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## The Mining Option – Patent Application – Description

WORLD INTELLECTUAL PROPERTY ORGANIZATION

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(Machine translation)

WORLD INTELLECTUAL PROPERTY ORGANIZATION

### Fuel Synthesis Method

### Field of the Invention

The invention relates to methods for making fuels comprising a nitrogen-based compound, and more particularly to fuels comprising urea and guandine. The invention also includes utilising by-products generated during the manufacture of such fuels.

### Background of the Invention

Fossil fuels constitute the largest source of energy in the world.

The vast majority of energy production in the world comes from burning fossil fuels. Reserves of fossil fuels are rapidly being depleted. Burning of fossil fuels also produces Carbon dioxide, contributing to global warming.

Accordingly there is a need for alternative fuels, and to systems that may ease concerns of carbon dioxide emissions.

Hydrogen may be used as an alternative fuel to drive hydrogen engines and/or to fuel fuel-cell energy conversion systems. However, some artisans of this industry suggest that neither it's compressed gaseous nor liquefied form may be sufficiently economical or practical for lending feasibility as a stand-alone alternative fuel solution.

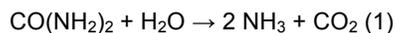
Bio-diesel is an alternative fuel for spark ignition engines. This fuel is a form of vegetable oil. While offering an alternative to the limited sources of the more customary fossil fuel derivatives, the bio-diesel type of alternative fuel may be recognized as being dependent upon the available surplus of agricultural product, and would compete with demands for food production.

Ammonia (NH<sub>3</sub>) represents another type of alternative fuel, which is nitrogen-based as opposed to being carbon based. When used for powering combustion systems, the ammonia exhibits a low flame propagation velocity relative to that of the more conventional hydrocarbon based fuels, and therefore requires certain design consideration. Further, the ammonia as a stand-alone fuel delivery system maybe recognized to pose certain safety risks.

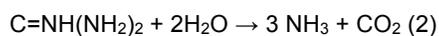
Anhydrous ammonia is a toxic substance. As a gas, ammonia can present a danger to health with a threshold level of 500 parts per million by volume in ambient air. To store a quantity of ammonia equivalent to fuelling an automobile or a truck with an equivalent of 60 gallons of gasoline may require about 342 kg of ammonia. If an accidental rupture were to occur, a toxic cloud of the ammonia could develop over a volume of atmosphere as great as 1 ,000,000 cubic meters.

Also nitrogen based, urea (CO(NH<sub>2</sub>)<sub>2</sub>) has also received some attention as an alternative fuel. It is known to be relatively safe, at least relative to the ammonia delivery models. When consumed as a fuel, the urea may be hydrolyzed with water to release ammonia and

carbon dioxide as represented by equation (1) as follows:



Guamidine ( $\text{C}=\text{NH}(\text{NH}_2)_2$ ) offers another type of nitrogen-based alternative fuel. WO2005/108289 teaches the use of guandine as an alternative fuel that may ease some of the concerns with emissions of greenhouse gases. Additionally, while the conventional fuels are known to pose certain carcinogenic risks that often require expensive procedures for clean-up of spills; guandine, on the other hand, may be characterized in liking with a fertilizer, wherein accidental spills may be handled with greater ease. When consumed as a fuel, the guandine may be hydrolyzed with water to release ammonia and water as represented by equation (2) as follows:



Guandine nitrogen-based fuels also have substantially safer characteristics than the respective safety characteristics of the more general types of fossil fuels. The hazard of fire during a traffic accident or crash landing in an airplane is always a serious concern due generally to the volatility of the otherwise more common types of fossil fuel. In contrast, with a guandine type of fuel system, the guandine will not burn until water and excess engine heat are added for hydrolysis, and thus may be seen to offer valuable safety benefits to the automotive and aero industries.

#### Summary of the Invention

According to an embodiment of the invention there is provided a method of making a fuel comprising a nitrogen-based compound, said method comprising the steps of:

(a) producing hydrogen and metal hydroxide by electrolysis of an aqueous solution containing a metal chloride wherein said solution comprises components selected from the group consisting of water, NaCl, KCl, MgCl, sea water, salt well brine, calcium chloride, and a combination thereof;

(b) exposing the metal hydroxide obtained by the electrolysis to an atmospheric fluid flow to sequester carbon dioxide from the atmosphere and produce at least one of metal carbonate and metal bicarbonate; and

(c) reacting nitrogen with the hydrogen produced from the electrolysis to form ammonia.

Preferably the method comprises the additional step (d) of reacting the ammonia with carbon dioxide to produce urea. More preferably the method comprises the additional step (e) of reacting the urea with ammonia to produce guandine.

Preferably the aqueous solution comprises mainly saltwater or brine and the metal hydroxide obtained by the electrolysis is sodium hydroxide.

Preferably step (b) is conducted in an osmotic exchanger, the osmotic exchanger being operatively configured to flow metal hydroxide solution from the electrolyzer within permeable walls of the osmotic exchanger, and wherein the osmotic exchanger is operatively disposed to expose external surfaces of the permeable walls for gaseous fluid communication with ambient atmosphere.

Reaction of the metal hydroxide by-product with atmospheric carbon dioxide enables carbon dioxide to be sequestered from the atmosphere whilst also converting the caustic metal hydroxide by-product into a non-caustic metal carbonate or bicarbonate. Sodium carbonate is widely known as washing soda, and sodium bicarbonate is widely known as baking soda. Both of these sodium salts have been historically mined for commercial purposes and both have wide ranging applications. Alternatively or additionally, the metal carbonate or bicarbonate can be used as ocean de-acidifying agents.

In a further embodiment, a discharge housing may receive discharge solution from the osmotic exchanger. The discharge housing may be operatively configured to dehydrate the discharged solution to yield carbonate/bicarbonate product for subsequent handling external the system — e.g., as a soda by-product.

In a further embodiment, the system may comprise an osmotic controller that controls at least one of (i) the flow of the ambient atmosphere fluid flow to the external walls of the osmotic exchanger, (ii) the ratio of metal hydroxide to water supplied to the osmotic exchanger, or (iii) the rate of discharge of the solution from the osmotic exchanger; based upon at least one of a concentration of the

metal carbonate/bicarbonate in the solution for discharge.

In a further embodiment, the permeable walls of the gas-to-solution transfer network of the osmotic exchanger may be supported by walls of a tower to a wind turbine.

