Ammonia as Hydrogen Storage Media, Sustainable Method to Hydrogen Evolution

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Abstract. The aim of this study is to highlight hydrogen energy as an alternative energy for fossil fuel regarding its producing possibility from cheap, easy and available sources. Since hydrogen gas molecules are smaller than all other gases, they can be leakage through many materials despite considerations taken, which is so dangerous. Therefore, looking for hydrogen-carrier chemicals such as oils, ammonia, and other materials have been attracting the attention of the scientist around the world. Here we review a study about hydrogen energy and ammonia as a source and storage media, focusing on the evolution of hydrogen to be used into advanced power generation device and vehicles applications.

1. Hydrogen

Hydrogen gas, or as it is sometimes called "hydrogen", is one of the elements of the first cycle of the periodic table, it is the smallest element. It is consist of proton and electron., its chemical symbol H, atomic number one, neck above the elements of the first group as well. In the standard conditions of pressure and heat, hydrogen is in the gaseous state, a colorless and odorless gas, a fast-flammable, nontoxic, and also a binary, monoclonal. Hydrogen gas is found in nature in the form of "H2" molecules, which is one of the lightest and abundant elements in the universe. Hydrogen is three-quarters of the size of the universe, which enters most covalent compounds. It is characterized by its hydrogen boiling point "-252 ° C" and its melting point "-259 ° C". It has a water solubility of 1.6 mg/liter. It has the largest dispersion capacity among all gases. Has the highest conductivity of the temperature, and the largest flow capacity. The degree to his wife is low. In the Palmer series, hydrogen shows four spectral lines in the visible spectrum, located at 656, 468, 434, and 410 nm. In the Hydrogen Spectrometer series, there are three strings in the infrared field: the Pashin series, the Prakt series, the Pond series, and the UV series, the Leman series. Hydrogen gas is an insulating gas for electricity.

Hydrogen is the most committing energy carrier’s futurity. It is a high effectiveness, pollution is low in fuel that can be utilized for transportation, power, heating, and generation in places where it is hard to use the electro.

2. Contributing to solving energy problems by using hydrogen derived from renewable energy sources

The energy currently being used as a fuel source is energy-efficient such as oil and fossil fuels. Studies have confirmed that this type of fuel has been introduced by 2053, where oil reserves have been found to last for 50 years, opening the way for a sustainable and environmentally friendly energy source. to solve this problem has been concerned Towards renewable energies.

Sources of Renewable Energy Hydrogen was diverted as a source of renewable energy, clean and sustainable next-generation energy source—is receiving increased attention as an activated secondary energy source for advancing the use of renewable energy.
3. Source of Hydrogen
Hydrogen is the ninth rank among the elements on the surface of the earth in terms of abundance if the elements are arranged according to the weight ratio, but if the order according to the number of atoms, it ranks third after the oxygen and silicon. Most of this hydrogen is in the form of water, but much of it is found in oil and living matter of various kinds. In the rocks, the hydrogen is relatively rare except what is found in the form of water crystallized with salts or absorbed by the clay. This element is abundant in stars and giant gaseous planets but is very narrow in the Earth's crust (1 ppm in size). The most common source of this element is water, which consists of hydrogen and oxygen atoms (H₂O). Other sources include most organic forms (all known forms of life), including coal, natural gas, and other fossil fuels. Methane (CH₄) is an important source of hydrogen.

Hydrogen can be prepared in several ways, such as passing steam on hot carbon, hydrolyzing hydrocarbons, strong base reactions in its water solutions with aluminum, electrolysis of water and acid exchange reactions with metals.

Hydrogen is produced largely by re-forming steam for natural gas at high temperatures (700-110 °C), where steam reacts with methane to produce carbon monoxide and hydrogen. Sunlight uses an energy source in photo electrolysis cell where it is split water to H₂ and O₂. Scientists sought to simulate plants in their ability to analyze water to its first two radicals with the presence of sunlight and chlorophyll, where oxygen and hydrogen are obtained. The latter is used by plants to interact with carbon dioxide to form carbohydrates, and plants have been imitated in the laboratory to produce hydrogen gas.

