

A GAS RECOVERY SYSTEM

TECHNICAL FIELD

This invention relates generally to a gas recovery system and a gas recovery method.

5

Background

Most of the energy used in the world today is derived from the combustion of carbon and hydrogen containing fuels such as coal, oil and natural gas. In addition to carbon and hydrogen, these fuels contain oxygen, moisture and contaminants such as ash, sulfur,
10 nitrogen compounds, chlorine, mercury and other trace elements. Awareness of the damaging effects of the contaminants released during combustion triggers the enforcement of even more stringent limits on emissions from power plants, refineries and other industrial processes. There is an increased pressure on operators of such plants to achieve near zero emission of contaminants and to reduce carbon dioxide (CO₂) emission.

15

Reduction in CO emission can be achieved by improving efficiency of energy utilization, by switching to lower carbon concentration fuels and by using alternative or CO₂ neutral energy sources. However, CO₂ emitting fuels will likely continue to be the main source of energy in the foreseeable future. Therefore, there exists a need for a system for addressing the
20 foregoing issues.

Summary

In accordance with a first aspect of the invention, there is disclosed a gas recovery system for plant cultivation, the gas recovery system comprising a generator for generating heat energy
25 and flue gas from natural gas supplied thereto, a temperature conditioning system in thermal communication with the generator for receiving heat energy generated from the generator for one of chilling and heating water for conveyance to a downstream facility, and a bioreactor for receiving the flue gas from the generator for cultivating plants therefrom, the flue gas comprising carbon dioxide (CO₂).

30

In accordance with a second aspect of the invention, there is disclosed a gas recovery method for plant cultivation, the gas recovery method comprising generating heat energy and flue gas by a generator from natural gas supplied thereto, receiving heat energy generated from the generator by a temperature conditioning system in thermal communication with the generator for one of chilling and heating water for conveyance to a downstream facility, and receiving the flue gas from the generator by a bioreactor for cultivating plants therefrom, the flue gas comprising carbon dioxide (CO₂).

10 **Brief Description of the Drawings**

FIG. 1 shows an exemplary system diagram of a gas recovery system in accordance with an aspect of the invention;

FIG. 2 shows an exemplary process flow diagram for a gas recovery method utilizing the gas recovery system of FIG. 1;

FIG. 3 shows an exemplary system diagram of one implementation of the gas recovery of FIG. 1 where natural gas is obtained from a natural gas feed source; and

FIG. 4 shows an exemplary system diagram of one implementation of the gas recovery of FIG. 1 with the energy storage system being a battery configured for heat exchange with a cryogenic vessel constituting the storage system for natural gas.

Detailed Description

An exemplary embodiment of the present invention, a gas recovery system 20, is described hereinafter with reference to FIGS. 1 to 4. The energy recovery system 20 may utilize a gas recovery method 100 as herein described. The energy recovery system 20 comprises a generator 22 for generating heat energy and flue gas from natural gas supplied thereto, a temperature conditioning system 24 in thermal communication with the generator 22, and a bioreactor 26. Preferably, the temperature conditioning system 24 for receiving heat energy generated from the generator 22 for one of chilling and heating water for conveyance to a downstream facility 27. Preferably, thermal communication between the temperature conditioning system 24 and the generator 22 is achieved via the transport or exchange of liquid, for example water, therebetween where water heat energized by the generator 22 is conveyed to the temperature conditioning system 24 for heat exchange therein before being conveyed back to the generator 22 preferably in a closed loop system, for example closed-loop piping. The bioreactor 26 is for receiving the flue gas from the generator for cultivating plants therefrom with the flue gas comprising carbon dioxide (CO₂). Preferably, the temperature conditioning system 24 is one of an adsorption chiller, a boiler and a hydronic boiler chiller.

Preferably, the generator 22 is one of a lean burn natural gas generator and a combined heat and power (CHP) generator. Also, the generator 22 is for generating electrical energy from the heat energy being generated thereby for provision to at least one of an energy storage system 28 and an energy consuming system 30. The energy storage system 30 can be at least one of a battery array and a capacitor array for storing electrical energy. Additionally or alternatively, the energy storage system 30 is at least one of a water reservoir and a water pipe network for storing heat energy.

Preferably, the bioreactor 26 is for cultivating algae which consumes the carbon dioxide in the flue gas being provided thereto. The bioreactor 26 is further for fixating the carbon dioxide in the flue gas with the algae for generating biomass therefrom. In harvesting the

algae, the bioreactor 26 comprises a harvesting facility 32 for harvesting the algae being cultivated. The harvesting facility 32 can comprise at least one of a tray assembly, a flocculation and flotation system and a centrifuge for harvesting the algae being cultivated.

