SUMMARY OF THE INVENTION

[0015] The present invention is an integrated system to provide both electric power and heat from various energy sources including solar, waste heat, biomass and fossil fuels. The combined heat and power system operates with a volatile organic working fluid that circulates in a variable speed heat engine type cycle, where the organic working fluid is heated to either its boiling point, a saturated state or past its boiling point, a superheated gas state, expanded through an expander, with relatively high pressure subcooled liquid working fluid injected into the expansion chambers of the expander such that the volatile organic working exiting the expander is in a saturated state, cooled in a condenser in thermal communication with the domestic hot water or space heating system, and pressurized and circulated by a pump. Heat exchange loops within the system define hot water production capability for use in space heating, domestic hot water, and/or process heat while the generator is coupled to the expander to produce electricity which is interconnected to the grid at fixed frequency and voltage in either a paralleling or island mode.

[0016] The foregoing has outlined, in general, the physical aspects of the invention and has served as an aid to better understanding the detailed description. Thus, the present invention is not limited to the method or detail of construction, fabrication, material, or application of use described and illustrated herein. Any other variation of fabrication, use, or application should be considered apparent as an alternative embodiment of the present invention.

[0017] There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood and in order that the present contribution to the art may be better appreciated.

[0018] Numerous objects, features and advantages of the present invention will be readily apparent to those of ordinary skill in the art upon a reading of the following detailed description of presently preferred, but nonetheless illustrative, embodiments of the present invention when taken in conjunction with the drawings. In this respect, before explaining the current embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[0019] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and devices for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and the scope of the present invention.

[0020] It is therefore a principal object of the present invention to provide a method and apparatus which will maximize the overall energy efficiency of the energy process of harvesting and converting solar energy to usable electrical power and heat, while overcoming the disadvantages and drawbacks of known methods of solar photovoltaic, solar thermal electric, and solar thermal systems.

[0021] Still another object of the present invention is to provide an integrated method and apparatus for operating the combined power and heat system in parallel when the grid is functioning and independently of the central grid system when the grid has failed.

[0022] Still another object of the invention is to provide an integrated method and apparatus for dynamically controlling the amount and ratio of electrical to thermal output of the system.

[0023] Still another object of the invention is to provide an integrated method and apparatus for optimizing the conversion of heat energy into electrical power and minimizing the power losses from the expansion of the working fluid to a superheated condition.

[0024] Still another object is to provide an integrated method and apparatus for energy recovery system, utilizing the waste heat usually rejected from the condenser of a facility's air conditioning and refrigeration system, the facility's attic or other sources of waste heat, to generate electric power and useable heat.

[0025] It is intended that any other advantages and objects of the present invention that become apparent or obvious from the detailed description or illustrations contained herein are within the scope of the present invention.

[0026] These together with other objects of the invention, along with the various features of novelty that characterize the invention, are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] In referring to the drawings,

[0028] FIG. **1** indicates a schematic diagram for a single source directly heated combined heat and power system; and,

[0029] FIG. **2** indicates a schematic diagram for a multiple source directly heated combined heat and power system.