Although these methods are important for the production of hydrogen, they are expensive and economically inefficient. This has reinforced the idea of using biotechnology to produce hydrogen using some bacteria. This gas is made up of some algae that can produce hydrogen gas naturally from water and with sunlight. [3]

4. Hydrogen Today and Future
Modern civilization is closely associated with oil for the operation of its powerful machines and the development of its industries and agriculture, which are essentially dependent on oil. But the accumulation of emissions, which are metaphorically the waste of burning oil derivatives, affects the environment in a negative way and threatens the climatic changes, particularly in terms of warming the planet Earth, due to the greenhouse effect resulting especially from the accumulation of carbon dioxide.

So, on the threshold of the 21st century, humanity finds itself facing political, economic and environmental crises, security risks and devastating wars no less dangerous than catastrophic geological changes.

More oil consumption will lead to faster threats to the environment and the life itself caused by pollution and, on the other, to the accelerated depletion of this precious resource, which leads to the intensification of conflicts and the loss of these stocks of useful material in the industrial and agricultural fields. Any other material necessary for the survival of humankind at this time of its qualitative and quantitative development.

Many environmentalists and energy scientists believe that only a few decades before the disaster, mankind has to make the necessary and significant transition from the economy of fossil fuel to the hydrogen economy. This requires the exclusion of fossil fuels from all its derivatives and replacement of sustainable alternative energy sources with the use of hydrogen as an energy vector.

Hydrogen Today, we can operate airplanes, cars, trains, ships, factories, heating homes, offices, hospitals, schools and others. Hydrogen, in its gas state, can transport electricity as long distances and through pipelines, efficiently and at the lowest possible cost. Hydrogen can be powered by energy fuel technology or other energy-generating machinery to provide consumers with electricity, clean drinking water and hydrogen as a chemical element with different uses and applications other than electricity. Hydrogen fuel uses can be classified mainly into the following four main fields:
1. Fuel for transport media (cars, aircraft) operating on hydrogen fuel cell technology and its wider applications for future use in power plants.

2. It can be used as a battery with a range of devices ranging from the small ones used in mobile personal computers to the hydrogen transport vessels that transport them from renewable power stations to remote power stations to solve the problems and costs of long networks and energy losses through them.

3. Generated fuel for thermal energy by burning it directly in boilers in power stations, in addition to being used as a propellant in rockets.

4. Nuclear fuel is a factor in nuclear reactors, especially the ITER technology, which works on the principle of power generation on the surface of the sun.[1]

5. Methods and problems of hydrogen Storage

Hydrogen storage safely and efficiently are the major technological difficulties that currently prevented barring the widespread adoption of hydrogen as an energy carrier and transmission to a so-called hydrogen economy.

1. The most general ways of hydrogen storage is gas compression of at high pressure > 200 bars. at ambient temperature, gas in- and out-flow are simple. However, the density of storage is low than other ways.

2. Liquid H₂, 25% to 45% of the energy consume to store it is liquefied with hydrogen. The storage density of the hydrogen is very high since hydrogen boils at -253 C° the necessary to maintain it is low temperature a large thermal insulation. Energy density of hydrogen can be improved.

Hydrogen storage as Solid state

- chemical storage: material absorb hydrogen under high pressures to form hydride, the process is reversible. The high weight is the main problem in this method of the absorbent material [1].

- Physical storage: micro materials - the most recent topics of hydrogen storage. At the applied pressure nanotubes, zeolites (microporous aluminosilicate) Activated carbon and metal-organic frameworks (MOFs) can be bonded weakly with hydrogen. [3]

6. Ammonia as an alternative to hydrogen sources

Extract hydrogen from ammonia and use it as clean fuel. Ammonia has been utilized for a long time to produce fertilizers and animal feed. It is also used as domestic detergents. Scientists wanted to use it as a kind of fuel where we get a clean source of energy. Scientists have made great efforts to do so, but their efforts have been hampered by the strength bonds between N₂ and H₂ atoms in the ammonia particles ... but they can be found a solution where:

At Princeton University three researchers discovered a method to weaken these bonds and not only that, but also released the hydrogen atoms, which are then binding together to form hydrogen gas.

Their research papers were published in the journal Matte Pezdek, in which one of them, Paul Churking, described the possibility of using this method as a new source of hydrogen. Another, Jessica Hoover, presented a model of this work in the same article published in the journal with the University of Virginia. Will also outline the impact of these results and will most likely be able to store, exploit and use hydrogen energy.