- 5 The gas recovery system 20 further comprises a dryer 34 for receiving the flue gas from the generator 22 for dewatering the algae being harvested into dry algae powder. The gas recovery system 20 further comprises a storage system 36 for storing and supplying the natural gas to the generator 22. The gas recovery system 20 further comprises a gas conditioning system 38 interfacing the generator 22 and the bioreactor 26 for filtering and
10 cooling flue gas being provided from the generator 22 to the bioreactor 26. Preferably, the downstream facility 27 is one of a refrigeration facility and a heating, ventilation and air-conditioning (HVAC) system.

The gas recovery method 100 utilised by the gas recovery system 20 comprises generating
15 heat energy and flue gas by the generator 22 from natural gas supplied thereto in a step 110, receiving heat energy generated from the generator 22 by the temperature conditioning system 24 in thermal communication with the generator 22 for one of chilling and heating water for conveyance to a downstream facility 27 in a step 112, and providing the flue gas from the generator 22 to the bioreactor 26 for cultivating plants therefrom in a step 114.

20

The gas recovery method 100 further comprises generating electrical energy from the heat energy being generated thereby for provision to the at least one of the energy storage system 28 and the energy consuming system 30 in a step 116. The energy consuming system 30 can be one or more of machineries, equipment, electrical systems, buildings, a facility and a
25 residential or commercial area.

The gas recovery method 100 further comprises cultivating algae by the bioreactor 26 in a step 120, harvesting the algae being cultivated in a step 122, and dewatering the algae being harvested into dry algae powder by the dryer 34 in a step 124. The gas recovery method 100
30 further comprises filtering and cooling flue gas being provided from the generator 22 to the

bioreactor 26, in a step 130, using the gas conditioning system 38 interfacing the generator 22 and the bioreactor 26.

In one implementation of the gas recovery system 20, as shown in FIG. 3, and the gas recovery method 100, heat energy and flue gas is generated by the generator 22 from natural gas supplied thereto, for example from a pipeline natural gas feed 40, a manifold or from a cryogenic vessel constituting the storage system 36. Heat energy is then transported from the generator through a liquid circulation system, for example a closed-loop piping system, which conducts the heat energy via heat exchange from the generator 22 at an exemplary 90 °C and transports the heat energy to the temperature conditioning system 24. Liquid circulating in the liquid circulation system loses heat in the temperature conditioning system through head exchange with the downstream facility 27 before being conveyed back to the generator 22 at an exemplary 80 °C for reheating thereof.

At the temperature conditioning system 24 then either chills water, for example from 11 °C to 7 °C, or heats the water, for example from 120 °C to 150 °C, through adsorption, conduction or other heat conditioning process, for provision to the downstream facility 27, for example a refrigeration system for food and beverages.

The flue gas from the generator 22 is cleaned and cooled by the gas conditioning system 38 before being provided to the bioreactor 26 for cultivating algae, for example, micro algae. As the flue gas contains carbon dioxide (CO₂), the circulated in the bioreactor 26 will consume the carbon dioxide, in addition to carbon dioxide fixation, to produce oxygen which may then be discharged into the environment. This substantially reduces the discharge of CO₂ into the environment. The use of clean fuel natural gas will further contribute to the reduction of environmentally damaging contaminants generated in the flue gas discharged by the generator 22. A portion of the algae in the bioreactor 26 may be harvested, with the remainder being recycled/recirculated within the bioreactor, and dried by the flue gas, at a preferable 40 °C whether provided directly from the generator 22 or subsequent to being

cleaned and cooled by the gas conditioning system 38, to dewater the harvested algae into dried algae, or preferably, dried algae powder.

Electrical energy may be generated by the generator 22, for example via combustion turbine
5 or engine constituting the generator 22. In another implementation of the gas recovery system 20, as shown in FIG. 4, and the gas recovery method 100, the electrical energy may be stored in, for example, a battery or battery array 42 by charging thereof. The battery or battery array or the like energy storage system 28 may in turn supply the energy to the energy consuming system 30 in addition or alternative to the generator 22 supplying the electrical
10 energy to the energy consuming system 30. As the battery or battery array will substantially heat up during charging and discharge of electrical energy, thereby bringing the temperature of the battery or battery array past the optimal or safe operating temperature range thereof, the energy storage system 28 and the storage system 36 for storing and supplying the natural gas to the generator 22 may be inter-configured for thermal communication therebetween.
15 Further, as the storage system 36 for the natural gas in this implementation, specifically specifically liquid natural gas in this case, is a cryogenic vessel/dewar 44 or the like storage vessel, the storage system 36 cools down during natural gas discharge, a coolant medium may be circulated between the storage system 36 and the battery or battery array during use of the gas recovery system 20. For example, the coolant medium may be provided at an
20 exemplary -120 °C to the battery or battery array which heats the coolant medium to an exemplary -30 °C prior to being fed back to the natural gas storage system 36 for re-cooling thereof to substantially the exemplary -120 °C again.