In a further embodiment, the permeable walls to the osmotic exchanger may be defined at least in part by micro, mesa or macro-porous membrane. In a particular example, the membrane material may comprise a hydrophobic GORE-TEX® micro-porous material.

In a further embodiment, the osmotic exchanger comprises hydrophilic material disposed within an interior of the osmotic exchanger between inwardly facing surfaces of the permeable walls, the hydrophilic material operatively disposed therein for increasing an effective surface area of the solution flow for absorbing the CO<sub>2</sub>.

Preferably step (b) utilises the Haber process wherein the reaction of the hydrogen with nitrogen may be facilitated by a catalyst. Favourably the catalyst is aluminium oxide or potassium oxide.

In a further embodiment, step (e), the method of producing guanidine, may comprise exposing urea to ammonia while irradiating the urea with light. The light irradiation may use a wavelength less than about 1240 nm. Preferably the light irradiation uses a light of wavelength less than about 1240 nm and greater than about 800 nm.

Preferably the electrolyzer is powered by a power source of the group consisting of at least one of solar, geothermal, hydro, hydrocarbon or wind-based energy generators.

The electrolysis may further produce chlorine or hydrochloric acid as a by-product.

The electrolysis may be conducted in a three or four chambered electrolyzer, producing hydrochloric acid as a by-product. At least a portion of the hydrochloric acid produced by the electrolysis may be reacted with at least a portion of the metal carbonate or metal bicarbonate produced in step (b) to produce at least a portion of the carbon dioxide required for step (d).

The electrolysis may be conducted in a one chamber electrolyzer, producing chlorine, Q<sub>2</sub>, as a by-product. At least a portion of the chlorine produced by the electrolysis may be reacted with at least a portion of the H<sub>2</sub> to form hydrochloric acid. Alternatively, at least a portion of the chlorine produced by the electrolysis may be dissolved in water to form hypochlorous acid. The hydrochloric or hypochlorous acid may then reacted with at least a portion of the metal carbonate or metal bicarbonate produced in step (b) to produce at least some of the carbon dioxide required for step (d).

In a further embodiment of the invention at least a portion of the chlorine or hydrochloric acid or hypochlorous acid by-product is introduced into or placed in contact with geological strata or crushed rock containing reactive salts of metals selected from the group comprising: alkali metals (IA of Periodic Table), alkaline earth metals (2A of Periodic Table) and transition elements (IB to VIIB of Periodic Table) or combinations thereof, forming chloride salts of said metals.

The geological strata or crushed rock may contain basalt, or other mineral. Preferably the geological strata or crushed rock contains substantial amounts of iron in the Fe<sup>2+</sup> ionisation state.

In a further embodiment at least a portion of the hydrochloric acid or hypochlorous acid may be reacted with geological strata or crushed rock containing Magnesium silicate and Iron (II) silicate to produce silica powder and chlorine-containing salts of iron and magnesium. The geological strata or crushed rock may contain olivine mineral.

Favourably the chlorine or hydrochloric acid or hypochlorous acid is introduced into the geological strata or crushed rock through seepage into the rock, or by application of pressure.

The chlorine or hydrochloric acid or hypochlorous acid may be introduced into the geological strata or crushed rock through seepage or application of pressure through at least one vertical well. The chlorine or hydrochloric acid or hypochlorous acid may be introduced into the geological strata or crushed rock through seepage or application of pressure through at least one horizontal well. The chlorine or hydrochloric acid or hypochlorous acid may be introduced into the geological strata or crushed rock through seepage or application of pressure through at least one vertical and at least one horizontal well.

The hydrochloric or hypochlorous acid may introduced into the geological strata or crushed rock by removing said geological strata or

crushed rock, applying hydrochloric or hypochlorous acid to the surface and mixing mechanically.

The insertion of a barrier surface may be completed prior to introduction of chlorine or hydrochloric acid or hypochlorous acid to prevent the transfer of chlorine or hydrochloric acid or hypochlorous acid or metal chloride compounds outside of the desired site of geological strata or crushed rock. Such a barrier surface must be impervious to chlorine. Such a barrier surface may be inserted into the area surrounding the geological strata or crushed rock by drilling and injecting a barrier compound into the rock. A suitable barrier compound would be a plastics resin. Alternatively, the geological strata or crushed rock may be removed from the ground and the void lined with suitable impervious liner before replacing the geological strata or crushed rock. Such a barrier is not required in geographical locations where naturally occurring impervious rock formations surround the geological strata or crushed rock to be treated with chlorine or hydrochloric acid or hypochlorous acid.

In accordance with another embodiment, a method of energy conversion comprises reacting guamdine for producing ammonia and/or hydrogen. The ammonia/hydrogen may drive a solid oxide fuel cell (SOFC), wherein hydrogen oxidation within the fuel cell produces electricity along with the release of heat and water in the form of steam. At least a portion of the steam released is used to drive a steam turbine-generator pair for generating further electrical energy. At least a portion of the steam passed through the turbine is recovered and returned to the guamdine hydrolysis process. In a particular embodiment for the energy conversion, the energy conversion system may be used to drive at least one of an electrical motor or power grid.

The invention offers an improved method of making a nitrogen-based fuel in the form of urea or guamdine. The method involves the step of sequestering carbon dioxide from the atmosphere and may be understood to further ease the concerns relative to global warming.

In a further embodiment, the invention offers a means of disposing of excess chlorine or hydrochloric acid or hypochlorous acid produced as by-products of the fuel synthesis method. If such guamdine or urea based fuel is to replace fossil fuels these by-products will be produced in vast quantities.