The new method also used ammonia with phosphine and ammonia. Hoover noted that the bond between nitrogen and hydrogen adheres homogeneously. When it breaks down, it produces a one of the hydrogen atom that is free and combines with another like hydrogen gas, which can then be marge and eventually burned to supply multiple types of engines and this is likely to leave an important impact on energy systems. This method is more efficient than other methods such as extracting hydrogen or adding an oxidizing element, and we may be capable to access more efficient methods afterward if we work on ammonia preparation methods.

despite the large numbers of complex compounds of transitional metals resulting from ammonia or water merging so that it gives a couple of electrons and a covalent bond, only a few know the extent to which consistency affects the bonding strength between nitrogen and hydrogen as well as between
oxygen and hydrogen. "Molybdenum ammonium supported by phosphine and terpyridine", which reduces the heat needed to break the nitrogen-hydrogen bond from 99.5 gaseous to a measurable value of 45.8 kcal per mole, Hydrogen heating on an insignificant addition to hydrogenation styrene; the compounds of similar Molybdenum They promote the bilateral liberation of hydrogen from water and harmonious hydrazine. The electrochemical and theoretical study has demonstrated the contribution to the influence of the oxidative stress reduction of minerals and ammonia acid.

The cost of ammonia energy is more than the cost of hydrogen unless hydrogen has minimal energy stored per volume, ammonia is the inexpensive energy source listed in Table 1. Note that these values are established on the HHV of the fuel and do not have the cost of conversation on to the useful forms the estimated of energy production from Ammonia a cost is US$1.2/kWh while with methanol is US$3.8/kWh and US$25.4/kWh for H2 [5]. Thus, ammonia offers a very applicable and cost-efficient fuel for fuel cells. [6]

| Fuel Storage System | P(bar) | Energy Density (G/m³) | Specific Volumetric coast (US$/m³) | Specific Energy coast (US$/GJ) |
|---------------------|--------|-----------------------|-----------------------------------|-------------------------------|
| Ammonia gas/prusserized tank | 10     | 13.6                  | 181                               | 133                           |
| Hydrogen/metalhydride | 14     | 3.6                   | 125                               | 35.2                          |
| Gasoline (C₈H₁₈)/liquid tank | 1      | 34.4                  | 1000                              | 29.1                          |
| LPG (C₃H₈)/ prusserized tank | 14     | 19.0                  | 542                               | 28.5                          |
| CNG (CH₄)/integrated storage system | 250    | 10.4                  | 400                               | 38.3                          |
| Metanol/liquid tank | 1      | 11.4                  | 693                               | 60.9                          |

### 6.1. Ammonia definition

Ammonia is a nitrogen and hydrogen compound with the formula NH₃. It is lighter than the air in weight and has a sharp taste, lighter than the air to reduce its mass volume in normal conditions 0.5863 g / Cm 3. The definition of the mullet at -8.77 °C, and boil at the grade (-33.4°C).

Constant value resistance this displacement is 1.8 × 10⁻⁵. The solution has weak alkaline properties. Because of this weak base, salts solutions derived from strong acids such as NH₄Cl are weakly acidic.

Ammonia degeneration in water decreases with high temperature; ammonia can be completely released from its solutions by heating. Ammonia is very soluble in water (0.907 g ammonia in one gram of water) and forms a solution known as ammonia hydroxide (NH₄OH) or ammonia. It contains NH₃, NH₄ +, OH- and ammonia particles that are not very effective when interacting with many chemicals. Most of the ammonia molecules in water remain intact.

Let the ammonia hydroxide a lot of acids and form the corresponding ammonium salts. If hydrochloric acid (HCl) is applied to ammonia hydroxide (NH₄OH), ammonium chloride solution (NH₄Cl) is used. When ammonia hydroxide is combined with some metals. When adding ammonia hydroxide to the blue solution (Cu) (NH₄) 4SO4).

Ammonia gas becomes liquid at -33.35 °C. The ammonia is boiled at the same temperature, and the freezer turns into a solid solid substance at -77.7 °C. In its transition from liquid to gas again, ammonia absorbs a great deal of heat from the outside, so that one gram of ammonia has 327 calories. Actually, fall into the cooling devices.