[0030] The same reference numerals refer to the same parts throughout the various figures.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0031] The present art overcomes the prior art limitations by providing a combined electricity and heat producing system fueled by various sources, primarily solar and other renewable sources integrated with combustion of fossil fuels for a supplemental heat source. With reference to the drawings, FIG. **1** illustrates a possible configuration of the principal hardware components comprising a system embodying the operating mechanisms to affect the benefits described. It is noted however that variations in equipment may be made and would be within the ambit of a person skilled in the art. Referring initially to FIG. **1**, one embodiment of the integrated Combined Heat and Power System **10** is a directly-heated, single closed loop system that includes a first (or primary) circuit thermal fluid conduit **15** and a secondary circuit thermal fluid conduit **78**. An advantage of the directly heated system is that it eliminates the inherent loss resulting from the pinch points of the various heat sources and sinks thus maximizing the efficiency of the cycle. First circuit **15** conducts the heated volatile organic working fluid from heating device **20** to the expander **30**. The expander **30** houses a positive displacement expander such as a rotary vane, scroll, screw, reciprocating or nutating engine. As the heated organic working fluid proceeds along an ideally isentropic path through the expander, its pressure and temperature fall, its volume expands, and accompanying those changes in state conditions, its enthalpy is converted to mechanical energy creating rotating shaft power which drives the alternator, **40**. Organic working fluid generally become drier and superheated because of the characteristic of their saturation envelope and the current practice is volatile organic working fluid exit the expander in a superheated state. The alternator, **40** delivers variable frequency and variable voltage output electric power to the transmission line, **42** connecting the alternator to the converter controller. The converter controller converts the variable frequency and variable voltage electric power to a fixed frequency and voltage that within tight parameters that enable the convert controller to synchronize its electric output with the electric grid or to maintain it within operating specifications if the grid has failed and the system is operating in an island mode. The conditioned power from the converter controller **45** is feed to the main circuit panel for distribution to the rest of the facility or the attached electric grid. Converter controller, **45** also monitors the temperature, pressure, electric power output and thermal output. Through sensors and control lines, **76**. The expander also features a port(s) for injection of subcooled liquid volatile organic working fluid. Injection of this subcooled liquid eliminates the superheat lo normally produce by expansion in organic Rankine cycle systems and enable useable mechanical power from the superheat created by expansion of the volatile organic working fluid. The combined mass flow of primary circuit **15** and secondary injection circuit **76** arrives at its exit conduit **16** at the saturation pressure and temperature for the volatile organic working fluid employed as the heat engine thermodynamic medium, a minimum approach difference above the temperature established in condenser **62**. The converter controller **45** determines the target condensing temperature based on ambient conditions, the available heat energy in heater **20**, the electrical and thermal load of the facility in real time. The converter controller can also be program to respond to "real time electric" pricing parameters that may present opportunities to arbitrage the real time price of electricity versus the cost of producing that same electricity from sustainable fuel. Spent ambient coolant is returned to the cooling tower or other ambient coolant source via conduit **38**. The spent saturate working fluid exiting the expander **30** is conducted by primary circuit **16** to condensing heat exchanger **62**. Condensing heat exchanger transfer the latent heat of condensation and the specific heat of subcooling to the facility's space heating system, or domestic hot water heating system or process heating system. The primary circuit **15** conducts the subcooled working fluid in a liquid state to the working fluid pump, **70**. where it is pumped to the operating of pressure of heater **20**, En route from working fluid pump **70**, a portion of the flow is separated from conduit **16** via secondary circuit, **78** to supply the injector valves **76** which modulate the mass flow of the liquid working fluid into the expansion volume of the expander **30**, such that the working fluid exits the expander **30** in a saturated state. It enters heater **20** via conduit **15** to repeat the heat engine with organic working fluid cycle.

[0032] Converter Controller **45** controls the temperature of the working fluid exits the heater, **20**. Although the Carnot cycle proves that the maximum power that lo can be generated from a heat engine cycle is the maximum delta temperature between the source and the sink temperature, this optimization does not necessarily hold true for integrated combine heat and power systems. For instance the greater the delta temperature difference of the conduits leading up to heater **20** the greater the heat losses from the entire system so that the amount of available energy at heater **20** is substantially less that it would be if the circuit was operated at a lower temperature but with more available energy to convert to power and useable heat. Moreover, the Carnot and Rankine cycles require superheating the fluid which means that the amount of heat energy available below the temperature of evaporation is not available to the power cycle. However, the trilateral flash cycle captures the heat available down to the condensing temperature and produces power from it. Based on the thermodynamic, economic parameters and the load profile converter controller, **45** can modulate the speed of the working fluid pump, **70** such that the working fluid exiting the heater **20** can be in a saturate or superheated state.