#### Brief Description of the Drawings

Subject matter for embodiments of the present invention may be further understood by reference to the following detailed description when read with reference to the accompanying drawings, in which:

Fig-1 is a simplified cross-section view of a portion of a carbon dioxide sequestering osmotic exchanger apparatus and flow diagram associated with its use;

Fig.2 is a simplified schematic diagram showing a saltwater /brine electrolysis unit for sourcing (I) hydrogen to the fuel synthesis module and also for sourcing (II) metal hydroxide to a carbon dioxide sequestering, osmotic exchanger apparatus;

Fig.3 is a further simplified diagram illustrating one embodiment of the method of fuel synthesis and showing a wind turbine for the energy source driving the electrolysis unit;

Fig.4 is a further simplified diagram illustrating another embodiment of the method of fuel synthesis and showing a wind turbine for the energy source driving the electrolysis unit;

Fig. 5 is simplified block diagram illustrating an embodiment of the fuel synthesis method of the invention and showing light irradiation of urea in the presence of ammonia for producing guamdine;

Fig. 6 is a simplified block diagram illustrating an embodiment of the fuel synthesis method of the invention, showing a fuel synthesis system in accordance with another embodiment of the present invention and showing ammonia bubbling through molten urea and light irradiation of urea in the presence of the ammonia bubbled therethrough;

Fig.7 is a simplified schematic diagram of a one chamber electrolysis unit that may be used for the electrolysis chamber in fuel synthesis embodiments of the present invention;

Fig.8 is a simplified schematic diagram of a three chamber electrolysis unit that may be used for the electrolysis chamber in fuel synthesis embodiments of the present invention;

Fig.9 is a simplified schematic diagram of a four chamber electrolysis unit that may be used for the electrolysis chamber in fuel synthesis

embodiments of the present invention;

Fig.10 is a schematic diagram showing the use of chlorine in the extraction of metal chlorides from fractured basalt mineral beds;

Fig. 11 is a schematic diagram showing the use of HCl in the extraction of metal chlorides from mineral beds;

Fig. 12 is a schematic diagram showing the introduction of HCl to a mineral bed via surface percolation, and the subsequent removal of metal chlorides via vacuum extraction, where naturally occurring unfractured rock acts as an impervious barrier prevent pollution;

Fig.13 is a schematic diagram showing the introduction of HCl to a mineral bed via a vertical and horizontal well, and the subsequent removal of metal chlorides via vacuum extraction, where impervious barriers have been introduced around the mineral bed to prevent pollution;

Fig.14 is a flow diagram illustrating the option for producing magnesium based cement during the method of fuel synthesis;

Fig.15 is a flow diagram illustrating the option for producing fumed silica during the method of fuel synthesis;

Fig.16 is a flow diagram illustrating the option for producing magnesium metal and hematite during the method of fuel synthesis; and Fig.17 is a flow diagram illustrating the options for producing magnesium based cement, fumed silica, magnesium metal and hematite during the method of fuel synthesis.

#### Detailed Description of the Preferred Embodiments

With reference to Figure 2, fuel synthesis system 200 comprises electrolysis unit 204 powered by a power source 202. Electrolysis unit or electrolyzer 204 is operable to electrolyze a solution of saltwater or brine to produce electrolysis product such as hydrogen and metal hydroxide. In some embodiments of the invention it may further produce chlorine and/or hydrochloric acid. The metal hydroxides may comprise sodium hydroxide, potassium hydroxide or magnesium hydroxide. Typically, the more abundant metal hydroxide is sodium hydroxide.

The metal hydroxide is passed from electrolyzer 204 by line 208 to metal hydroxide solution reservoir 214. It may be understood that the metal hydroxide may be passed to the reservoir in solution of water as provided from the electrolyzer. In further embodiments, a particular pH maybe desired within the reservoir 214 for passage to the osmotic exchanger. If the pH of the solution may be too great by excess concentration of hydroxides, additional water may be added to the reservoir by way of optional source 254 via control valve 258.

The metal hydroxide solution from reservoir 214 may be passed through line 216 via valve 218 to pump 220. The pump, in turn, may drive the fluid input line 222 to the osmotic exchanger 100 via valve 226. In some alternative embodiments, the pump could be removed and the fluid could be propagated through the osmotic network of exchanger 100 under the influence of

6 gravitational forces.

More commonly, however, pump 220 may be used in combination with the various valves as illustrated for representing examples for the osmotic module. These pumps and valves may be understood to lend greater control for the establishment of pH levels and for the sequestering efficiencies of the sequestering module for the fuel synthesis system 200.

To assure that the pressure at the input line 222 does not exceed a certain level, a pressure sensor 224 may be used to deliver a pressure signal 223 to the controller 258. Controller may then govern the operation of pump 220 and valves 218, 226 based upon the pressure sensed and the efficiencies of the flow of fluid through the osmotic exchanger 100. With the assistance of valves 226, 232, the pressure within osmotic exchanger 100 may be kept at a certain predetermined level via regulation by controller 258 based on the pressure sensed by sensor 224. For example, the pressure may be kept close to atmospheric pressure to enable free passage of CO<sub>2</sub> through the permeable membrane material. Normally, the pressure may need to be slightly higher at the input end than at the output end so as to maintain a slow flow rate. It may further be recognized that use of pressures near atmospheric levels may reduce the strength requirements of the membrane material.

Further referencing Figure 2 in association with Figure 1, osmotic exchanger 100 comprises walls of permeable membrane material 101 that define the osmotic conduit with a channel therethrough. Metal hydroxide solution passing through the channel of the osmotic conduit may flow along inwardly facing surfaces 103 of walls 101 of the permeable material. Thus, gases of the external atmosphere may

permeate the walls for interaction with the solution within the channel. For example, referencing the exploded view of Figure 1, carbon dioxide may pass through external face 105 of permeable wall 101 and beyond inwardly facing surface 103 for reaching and interacting with metal hydroxide of the solution within the lumen. As the solution further flows through the channel defined by the permeable walls, additional carbon dioxide of the atmosphere may react with additional hydroxide of the solution for producing metal carbonates and/or metal bicarbonates. Thus, the downstream portion 134 of the osmotic exchanger 100 may exhibit a concentration of carbonate greater than that proximate input 122 of the osmotic exchanger.

The permeable walls 101 of the osmotic exchanger 100 may comprise a microporous, mesoporous or macroporous membrane material. The pore size freely passes atmospheric gases, including carbon dioxide, while excluding liquid such as water from entering or exiting the membrane. For relative understanding, microporous may refer to a pore size of less than about 2nm. Mesoporous may be understood to refer to a pore size of greater than about 2nm and less than about 50nm and macroporous may reference a pore size of greater than 50nm. It may be theorized that a pore size smaller than  $\sim 1\mu\text{m}$  could be sufficient to exclude the liquid water. In a particular embodiment a microporous membrane was selected as a material that was hydrophobic, so as to prevent the membrane from being wetted by the water, an example of such a material is a GORE-TEX® microporous material.

Further referencing Figure 1, the interior channel defined by the inwardly facing surface 103 of the membrane material 101 may be filled with a hydrophilic material to increase the effective surface area of the absorbing solution. A cellulose fiber or nylon fiber may be used to pack the lumen. For example, in a particular embodiment, the fibers of hydrophilic material may be disposed within the channel with a density therein of up to 20% to 90% of the channel volume. Accordingly, the permeable walls defining the lumen to the channel of the osmotic conduit may be wrapped around the hydrophilic fibers and thus retain better structure and/or rigidity. Likewise, the osmotic conduits may be capable of formation with diameter greater than that which might otherwise be required. And similarly, the over-all osmotic network might therefore be realized with lower fabrication cost than otherwise expected with narrow diameter lumens.