In addition, a portion of the flue gas, either directly from the generator or after the flue gas
25 has been filtered and cooled by the gas conditioning system 38, may be directed to the cryogenic vessel/dewar 44, for example liquefied natural gas (LNG) vessels, for heat exchange therewith. The heat exchange with the cryogenic vessel/dewar 44 will cool the portion of the flue gas, specifically the CO₂ contained therein, into liquid or dry ice.

Aspects of particular embodiments of the present disclosure address at least one aspect, problem, limitation, and/or disadvantage associated with existing gas recover systems. While features, aspects, and/or advantages associated with certain embodiments have been described in the disclosure, other embodiments may also exhibit such features, aspects, and/or advantages, and not all embodiments need necessarily exhibit such features, aspects, and/or advantages to fall within the scope of the disclosure. It will be appreciated by a person of ordinary skill in the art that several of the above-disclosed structures, components, or alternatives thereof, can be desirably combined into alternative structures, components, and/or applications. In addition, various modifications, alterations, and/or improvements may be made to various embodiments that are disclosed by a person of ordinary skill in the art within the scope of the present disclosure, which is limited only by the following claims.

Claims

1. A gas recovery system for plant cultivation, the gas recovery system comprising:
 - a generator for generating heat energy and flue gas from natural gas supplied thereto;
 - a temperature conditioning system in thermal communication with the generator for receiving heat energy generated from the generator for one of chilling and heating water for conveyance to a downstream facility; and
 - a bioreactor for receiving the flue gas from the generator for cultivating plants therefrom, the flue gas comprising carbon dioxide (CO₂), the bioreactor being for cultivating algae which consumes the carbon dioxide in the flue gas being provided thereto and for fixating the carbon dioxide in the flue gas with the algae for generating biomass therefrom, the bioreactor comprising at least one of a tray assembly, a flocculation and flotation system and a centrifuge for harvesting the algae being cultivated; and
 - a dryer for receiving the flue gas from the generator for dewatering the algae being harvested into dry algae powder.
2. The gas recovery system as in claim 1, the generator being one of a lean burn natural gas generator and a combined heat and power (CHP) generator.
3. The gas recovery system as in claim 1, the generator being further for generating electrical energy from the heat energy being generated thereby for provision to at least one of an energy storage system and an energy consuming system.
4. The gas recovery system as in claim 3, the energy storage system being at least one of a battery array and a capacitor array for storing electrical energy.

5. The gas recovery system as in claim 3, the energy storage system being at least one of a water reservoir and a water pipe network for storing heat energy.
6. The gas recovery system as in claim 1, the temperature conditioning system being one of an adsorption chiller, a boiler and a hydronic boiler chiller.
7. The gas recovery system as in claim 1, further comprising a storage system for storing and supplying the natural gas to the generator.
8. The gas recovery system as in claim 1, further comprising:
a gas conditioning system interfacing the generator and the bioreactor for filtering and cooling flue gas being provided from the generator to the bioreactor.
9. The gas recovery system as in claim 1, the downstream facility being one of a refrigeration facility and a HVAC system.
10. A gas recovery method for plant cultivation, the gas recovery method comprising:
generating heat energy and flue gas by a generator from natural gas supplied thereto;
providing heat energy generated from the generator to a temperature conditioning system in thermal communication with the generator for one of chilling and heating water for conveyance to a downstream facility;
providing the flue gas from the generator to a bioreactor for cultivating plants therefrom, the flue gas comprising carbon dioxide (CO₂);
cultivating algae by the bioreactor, the cultivated algae consuming the carbon dioxide in the flue gas being provided thereto, and fixating the carbon dioxide in the flue gas for generating biomass therefrom;
harvesting the algae being cultivated using at least one of a tray assembly, a flocculation and flotation system and a centrifuge for harvesting the algae being cultivated; and

dewatering the algae being harvested into dry algae powder by a dryer using the flue gas received from the generator.

11. The gas recovery method as in claim 10, further comprising:

5 generating electrical energy from the heat energy being generated thereby for provision to at least one of an energy storage system and an energy consuming system, the generator being one of a lean burn natural gas generator and a combined heat and power (CHP) generator.

10 12. The gas recovery method as in claim 11, the energy storage system being at least one of a battery array, a capacitor array, a water reservoir and a water pipe network for storing at least one of heat energy and electrical energy, and the temperature conditioning system being one of an adsorption chiller, a boiler and a hydronic boiler chiller.

15

13. The gas recovery method as in claim 10, the downstream facility being one of a refrigeration facility and a HVAC system.

14. The gas recovery method as in claim 10, further comprising:

20 filtering and cooling flue gas being provided from the generator to the bioreactor using a gas conditioning system interfacing the generator and the bioreactor.