[0033] Referring next to FIG. **2**, an alternate embodiment of the directly heated integrated combined heat and Power system **2** is shown. Here, waste heating device, **80** consist of a heat exchanger in the refrigerant loop of the facility's air conditioner or refrigeration equipment located between the compressor and condenser of said system. This waste heating device, **80** can transfer the cooling BTUs as well as the heat of compression from the compressor to preheat the liquid volatile organic working fluid. Conduit **82** conducts the preheated liquid working fluid from the waste heating device **80** to high temperature solar collectors, **20**. The higher temperature solar collectors can be various style solar collectors designed to produce heat above 200° F. As the solar collectors, **80** heats the fluid the velocity of the working fluid through the expanders can be controlled by the speed of the variable speed working fluid pump, **70**. By controlling the speed of this pump, the converter controller can determine if the working fluid will leave the solar collectors by a conduit **82** in a saturated bi-phase state or in a superheated state. The working fluid exiting the collectors can be either directed to the combustion heater, **90** via conduits **82** and **83**, or directed to bypass the combustion heater, **90** via conduit **87**. If the working fluid is directed to the combustion heater **90**, the energy output of the combustion heater **90** can be modulated to produce either saturated working fluid or superheated working fluid as determined by converter controller **45** by controlling the modulation of the combustion heater **90** and the speed of the variable speed pump **70**. The heated working fluid exiting the combustion heater, **90** can be directed by conduit **84** directly to the expander or directed by conduit **85** to bypass the expander. Upon enter the expander, **30**, the heated organic working fluid proceeds along an ideally isentropic path through the expander, its pressure and temperature fall, its volume expands, and accompanying those changes in state conditions, its enthalpy is converted to mechanical energy creating rotating shaft power which drives the alternator, **40**. Organic working fluid generally becomes drier and superheated because of the characteristic of their saturation envelope. The current practice in organic Rankine cycle systems is to have the volatile organic working fluid exit the expander in a superheated state. The alternator, **40** delivers variable frequency and variable voltage output electric power to the transmission line, **42** connecting the alternator to the converter controller. The converter controller converts the variable frequency and variable voltage electric power to a fixed frequency and voltage that within tight parameters that enable the convert controller to synchronize its electric output with the electric grid or to maintain it within operating specifications if the grid has failed and the system is operating in an island mode. The conditioned power from the converter controller **45** is feed to the main circuit panel for distribution to the rest of the facility or the attached electric grid. Converter controller, **45** also monitors the temperature, pressure, electric power output and thermal output. Through sensors and control lines, **76**. The expander also features a port(s) for injection of subcooled liquid volatile organic working fluid. Injection of this subcooled liquid working fluid eliminates the superheat normally produce by expansion in organic Rankine cycle systems and produces useable mechanical power from the superheat energy created by expansion of the volatile organic working fluid. The combined mass flow of primary circuit **84** and secondary injection circuit **76** arrives at its exit conduit **16** at the saturation pressure and temperature for the volatile organic working fluid employed as the heat engine thermodynamic medium, a minimum approach difference above the temperature established in condenser **60**. The converter controller **45** determines the target condensing temperature based on ambient conditions, the available heat energy in heater **20**, the electrical and thermal load of the facility, and real time pricing information. The converter controller can also be program to respond to “real time electric” pricing parameters that may present opportunities to arbitrage the real time price of electricity versus the cost of producing that same electricity from onsite electric generation. Spent ambient coolant is returned to the cooling tower or other ambient coolant source can transfer all or a portion of the heat of the spent working fluid depending on the load of the facility, ambient conditions and operating parameters of the building. The spent saturate working fluid exiting the expander **30** is conducted by first circuit **34** to space heating heat exchanger, **62**. Space heating heat exchanger **62**, can transfer all or a portion of the heat of the spent working fluid depending on the load of the facility, ambient conditions and operating parameters of the building. The spent working fluid exiting heat exchanger, **62** is conducted by first circuit **34** to domestic hot water heat exchanger **64**. Domestic hot water heat exchanger **64** can transfer all or a portion of the heat of the spent working fluid depending on the load of the facility, ambient conditions and operating parameters of the building. The spent working fluid exiting domestic hot water heat exchanger **64** is conducted by first circuit **34** to ambient condenser, **60**. Ambient condenser **60** removes heat from the spent working fluid so that the working fluid condenses in to a liquid and is slightly subcooled. The condensed liquid working fluid exits the ambient condenser **60** and is conducted by first circuit **34** to a receiving vessel, **65**. Receiving vessel stores excess working fluid to compensate for the dynamic operating conditions of the system. The liquid working fluid exiting the condenser, **65** is conducted by primary circuit **34** to the variable speed working fluid pump. The variable speed working fluid pump pressurizes the working liquid working fluid to a pressure above the pressure produced in the hottest of the heat sources **80**, **20**, or **90**. The pressurized liquid working fluid leaves the working fluid pump, **70** and is conducted by conduit **16** to an oil separator, **75** were substantially all of the oil is removed from the working fluid. The oil removed by the oil separator **75** is conducted by conduit **74** back to the expander where it is injected into the oil port of the expander using the pressure developed by the working fluid pump. The evaporation temperature produced by the condensing heat exchanger transfers the latent heat of condensation and the specific heat of subcooling to the facility's space heating system, or domestic hot water heating system or process heating system. The primary circuit **15** conducts the subcooled working fluid in a liquid state to the working fluid pump, **70**. where it is pumped to the operating of pressure of the heater **20**, En route from working fluid pump **70**, a portion of the flow is separated from conduit **16** via secondary circuit, **78** to supply the injector valves **76** which modulate the mass flow of the liquid working fluid into the expansion volume of the expander **30**, such that the working fluid exits the expander **30** in a saturated state. It enters heater **20** via conduit **15** to repeat the heat engine with organic working fluid cycle. The expander **30** houses a positive displacement expander such as a rotary vane, scroll, screw, reciprocating or nutating engine. As the heated organic converter controller **45** can control the system such that the volatile organic working fluid exiting the solar collectors, **20** is either in a saturate state or a superheated state. working fluid proceeds along an ideally isentropic path through the expander, its pressure and temperature fall, its volume expands, and accompanying those changes in state conditions, its enthalpy is converted to mechanical energy creating rotating shaft power which drives the alternator, **40**.