It may be further theorized, merely for purposes of facilitating understanding, that perhaps the hydrophilic fibers within the lumen may be effective for enhancing the turbulence of the solution within the channel so as to thus enhance the exchange of gases permeating the walls of the osmotic conduit and thereby enhance the sequestering operability of the solution within the osmotic conduit.

In a particular embodiment, the osmotic conduits for the exchanger may be formed with channel diameter(s) from 1 mm to about 100 mm. The length of these lumens could be formed with an extent up to, for example, 10 to 200 meters long.

Returning with further reference to Fig. 2, the osmotic exchanger 100 could be understood to comprise multiple osmotic conduits as described relative to Fig. 1. Accordingly, the plurality of tubes or lumens as defined by the permeable materials may be referenced as an osmotic exchange network. The osmotic exchange network may be disposed to expose the external walls for communication with an atmospheric fluid flow. In operation, the flow of atmospheric gases to the external walls of the osmotic exchange network may allow carbon dioxide to permeate the pores of the walls for interaction with the metal hydroxides of the solution within the osmotic conduits.

Further referencing figure 2, as the solution propagates to the exit of the osmotic exchanger, a pH sensor 230 may monitor the pH and send a signal to controller 258 regarding the pH. Based upon the pH determined, controller 258 may control valve 232 via line 231 for opening or closing the valve for either recirculation path 236 or discharge port 234. Accordingly, the portion of solution initially passed through the osmotic exchanger may be recalculated. That is, it maybe passed back for further reprocessing via fluid path 236, pump 248 and line 250 via valve 252 for return to metal hydroxide reservoir 214. As maybe recognized, pump 248 may be used to counter gravitational forces and likewise to counter pressure within reservoir and/or for establishing sufficient pressure by which to punch-through check valve 252.

By such recirculation control, the controller 258 may be able to regulate the flow of the absorbing solution through the membrane exchange network. Additionally, the return loop may allow the fluid to make multiple passes through the osmotic network as may be required to meet a given level of pH via the sequestering of carbon dioxide from the atmospheric conditions. Once the level of pH has been established, the controller 258 may enable the valve 232 for discharge of sent solution via discharge line 234. In one example of operation, the input pH may be in the range near  $\text{pH} = 14$  (perhaps 13-15) proximate sensor 228. The desired target range for the pH at the output is about 8.2 for enabling ocean disposal. For given processes where it is desirable to have the solution consist primarily of carbonates, the pH solution may be alternatively targeted for a range greater than 10.3, e.g., perhaps 10.3 to 12.3.

In accordance with a further particular embodiment, the discharge may be realized along path 238 for release to an external body of water 240 such as, for example, an ocean. In such embodiment, controller 258 may monitor 241 the pH of the ocean by way of, for example, sensor 242. The controller may thus regulate the release along path 238 based upon the comparison of the pH of the ocean relative to that of the solution for discharge. For example, the pH of the solution for discharge may be monitored for a pH slightly higher than that of the external body of water. Upon so determining, the controller 258 may enable discharge of the solution into the external body of water. Thus, upon establishing a level of pH of 8.2 as being slightly more basic than the ocean pH of 8.1, the discharge may be

effected and likewise may serve to assist stabilization of the ocean pH.

In an alternative embodiment, further referencing Fig. 2, the discharge from the osmotic exchanger is routed to dehydrator 244 by way of discharge line 239. As thus implied, the dehydrator 244 may dehydrate the carbonate solution for metal bicarbonate and carbonates byproduct, which may then be released to land dumps and/or for external handling or transport — e.g., as washing soda product.

In further embodiments, as the dehydrator dehydrates the discharged carbonate solution, a portion of the water may be recovered and routed back to the optional water source reservoir 256 via fluid line 246. It may be understood that line 246 inherently may include a pump and valves (not shown) operable to assist the circulation of the recovered water back to the optional water reservoir 256. It may similarly be understood that such recovery module may further include a condenser (not shown) that may condense the steam recovered from the dehydrator.

Further referencing Fig. 2, the fuel synthesis by one perspective and embodiment, could be understood to be defined by the generation of the hydrogen gas at fluid line 206. However, as mentioned earlier herein, this form of elemental hydrogen may be understood to pose certain practical limitations in application as the raw fuel for transport and/or application in propulsion systems. Accordingly, in a further embodiment of the present invention, the hydrogen is passed 206 to an ammonia synthesis vessel 210.

In ammonia synthesis vessel 210, the hydrogen is combined with nitrogen to form ammonia. This vessel may incorporate known methods of synthesis such as that of the Haber process wherein the reaction of the hydrogen with nitrogen may be facilitated by a catalyst as known, such as for example a catalyst of an iron catalyst and/or via further promoters such as aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) and potassium oxide (K<sub>2</sub>O).

The ammonia from ammonia synthesis vessel 210 may be further passed to urea/guandine synthesis vessel 212.

It may thus be recognized that the synthesis of urea from ammonia requires a combination of ammonia with carbon dioxide by which to form the urea molecule, as represented by the equation (3) as follows:



In certain regions, the available quantity of carbon dioxide may be limited. Accordingly, to facilitate the urea production from the guandine, the carbon dioxide might be initially thought as having to be sourced from an external source. Alternatively, in accordance with a further embodiment of the present invention hereby disclosed, a process may be used for recovering carbon dioxide from the metal carbonates formerly sequestered by the osmotic exchanger.

[0068] For such embodiment, the metal carbonate discharged from the sequestering osmotic exchanger may be treated with hydrochloric acid (HCl) for releasing carbon dioxide and the associated metal salt. In a particular example for the electrolysis unit 204, referencing Fig. 2, the HCl may be sourced as one of the by-products (not shown specifically in Fig. 2) resulting from the electrolysis of saltwater. This HCl may be used as the acid for reaction with the metal carbonate resulting from the sequestering osmotic exchanger. The resulting carbon dioxide recovered may then be passed to the urea synthesis vessel 212 for assisting the formation of urea when combined with the ammonia. It may be recognized, therefore, that such optional embodiment of the present invention may permit the carbon dioxide sequestering fuel synthesis system to be employed in geographic territories/regions of the world of low concentration or availability of carbon dioxide.