Pressure and Temperature: This substance cannot be obtained in liquid condition at atmospheric pressure and at a temperature higher than 28 degrees Fahrenheit.
Ignition: This gas ignites if mixed with air venting: This vent can be detected by the smell of smell and reduce the venting place by igniting the fingers of sulfur near and repeat near the place of doubt and the presence of vent and showing white smoke in the case of a vent Lubrication: Ammonia is mixed thoroughly with lubricating oils.

6.2. Ammonia definition

6.2.1. Ammonia Electrolysis. Ammonia Electrolysis technology is electrochemical cell called Ammonia Electrolytic Cell (AEC). The AEC works as described: watery ammonia (NH3/H2O) in the existence of (KOH) is fed into the anode compartment of the AEC where NH3 is oxidized in the existence of OH- in accordance with:

\[
2\text{NH}_3 + 6\text{OH}^- \rightarrow \text{N}_2 + 6\text{H}_2\text{O} + 6\text{e}^-
\]

At the cathode, a solution of KOH provides and water is decreasing in alkaline medium in accordance with:

\[
2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 6\text{OH}^-
\]

All reaction is given by

\[
2\text{NH}_3 \rightarrow \text{N}_2 + 3\text{H}_2
\]

The production voltages of hydrogen at 25 in alkaline media through of the ammonium electrolysis is 0.058 Vs theoretically and consuming energy is 1.55 W-h per gram of H2 production. Potassium hydroxide is the electrolyte of the system and water works as the solvent, that is, neither KOH nor water are consumed through the operation of the cell [9] show figure 1, 2.

6.2.2. Ammonia decomposition. Ammonia decomposition (cracking) is simply the reverse of the synthesis reaction

\[
\text{NH}_3 (g) \rightarrow \frac{1}{2} \text{N}_2 (g) + \frac{3}{2} \text{H}_2 (g) \quad \Delta H = +46 \text{ kJ/mol}
\]

![Figure 1.](image1.jpg) Electrical cell for Ammonia production.  
![Figure 2.](image2.jpg) Ammonia Electrolysis.
Note that the reaction is endothermic. The temperature need for efficient cracking depends on the catalyst. There is a wide kind of materials that have been found to be effective, but some (e.g., supported Ni catalysts) need temperatures above 1000°C. Others have high transformation; efficient of temperatures is extended from 650 to 700°C. A probable design for an ammonia cracking reactor is demonstrated in Figure. 4 illustrative system of ammonia decomposition.

The ammonia Liquid would be pumped from a storage tank through a heat exchanger to take waste heat from the hot gases out of the cracking reactor. The heated gases would then go through a furnace or catalytic combustor to heat them to the temperatures is necessary for the reaction. The flow exiting the reaction would go to a portions system which would be optimized to produce a very pure flow of hydrogen while still leaving sufficient hydrogen with the nitrogen and un-reacted ammonia to equip heat for the endothermic cracking reaction. [10] Figure 3. show system of ammonia decomposition.

![Ammonia decomposition systems](image)

**Figure 3.** Ammonia decomposition systems.

6.2.3. **Produce hydrogen from Ammonia by the solar cell.**

A group Australian National University which working in the field of solar thermal energy has been the attention of separation ammonia system by using solar energy, their experimental titled solar driven ammonia based closed loop thermos-chemical energy storage system. The system uses a whole receiver including 20 reactor tubes filled with iron-based catalyst material exposed to collect the radiation from a 20m² dish solar concentrator that dissociates ammonia under the effect of concentrated solar energy so that the products can be stored and recycled through a conventional ammonia synthesis converter to achieve 24 h power production. They also demonstrated the reliability of the operation over a range of conditions including cloud transients has been demonstrated [11]. show figure 4.

7. **Ammonia Applications**

7.1. **Applications of ammonia in electric power production units (fuel cell)**

The ammonia fuel cells operate under the same principles as conventional alkaline cells by transferring hydroxide ions through the cell solution with an electrochemical membrane. The reaction at the cathode is given by [12]:

\[
O_2 + 2H_2O + 4e^- \rightarrow 4OH^- + O_2 + 2H_2O + 4e^- \rightarrow 4OH^- (1)
\]
At the anode:

$$2\text{NH}_3 + 6\text{OH}^- \rightarrow \text{N}_2 + 6\text{H}_2\text{O} + 6\text{e}^- + 2\text{NH}_3 + 6\text{OH}^- \rightarrow \text{N}_2 + 6\text{H}_2\text{O} + 6\text{e}^- \quad (2)$$

This gives an overall reaction of:

$$4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O} + 4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O} \quad (3)$$

Figure 6 shows direct ammonia fuel cell show working mechanism of ammonia alkaline exchange membrane fuel cells (AEFC) Figure 5 direct ammonia fuel cell show working mechanism of ammonia (AEFC) [13] Ammonia is involved in many applications of hydrogen fuel cells as a source of direct and indirect energy.