[0034] From the aforementioned description, an apparatus and its method for producing sustainable electricity and heat has been described. The apparatus, as a system, is uniquely capable of producing both electricity and heat from sustainable fuels at minimal energy input. The apparatus as described and its various components may be manufactured from many materials, including but not limited to aluminum, steel, polymers, high density polyethylene, nylon, ferrous and non-ferrous metals, their alloys, and composites.

[0035] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. Therefore, the claims include such equivalent constructions insofar as they do not depart from the spirit and the scope of the present invention.

I claim:

1. An integrated system producing electricity and heat for a facility comprising:
- at least one heat source producing one of a saturated liquid or superheated vapor;
- an expander heat engine, receiving one of a saturated liquid or a superheated vapor from said at least one heat source, and having ports for injection of subcooled volatile organic fluid into an expansion chamber of the expander such that said volatile organic fluid exiting said heat engine expander is in a saturated state;
- a first circuit configured to transport said volatile organic working fluid, said first circuit in thermal communication with said heat source where heat transferred therefrom raises the temperature of said volatile organic working fluid to one of a saturated bi-phase state or a superheated gas state, said first circuit further comprising:
  - said heat engine expander being driven by said volatile organic working fluid under heat and pressure producing mechanical power to an output shaft;
  - an alternator operatively coupled to said output shaft generating electricity;
  - a converter-controller, converting the electricity from said alternator into specified alternating current and controlling the operations of said system;
  - a heat exchanger in fluid communication with said expander reducing the temperature of said volatile organic working fluid, said volatile organic working fluid exiting said expander in a liquid state and transferring latent and specific heat of said volatile organic working fluid to said facility's heating system, domestic hot water system, and process heat system; and,
  - a variable speed pump pressurizing and circulating said volatile organic working fluid through said system, the speed of said pump responding to signals from said converter controller and determining the state of said volatile organic working fluid entering said expander, the amount of electricity produced versus thermal power produced by said system;
- a second circuit in thermal communication between said variable speed pump and said expander and transporting said volatile organic working fluid exiting said pump to said expander such that said volatile organic working fluid exits said expander in a saturated state, said second circuit further comprising:
  - an injection valve dynamically controlling the flow of said volatile organic working fluid into said expander based on signals from said converter-controller.

2. An integrated combined heat and electricity system according to claim **1**, wherein said heat source is at least one solar collector directly heating said working fluid.

3. An integrated combined heat and electricity system according to claim **2**, wherein said heat source includes waste heat from said facility's air conditioning or refrigeration system, said facility's attic space, or said facility's process heat.

4. An integrated combined heat and electricity system according to claim **1**, wherein said heat source is a combustion burner consuming one of fossil fuel or biomass fuel.

5. An integrated combined heat and electricity system according to claim **4**, wherein said heat source is a fossil fuel combustion burner.

6. An integrated combined heat and electricity system according to claim **5**, wherein said volatile organic working fluid is heated directly by said heat source.

7. An integrated combined heat and electricity system according to claim **1**, further comprising:
- said volatile organic working fluid being heated by one of at least one solar collector, waste heat from said facility's air conditioner, biomass fuel combustion, or fossil fuel combustion; and,
- a transfer fluid transferring heat to said volatile organic fluid through said heat exchanger.

8. An integrated combined heat and electricity system according to claim **1**, wherein said volatile working fluid is heated by waste heat from another lo power generator system including an internal combustion generator, turbine, micro turbine, or fuel cell, said waste heat exceeding 200° F.

9. An integrated combined heat and electricity system according to claim **1**, wherein said first circuit includes a receiver downstream of said expander to provide a reservoir for cooled volatile organic working fluid and a head for said variable speed pump.

10. An integrated combined heat and electricity system according to claim **1**, wherein said expander is cooled by an evaporative cooling tower.

11. An integrated combined heat and electricity system according to claim **1**, wherein said first circuit includes an emergency bypass around said expander for said volatile organic working fluid.