Moving forward with reference to Fig. 3, in accordance with a particular embodiment of the present invention, the power source 202 as referenced in Fig. 2 may be recognized as a wind turbine power source. Wind of an atmospheric fluid flow may drive the turbine blades of the wind turbine 302 by which to provide electricity for powering the electrolysis unit 304. Again, the electrolysis unit 304 may produce product of metal hydroxide for output 314 and hydrogen that is delivered via fluid line 306 to ammonia synthesis vessel 310. This ammonia is in turn passed to urea/guandine synthesis vessel 312.

Tower 370 supports the wind turbine 302 at a height sufficient to allow rotation of the turbine blades. Supported and extending along a partial height of the tower 370, osmotic exchanger 100 may receive and flow the metal hydroxide solution within the osmotic exchange network of the osmotic exchanger 100. It may be recognized that this osmotic exchange network may comprise an embodiment such as that described previously herein relative to Fig. 2. Again, discharged solution may feed a discharge collection reservoir 339. This concentration of this collection reservoir may be kept at a pH via a concentration of the carbonate/bicarbonate dependent upon the rate of metal hydroxide feeding the osmotic exchange network and the level of recirculation within the osmotic exchange network and rate of sequestering from the ambient atmospheric fluid flow. Again, in particular embodiments, the concentration of metal hydroxide that feeds the osmotic exchanger along with the circulation and recirculation within the osmotic exchanger may be controlled by a controller for establishing a ratio of carbonates/bicarbonates for a predetermined level of pH in the discharge reservoir. With a given level of pH

established in the discharge reservoir 339, the solution may then be released to the external body 340 of water (e.g., ocean) via line 338.

Chlorine gas 360 may be a by-product of the electrolysis unit 304. This chlorine gas must be stored 362 or used in further application as described further below.

Figure 4 illustrates another embodiment of the invention. Any renewal source of energy such as wind, geothermal, solar, wave, or tidal energy may be illustrated as the source of generated electricity. Again, a wind turbine 402 provides the power source for the electrolysis unit. In this embodiment the electrolysis unit 404 produce products of metal hydroxide for output 414 and hydrogen that is delivered via fluid line 406 to ammonia synthesis vessel 410, as well as oxygen 408 and hydrochloric acid 460 as by-products. The ammonia is passed to urea/guandine synthesis vessel 412 and the hydrochloric acid 460 is stored 462 or used in further applications as described further below.

Fig. 5, illustrates a urea/guandine synthesis system 500 receives ammonia by way of valve 598 and carbon dioxide via valve 599, which in turn are collectively input to reaction vessel 580 via fluid input line 597. The reaction vessel is heated to a temperature greater than 100° C, while the gases of ammonia and carbon dioxide move upward into the reaction vessel 580. In further embodiments, the reaction vessel 580 may be kept at temperature sufficient for sustaining molten state of the guandine/urea in the collection reservoir at the bottom. For example, the temperature may be kept at a level of 35° C to 150° C.

The upward flow of gases in the reaction vessel 580 is facilitated by gas circulatory circuit defined at least in part by exhaust line 584, which in turn passes the gases to condenser housing 586. The condenser housing includes an ammonia and carbon dioxide gas recycle line 590 that can be kept in a forward flow through the recycle line via at least one of a Ventun effect at the junction of line 590 relative to the further recycled line 596 and/or in combination with a similar Ventun effect proximate the input line 597 acting upon the junction of recycle return line 596.

During synthesis, as the ammonia and carbon dioxide move upward in the reaction vessel 580, they encounter reactor baffles 582 which may serve to agitate the gases together with the enhanced temperatures so as to react and facilitate the urea formation from the gas reactions. As the urea then begins to move downward under the influence of gravitational forces, the urea is further exposed to ammonia and may thus further react for producing guandine. To enhance this reaction of the urea with ammonia for enhanced efficiencies in the production of guandine, a light may be irradiated into the chamber to strike the urea and to excite its molecular state for stimulating its further reaction with ammonia.

In a particular embodiment, the light source 503 may comprise at least one of a light emitting diode or solid state laser of energy of about 1 eV, which may be of a wavelength less than 1240 nm. In the case of a solid state laser such as a gallium arsenide solid state laser, the monochromatic light may be of wavelength less than 1240 nm and greater than 800 nm, and may be directed an incident beam 505 into the chamber for acting upon particles of urea in the environment of ammonia. In actual applications, the urea molecules will have a range of energy levels, due to molecular vibrations and rotations, and complexes with adjacent molecules, so there will be a range of light energies, near 0.9 eV, that will be suitable for exciting the urea molecules. By certain embodiments of the present invention, light-emitting diodes (LEDs) or solid state lasers that emit light with energy near 1 eV, or equivalent to a wavelength below 1240 nm may be proposed with suitable energy. In practice an array of infrared lasers or LEDs may be mounted outside a section of the reaction vessel 580 that is to contain the ammonia and urea in a solvent that is either water or an alcohol or may contain the urea in its molten form without any added solvent. If mounted external the reaction vessel, the portion of the vessel may comprise a window that is essentially transparent to infrared light. Alternatively, the arrays or lights can be mounted inside the reaction chamber and kept cooled to a temperature below the maximum operating temperature of 85 C.

Further referencing Fig. 5, as the urea and guandine forms, it falls to the bottom of the reaction vessel 580 as a solution of molten guandine/urea. The resulting water vapor and excess un-reacted ammonia and carbon dioxide gases that do react during a first passage may exit through an exhaust gas line 584 and be passed to condenser chamber 586. In the condenser housing, cooling coils 587 may cool the exhaust gases, which in turn may condense water while keeping the majority of the exhausted ammonia and carbon dioxide in their gas state; although, a certain amount will be dissolve into the recovered water. The water condensed will accumulate within the collection tank 588 within the condenser 586. Gas passages in the walls of the condenser chamber 586 permit the escape of the carbon dioxide and the ammonia to the recycle line 590.