Ammonia is involved in many applications of hydrogen fuel cells as a source of direct and indirect energy. Figure 6 shows ammonia applications in the unit of electric power.

7.2. Applications of ammonia in internal combustion engines.

Liquid ammonia is suitable for vehicle fuel in the era of sustainable H\textsubscript{2} society. Liquid ammonia has a twice higher energy density in storage and half expanded energy in delivery compared with liquid hydrogen.

Ammonia is capable to spark ignition internal combustion engines.

Stable combustion is carried out by using outside by thermal cracker which can control hydrogen fraction.
Pure ammonia is available at high load and overcomes knocking even under highly charged condition. Ammonia fed in SI engine seems to be a good alternate for heavy-duty diesel engines the inclusion of an example of research shows the use of ammonia in internal combustion engines this test was performed on the Lombardini engine. It is a four-stroke engine consisting of two cylinders sparking the ignition engine with water cooling and injection system. Details of the engine specifications are present in Table 2[15].

The tests were measured in the brand hydrokinetic dynamometer. This device gives the power, torque and engine speed. The experiments were performed at 30/70 NH$_3$/H$_2$, 10/90 NH$_3$/H$_2$, 100% hydrogen, 100% methane and gasoline fuel by changing the ignition timing.

| Table 2. Details of the engine specifications. |
|-----------------------------------------------|
| Cylinder number | 2 |
| Cylinder volume | 505cc |
| Electronic Engine Unite | Bosch Motronic |
| Cylinder Bore | 72mm |
| Stroke | 62mm |
| Engine Power | 20.4HP 5000d/d |
| Engine Torque | 34NM 2150d/d |
| Compression Ratio | 10.7:1 |

Fuel is supplied to the inlet-outlet by injection. The tests were performed at 1400 ± 10 rpm, and CO, THC, NO emissions were measured with the MGA 1500 gas analyzer. All test measurements were analyzed at a constant load of 7 ± 0.35 nm and 1400 ± 20 rpm. Figure 7 shows the plot diagram of the engine and gasoline fuel by changing the ignition timing. Fuel is supplied to the inlet-outlet by injection. The tests were performed at 1400 ± 10 rpm, and CO, THC, NO emissions were measured with the MGA 1500 gas analyzer. All test measurements were analyzed at a constant load of 7 ± 0.35 nm and 1400 ± 20 rpm. Figure 7 the pilot diagram of the engine.

Figure 8 depicts the values of thermal braking efficiency (BTE) versus spark timing for H$_2$, CH$_4$, H$_2$/NH$_3$, and gasoline.

The highest values (BTE) are obtained about 15% H$_2$/NH$_3$ (70/30). The minimum (BTE) values are obtained about 10.84% in hydrogen fuel. When the timing of a spark increases, BTE first increases and then the BTE values are reduced. When BTE is compared to H$_2$, H$_2$/NH$_3$, and BHT, hydrogen is less benzene because of a volumetric decrease in hydrogen.

If NH$_3$ is added to hydrogen, the volumetric efficiency is higher than hydrogen, BTE) than H$_2$/NH$_3$ mixtures. However, NH$_3$ was compared with gasoline, which showed that efficiency and energy increased due to the possibility of high compression ratio Torque and Power.
Figure 7. The pilot diagram of 1- Engine Test Chassis 2- Hydrokinetic Dynamometer 3-Engine 4- Control Unit 5- Main Fuel Tank 6- Regulator 7- Fuel Selection Switch 8- Gas Fuel Tank 9- Mass Flow Meter 10- Exhaust Gas Analyzer.

Figure 8. The values of thermal braking efficiency (BTE) versus spark timing.