12. An integrated combined heat and electricity system according to claim **1**, wherein said converter-controller compares temperature and pressure signals in said heating device and said expander to determine amount said organic working fluid is saturated and superheated and controls the amount of said working fluid injected and the speed of said pump to control the state of the working fluid entering said expander.

13. An integrated combined heat and electricity system according to claim **1**, wherein said converter-controller operates in an interconnecting paralleling mode and an island mode when an utility electric grid fails.

14. A method for utilizing thermal energy for the production of mechanical power, electrical power, hot water, space heating or process heat for a facility by controlling the temperature, pressure and state of a volatile organic fluid entering and exiting an expander of a heat engine cycle comprising:
- a) circulating and substantially adiabatically pressurizing said volatile organic fluid through a heat engine system;
- b) circulating a portion of the pressurized volatile organic fluid to a heat exchanger of said system;
- c) circulating the balance of the pressurized volatile organic fluid to injectors that communicate directly with an expansion volume of said expander;
- d) providing an external heat energy source and passing said external heat energy source in heat exchange relationship with said circulating volatile organic fluid;
- e) transferring the heat from the external heat energy source in a substantially isobaric manner to the circulating volatile organic fluid to one of a saturated or superheated state;
- f) further circulating the heated volatile organic fluid from the heater to said expander;
- g) injecting the unheated portion of the pressurized volatile organic fluid into the expansion volume of the expander so that the volatile organic fluid exits the expander in a saturated state;

h) providing a flow path for the volatile organic fluid through the expander, substantially adiabatically expanding said volatile organic fluid and exhausting the combined mass flow of said volatile organic fluid from the expander;

i) passing thermal transfer fluid from one of the facility's domestic hot water system, space heating system or process heat system in a heat exchange relationship with said volatile organic fluid exiting the expander; wherein said volatile organic fluid from the expander is in saturation state at a temperature sufficient to transfer heat from said volatile organic fluid to one of the domestic hot water system, space heating system or process heat system, at a minimum delta temperature between said volatile fluid and the heat transfer media;

j) removing heat of condensation of said volatile organic fluid medium in substantially isobaric manner to create a liquid phase condensate at a saturation temperature approximating the minimum reliable approach difference above the lowest temperature of said coolant fluid;

k) returning the liquid phase condensate produced to circulation in said system;

l) controlling the saturation temperature and pressure of said volatile organic fluid leaving the heater in response to the dynamic temperatures and pressures of the thermal energy to the system, ambient conditions and electrical and thermal loads of the facility; and,

m) controlling the saturation temperature and pressure of said volatile organic fluid in response to load demands of the facility and the targeted temperatures of the domestic hot water system, the space heating system and the process heat system to foster the saturation conditions of said volatile organic working fluid medium permits condensation.

15. The method of claim **14**, wherein controlling the temperature, pressure and state of said volatile organic fluid entering the expander includes sensing changes in temperature of the heater and the temperature of volatile organic fluid and controlling the mass flow through heater and volatile organic fluid by controlling the circulation of said volatile organic fluid and pressurizing said volatile organic fluid.

16. The method of claim **14**, wherein controlling the temperature, pressure and state of the volatile organic fluid leaving the expander includes sensing changes in electrical and thermal loads of the facility and controlling the lo mass flow through heater and volatile organic fluid in response thereto.

17. The method of claim **14**, wherein controlling the temperature, pressure and state of the volatile organic fluid entering the expander includes sensing changes in temperature of a condenser and the temperature of said volatile organic fluid and controlling the mass flow through a condenser and volatile organic fluid in response to the sensed changes in said fluid temperatures.

18. The method of claim **14**, wherein controlling the temperature, pressure and state of the volatile organic fluid leaving the expander from the heater comprising sensing changes in electrical and thermal loads of the facility and controlling the mass flow through heater and volatile organic fluid in response to the sensed changes in facility electrical and thermal loads.

19. The method of claim **14**, wherein controlling the mass flow to the expander comprises providing valve controlled injectors which introduce mass flow quantities of one of liquid, vapor or biphase volatile organic fluid into an expansion volume for mixing with the vapor phase fluid in transit therethrough, said valve controlled injectors locating along the travel path through the turbine.

20. The method of claim **14** wherein said external heat source includes at least one solar collector.

21. The method of claim **20** wherein the external heat source includes waste heat recovered from one of said facility's air conditioner or refrigeration equipment, attic, or other process waste heat.

22. The method of claim **21** wherein the external heat source includes heat from a separate heat engine system.

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