The water collected in the bottom of the collection tank 588 is then passed to the water reclamation vessel 594 via fluid line 591 and pressure reducing valve 592. The water passed into the water reclamation housing 594 may experience a reduced pressure operable to outgas gases such as any ammonia and carbon dioxide that may have been dissolved therein. The out-gassing of carbon dioxide and ammonia may be pumped via pump 595 via return line 596 back to the gas input line 597 for the reaction vessel 580. It may be recognized that the pump 595 may be operable to establish a low pressure atmosphere within the water recovery out-gassing chamber 594 at least relative to the operability of the pressure reducing valve 592. Water 507 reclaimed in the bottom of the reclamation housing 594 may then be released to the waste reservoir 511. As the level of the molten guandine/urea reaches a certain threshold within the

reaction vessel 580, valve 501 may be opened to release and source the guamdine/urea for external use.

In accordance with an alternative embodiment of the present invention, referencing Fig. 6, a guamdine synthesis system 600 receives urea from a bulk urea tank 627 via valve 629 for entry to reaction vessel 680. Ammonia may be supplied to the reaction vessel 680 from input 615 via valve 613. Ammonia passes to an ammonia chamber of the reaction vessel 680. From the ammonia chamber, it may pass into the urea through a gas permeable wall 617. As passed through the permeable barrier wall, the ammonia bubbles through the molten urea/guamdine reservoir 681.

As the ammonia bubble through the urea, light from a light source 603 may be irradiated into the molten solution for assisting the reaction of the urea with the ammonia for producing the guamdine. As represented earlier for embodiments described relative to Fig. 5, the light may comprise at least one of a light emitting diode or a solid-state and/or gallium arsenide solid state laser of energy greater than about 0.9 eV, as may be associated with wavelength less than 1240 nm. In further embodiments, the light may be of wavelength less than about 1240 nm and greater than 800 nm.

As the ammonia reacts with the urea to form guamdine, it may yield water vapor which is then exhausted out of the reaction vessel 680 by way of exhaust line 684 via pressure sensitive valve 631. Additionally, the excess ammonia that does not react may similarly be exhausted through the exhaust line. This recovered gas is passed to the condenser 686.

Further referencing Fig. 6, the gases passed to condenser 686, similarly as describe before relative to Fig. 5, may be cooled by the condenser coil 687 for recovering water droplets 689 that may collect into the water collection tank 688 near the base of the condenser chamber 686. Ammonia gases may exit the condenser chamber via the recirculation pump 621 in recovery line 690, 623. This recovery line may pass the ammonia back to the ammonia chamber of the reaction vessel 680. The water recovered in the collection tank 688 of the condenser chamber 686 may be passed to the water reclamation housing 694. Again, the pressure may be reduced in this housing to assist out-gassing of dissolved ammonia for reclamation of the water 607. The out-gassed ammonia may likewise be pumped back to the ammonia chamber of the reaction vessel 680 via pump 695 in recovery line 696. The water reclaimed may then be released via valve 609 to an external water discharge reservoir 611.

The guamdine produced in the reaction vessel may pool at the bottom of the reaction vessel. Accordingly, it may then be output as guamdine/urea output product via output valve 625. As output, it may then be used in subsequent external applications.

Figure 7 illustrates a simple single chamber electrolysis unit 700. Such an electrolysis unit may be used in the embodiments of the invention described previously herein relative to Figs. 2 and 3. With saltwater as the electrolyte, the products of such a unit are hydrogen (H<sub>2</sub>), chlorine (Cl<sub>2</sub>) and sodium hydroxide (NaOH).

Once power is applied to the electrolysis unit the cathode (-) 768 will attract the hydrogen ions for gaining electrons at the electrode and thereby combine to form hydrogen gaseous molecules

H<sub>2</sub> from the chamber, for subsequent output as the hydrogen source 706. At the opposite anode

(+) electrode 766, chlorine anions are attracted to the electrode for release of electrons and combination as chlorine molecules, Cl<sub>2</sub>. These chlorine molecules, in turn, are released from the unit at chlorine output 776. Sodium hydroxide will be output from the hydroxide output port 716. As this reaction is sustained, further filtered seawater may be sourced to the input port 764 of the electrolysis unit 700.

Fig. 8 illustrates a three chamber electrolysis unit 800. Such an electrolysis unit may be used in connection with the embodiments of the invention described previously herein relative to Figs. 2 and 4. In this example, the electrolysis unit comprises three chambers #1, #2, #3. These chambers are separated by respective cation or anion exchange membranes. Anion exchange membrane 872 separates the first and second chambers #1 and #2 respectively. Cation exchange membrane 870 separates the second and third chambers #2 and #3.

Initially, a given level of metal hydroxide such as sodium hydroxide may be provided in the first chamber #1 to serve as a starting basis for the electrolysis unit. Additionally, filtered seawater or brine may be placed in the first chamber #1 to assist its initial starting condition. The second chamber #2 may be primed with a given level of HCl for its starting condition; while the third chamber #3 may be primed with a predetermined level of sulfuric acid. It may be understood that the sulfuric acid in the third chamber may be used to increase the electrical conduction for a sulfate without risk of release of the sulfate ion.

Once primed, power may be applied to the electrolysis unit for operation. The cathode (-) electrode 868 will attract the hydrogen ions for gaining electrons at the electrode and thereby combine to form hydrogen gaseous molecules H<sub>2</sub> from the chamber, for subsequent output as the hydrogen source 806. At the opposite anode (+) electrode 866, the sulfuric acid assists in the preferred affinity of oxygen ions to the electrode for release of electrons and combination as oxygen molecules O<sub>2</sub>. These oxygen molecules, in turn, are released

from the third chamber #3 at oxygen output 876. As the reaction further ensues within the three chamber electrolysis unit, it may be understood that hydrogen cations may pass through the cation exchange membrane 870 from the third chamber into the second chamber. In this second chamber, the hydrogen ions may thereby combine with chlorine ions that have been passed from the first chamber to the second chamber via anion exchange membrane 872. Accordingly, the hydrogen and the chlorine combine to form the HCl at hydrochloric acid output 878 from the second chamber.

At chamber one, while hydrogen is released at hydrogen output 806; it may further be understood that the metal hydroxides, sodium hydroxide in this example, will be output from the hydroxide output port 816 of the first chamber. As this reaction is sustained, further filtered seawater may be sourced to the input port 864 of the first chamber of the three chamber electrolysis unit 800.

Referencing Fig. 9, an electrolysis unit 900 may comprise a four chamber electrolysis circuit, also known as a four chamber electro-dialysis cell. Such electrolysis unit may be used for that of the embodiments described previously herein relative to Figs. 2 and 4. In this example, further referencing Fig. 4, the electrolysis unit comprises four chambers #1, #2, #3 and #4. These chambers are separated by respective cation or anion exchange membranes. A cation exchange membrane 974 separates the first and second chambers #1 and #2 respectively. Anion exchange membrane 972 separates the second and third chambers #2 and #3. While the cation exchange membrane 970 separates the third and fourth chambers #3 and #4.