Table 3 shows average torque values [N × m] and power values [kW]. Torque and power values are 7 ± 0.35 Nm, 1.06 ± 0.4 kW. Almost all measurements were made in the same conditions (approximately ± 1 temperature and atmospheric pressure) for 70/30 (H₂/NH₃, 90/10 H₂/NH₃), hydrogen (100%) and gasoline fuel in the internal combustion engine.

Emission Parameters of CO, THC, NO and sun MGA 1500 gas analyzers are measured using H₂ and the H₂/NH₃ mixture in the engine.

|          | CH₄ | H₂/NH₃ (70/30) | H₂/NH₃ (90/10) | Gasoline | H₂ |
|----------|-----|----------------|----------------|----------|----|
| Torque (Nm) | 6.83 | 7.03           | 7.02           | 7.34     | 6.65 |
| Power (kW)  | 1.02 | 1.06           | 1.05           | 1.10     | 1.04 |
Carbon, carbon dioxide and HC emissions do not occur. Emission values are not included in Table 4 for each fuel [16].

| NO. | CA (BTDC) | CH₄ | H₂/NH₃ (70/30) | H₂/NH₃ (90/10) | Gasoline | H₂ |
|-----|-----------|-----|----------------|----------------|----------|-----|
| 5   | -         | -   | +5000          | -              | 2779     |
| 10  | -         | -   | +5000          | 657            | 3576     |
| 15  | 347       | +5000 | +5000          | 926            | 3918     |
| 20  | 425       | +5000 | +5000          | 971            | 4980     |
| 25  | 719       | +5000 | +5000          | 1103           | -        |
| 30  | 851       | -   | -              | 1285           | -        |

8. Summary.
In this study, ammonia was treated as a source of energy because it is possible to obtain hydrogen from it in different ways such as ammonia cracking and electrolysis of ammonia, in addition to the use of solar energy to produce ammonia and the cost is less expensive and easier to produce. We also referred to the applications of ammonia as an energy source for the production of electrical energy. Internal combustion engines were concluded.

References
[1] National energy education development hydrogen at glance" [http://www.need.org](http://www.need.org)
[2] Toshiba Group CSR Report 2015,"Highlight of FY2014 Activities 1", [https://www.toshiba.co.jp/csr/en/highlight/2015/pdf/enr_pdf.pdf](https://www.toshiba.co.jp/csr/en/highlight/2015/pdf/enr_pdf.pdf)
[3] A Sherif and et al 2003 " Principle of hydrogen Energy Production, storage and Utilization, Journal of Scientific & Industrial Research 62 46-63.
[4] K. L. Lim et al. 2010 " Solid-state Materials and Methods for Hydrogen Storage: A Critical Review" Chem. Eng. Technol 33 (2) 213–226.
[5] Zamfirescu C and Dincer I. 2008. J. Power Sources 185 459–465.
[6] Kaye IW and Bloomfield DP. 1998 Conference of Power Source (Cherry Hill) 408–409.
[7] Archived from the original on 27 November 2007 "Ammonium hydroxide physical properties" (PDF).
[8] F. Vitse, M. Cooper, and G.G. Botte 2005 "On the use of ammonia electrolysis for hydrogen production" J. Power Sources 142 18.
[9] Ammonia electrolyzer cell AEC.
[10] George Thomas “A Study of Issues Related to the Use Ammonia for On-Board Vehicular Hydrogen Storage U.S. Department of Energy" [http://www.itpowergroup.com](http://www.itpowergroup.com)
[11] Keith Love grove —Concentrating Solar Fuels for export [http://www.itpowergroup.com](http://www.itpowergroup.com)
[12] Potential Roles of Ammonia in a Hydrogen Economy[12]
[13] Electrochem 2010 Solid-State Lett. 13(8) B83-B86.
[14] The power plant as super battery [https://visual.ly/community/Infographics/technology/powerplant-superbattery](https://visual.ly/community/Infographics/technology/powerplant-superbattery)
[15] EMTIAZ ALI BROHI 2014 "Ammonia as fuel for internal combustion engines " Department of Applied Mechanics Division of Combustion CHALMERS UNIVERSITY OF TECHNOLOGY Gothenburg, Master thesis Sweden.
[16] ãÔÎÍ Üç ÇãôNÇÇp Çãôlããålãó ‘’Ammonia as a hydrogen storage and the feasibility for the internal combustion engine ’’.