Initially, a given level of metal hydroxide such as sodium hydroxide may be provided in the first chamber #1 to serve as a starting basis for the electrolysis unit. Additionally, filtered seawater or brine may be placed in the second chamber #2 to assist its initial starting condition. The third chamber #3 may be primed with a given level of HCl for its starting condition; while the fourth chamber #4 may be primed with a predetermined level of sulfuric acid. It may be understood that the sulfuric acid in the fourth chamber may be used to increase the electrical conduction for a sulfate without risk of release of the sulfate ion.

Once primed, power may be applied to the electrolysis unit for operation. The cathode (-) 968 will attract the hydrogen ions for gaining electrons at the electrode and thereby combine to form hydrogen gaseous molecules H<sub>2</sub> from the chamber, for subsequent output as the hydrogen source 906. At the opposite anode (+) electrode 966, the sulfuric acid assists in the preferred affinity of oxygen ions to the electrode for release of electrons and combination as oxygen molecules O<sub>2</sub>. These oxygen molecules, in turn, are released from the fourth chamber #4 at oxygen output 976. As the reaction further ensues within the four chamber electrolysis unit, it may be understood that hydrogen ions may pass through the cation exchange membrane from the fourth chamber into the third chamber. In this third chamber, the hydrogen ions may thereby combine with chlorine ions that have been passed from the second chamber to the third chamber via anion exchange membrane 972. Accordingly, the hydrogen and the chlorine combine to form the HCl at hydrochloric acid output 978 from the third chamber.

At chamber one, while hydrogen is released at hydrogen output 906; it may further be understood that the metal hydroxides, sodium hydroxide in the current example, will be output from the hydroxide output port 916 of the first chamber. As this reaction is sustained, further filtered seawater may be sourced to the input port 964 of the second chamber of the four chamber electrolysis unit 900.

Hydrogen gas is a product of each of the electrolysis units described in Figures 7 to 9. This hydrogen gas is used to form ammonia as discussed in relation to Figures 2 to 6.

Metal hydroxides are a product of each of the electrolysis units described in Figures 7 to 9. These hydroxides are used to sequester carbon dioxide as hereinbefore described, using the osmotic exchanger apparatus described in relation to Figures 1 and 2 to forming metal carbonate or metal bicarbonate as hereinbefore described.

Any oxygen by-products may be vented to the air or captured for industrial use.

As can be seen from Figures 7 to 9, chlorine and/or hydrochloric acid are by-products of the fuel synthesis method of the current invention. Chlorine and hydrochloric acid are important commodities in the World economy, but are difficult to store and/or transport safely. In particular, elemental chlorine is a very toxic gas at standard temperature and pressure. Chlorine may also be dissolved in water to form hypochlorous acid.

Figure 10 illustrates a further embodiment of the invention whereby the chlorine by-product 10 of the electrolysis unit 12 may be pumped using pump 14 through a vertical well 11 into a mineral bed 13, such as fractured basalt or other mineral. Preferably the mineral bed contains substantial amounts of iron in the Fe<sup>2+</sup> ionization state.

Chlorine reacts with the basalt to form chloride salts, which are much more stable and more easily transportable than elemental chlorine gas. These metal chlorides are generally soluble in water so may easily be extracted from the mineral bed and subsequently dried for storage or transport. Metal chlorides can also be reacted with a basic solution of carbonates to precipitate metal carbonates. Metal

carbonates have low solubility, and can be used as a means to sequester atmospheric carbon dioxide or can be stored as valuable raw materials for the production of industrial chemicals and metals.

Alternatively, the chlorine by-product of the electrolysis unit may be reacted with some of the hydrogen produced by the electrolysis unit to form hydrochloric acid, HCl. Or, in a further alternative embodiment, HCl may be a direct by-product of the electrolysis unit, as described with reference to Figures 8 and 9. Figure 11 illustrates an embodiment of the invention whereby the HCl by-product 16 may be pumped or allowed to flow under gravity through a vertical well 18 into a mineral bed 17. The mineral bed may be fractured basalt or other mineral. Preferably the mineral bed contains substantial amounts of iron in the  $Fe^{2+}$  ionization state.

The HCl reacts with the basalt to form metal chloride salts which may be removed from the mineral bed 17 using either a vacuum pump 19 on the surface or subterranean pump 20. The soluble salts can then be dried and safely stored or transported. Alternatively, metal chlorides can be reacted with a basic solution of carbonates to precipitate metal carbonates. Metal carbonates have low solubility, and can be used as a means to sequester atmospheric carbon dioxide or can be stored as valuable raw materials for the production of industrial chemicals and metals.

When HCl or Cb is to be pumped into a geological formation it is important to prevent seepage of these chemicals into surrounding areas.

In some cases this is achieved naturally, through the presence of a naturally occurring region of rock that is not fractured. As illustrated in Figure 12, a region of unfractured rock 22 is impervious to the HCl and/or chlorine, so forms an impervious barrier 23. The HCl 25 resulting either directly from the electrolysis unit 21, or via a chlorine by-product, is allowed to drip and percolate through the surface of the fractured rock 24. The resulting chloride salts are then removed via vertical well 26 using vacuum extraction 27.

In the example shown in Figure 13, an impervious barrier 30 has been introduced into the rock surrounding the extraction site. Such a barrier is typically formed by drilling holes into the geological formation surrounding the area that will be exposed to the hydrochloric acid and using high pressure to inject a non-reactive material, such as a resin or plastic resin or wax that is not reactive to hydrochloric acid, into these drilled holes.

The HCl 33 resulting either directly from the electrolysis unit 32, or via a chlorine by-product, is either pumped or allowed to flow under gravity into mineral bed 31 via vertical well 34 and horizontal well 35. The resulting chloride salts are then removed via horizontal well 37 using vacuum extraction 36.

Preferably the selected geological formation has a geological layer below the useful ore that in effect acts as an impervious barrier. By drilling holes to this foundation layer and injecting a material which is non-reactive to HCl into bores above this foundation layer an encircling barrier of non-reactive material above and on each side of the ore bearing area can be created.

Alternatively, rock may initially be removed from the volume. A liner which is impervious to HCl and/or Cb is then used to line the void, and the rock is then put back into place for treatment with HCl and/or Cb

Many of the best sites for wind (and for wave) energy are situated on basalt formations. These include sites in the Aleutian Islands of Alaska, Argentina, Chile, Iceland, Norway and Scotland. Basalt is rich in oxides of Si, Fe, Al, Mg, Ti, Ca and the alkali metals. Some of the best wind energy sites are rich in the mineral group olivine, which is mainly mixtures of fayalite ( $Fe_2SiO_4$ ) and forsterite ( $Mg_2SiO_4$ ). These minerals can be reacted with hydrochloric acid by-product to form the respective magnesium and iron(II) chlorides and silica ( $SiO_2$ ).

Figure 14 is a flow chart which illustrates how by-products of the fuel synthesis system can be used to make magnesium oxide, MgO, and magnesium cement. There is a demand for MgO to make cement and other building materials. MgO may be formed from the MgCb obtained from reaction with olivine mineral combined with the sodium hydroxide obtained from the electrolysis of saltwater. A four chamber electrolysis unit 40 as described with reference to Figure 9 is used to electrolyse a saltwater solution. By-products of the electrolysis unit 40 include hydrochloric acid 41 and sodium hydroxide 42. Magnesium and iron (II) chloride,  $(Mg_5Fe)Cb$  58,59, are formed through reaction of the hydrochloric acid by-product 41 with olivine mineral 44. Sodium carbonate,  $Na_2CO_3$  45 is formed through reaction of the sodium hydroxide by-product 42 of the electrolysis unit 40 with carbon dioxide when the pH is greater than 7. This can be achieved using the osmotic exchanger apparatus described with reference to Figures 1 and 2. Reaction 46 of these metal chlorides with sodium carbonate 45 produces a mixture of iron (II) carbonate and iron (II) hydroxide 48, magnesium carbonate 47 and sodium chloride 49. The iron (II) carbonate may be removed by increasing the pH, decreasing its solubility. The sodium chloride by-product 49 can be removed easily due to its increased solubility in cold water.

Magnesium carbonate 47 is then heated at  $650^{\circ}C$ , producing magnesium oxide, MgO 50, which can be combined with Portland cement 51 to form Eco-Cement™ 52. Eco-Cement™ is a type of cement which uses MgO combined with Portland cement to reduce the

environmental impact relative to conventional cement. The Eco-cement™ comprises 15-95% MgO and 5-85%

Portland cement. Carbon dioxide 53 released during this reaction may be recycled through combination with NaOH to form sodium carbonate. NaCl 49 released during this reaction may be recycled by solubilising and subjecting to electrolysis in electrolysis unit 40.

Figure 15 illustrates how by-products of the fuel synthesis system can be used to make fumed silica, SiO<sub>2</sub>. This can be processed into 'sugar sand' through combination with a quantity of FeCb. Such sand is much appreciated on beaches because one can walk on it comfortably in bright sun and high ambient temperatures. It can also be used to make concrete with very high albedo so that buildings in hot climates do not need nearly so much air conditioning and roads do not degrade as quickly due to excessive heating. As shown in Figure 15, in reaction chamber #2, olivine mineral 44, (Mg,Fe)<sub>2</sub>SiO<sub>4</sub>, is combined with the HCl by-product 41 from a four chamber electrolysis unit 40. This results in the products magnesium chloride 58, iron (II) chloride 59 and H<sub>4</sub>SiO<sub>4</sub> 60. H<sub>4</sub>SiO<sub>4</sub> 60 can then be heated in heating unit 62 to form fumed silica, SiO<sub>2</sub> 63.

Magnesium chloride 58 and iron chloride 59 can then be further reacted with sodium carbonate 45, formed through reaction of NaOH by-product 42 with carbon dioxide when the pH greater than 7. This can be achieved using the osmotic exchanger apparatus 66 described in more detail with reference to Figures 1 and 2. The resulting products are magnesium carbonate 47 and iron (II) carbonate 48. Sodium chloride 49 released during this reaction may be recycled by solubilising and subjecting to electrolysis in electrolysis unit 40.

As shown in Figure 16, the magnesium chloride 58 and iron (II) chloride 59 products of reaction chamber #2 may be further processed to form magnesium metal 70 and hematite, Fe<sub>2</sub>O<sub>3</sub> 71.

Magnesium metal 70 is formed through the electrolysis 72 of molten magnesium chloride. The chlorine by-product 73 of this electrolysis reaction may then be combined with iron (II) chloride 59 to produce iron (II) chloride 74. Iron (III) chloride 74 may then react with sodium carbonate 57 and water to form iron (III) hydroxide 75 which can be dehydrated to form hematite 71.

Figure 17 shows a flow diagram for a 4 chamber electro-electrodialysis based method of fuel synthesis. It summarises the different uses of the HCl 41 and NaOH 42 by-products described in greater detail with reference to Figures 14 to 16. The hydrogen 64 product of the electrolysis unit 40 is used to make urea and/or guanidine 55 as hereinbefore described. The oxygen byproduct 43 may be vented to the atmosphere or used for various industrial applications such as heating 6g coke for steel manufacture.

HCl solutions are also useful for the extraction of valuable materials from ore including copper, silver, gold, nickel and zinc. Some of the best sites for saltwater electrolysis also have sources of such ore nearby. The metal oxides and sulfides present in the ore react with HCl to produce metal chlorides. HCl solutions are useful for the extraction of these materials because the chloride salts of the cations are generally solution in water or melt at low temperatures and because chloride anions bind the cations more strongly than do oxide anions and about as strongly as sulphide anions, for example as in the exothermic reaction set out in equation (4) which follows:



Exhausted coal mining sites or exhausted coal beds are both suitable sites for the extraction of valuable metals using HCl solutions. This method allows valuable mineral exploitation without the need to re-bore entrance holes into the coal seam or conduct additional or extensive geological surveys.

In the method of the present invention, however, the hydrogen is derived from the electrolysis of salt water, rather than from natural gas, and so the production of ammonia, or ammonia-carriers such as urea and guanidine as fuel need not necessarily exacerbate the problem of global warming. Further, the sequestering of carbon dioxide via the hydroxides may be understood to further ease the concerns relative to global warming.

Around 35 million barrels of oil are consumed per day in the US and EU combined. If the goal is to replace petrol with the use of guanidine fuel compositions then equally large capacities of the other by-products (Cb or HCl and NaOH) will be created during this process for producing the hydrogen needed for the synthesis of guanidine fuel. The method of the invention teaches how these by-products can be used.