

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019

Effect of Hydrogen Production from Coal Gasification on Environment

Dr. Anil Kumar

Assistant Professor, Department of Chemistry, D.A.V. (PG) College, Dehradun, India

ABSTRACT: This review deals with coal gasification, which is a process that converts carbonaceous materials, such as coal, petroleum, petroleum coke, or biomass, into carbon monoxide and hydrogen. Coal gasification as a power-generation technology is gaining popularity due to the ready global availability of the raw material (coal), as well as positive environmental issues associated with this technology over other combustion technologies. To ensure optimal process efficiency, an in-depth understanding of the coal properties influencing gasification behavior is required. Gasification performance is dependent on coal type and gasifier configuration. Typically, gasifiers are classified according to the type of reactor used and the way in which fuels and oxidant flow. The choice of gasification technology is dependent on a variety of factors, but coal type is generally the least flexible factor and gasification technology selection is typically based on the coal to be processed.

Hydrogen production by coal gasification is also capable of separating and recovering CO₂ at the same time as necessary hydrogen production and is attracting attention as one of key technologies for achieving a hydrogen society.

There is increasing interest in the role that hydrogen-based energy systems may play in the future, especially in the transport sector. They appear to be an attractive alternative to current fossil fuel-based energy systems in the future, since these have been proven to affect climate due to greenhouse gases emissions. Nevertheless, any future hydrogen-based economy would need to assess the possible global environmental impacts of such alternative energy production. British scientists have recently reviewed current understanding of the fate and behaviour of hydrogen in the atmosphere and characterised its major sources and sinks. They show that, contrary to most expectations, hydrogen is an indirect greenhouse gas with a potential global warming effect. They then quantified the global warming potential of hydrogen in comparison to CO₂ and the global warming consequences of replacing the current fossil fuel-based economy with one based on hydrogen.

KEYWORDS: hydrogen, gasification, coal, environment, production, technology

I. INTRODUCTION

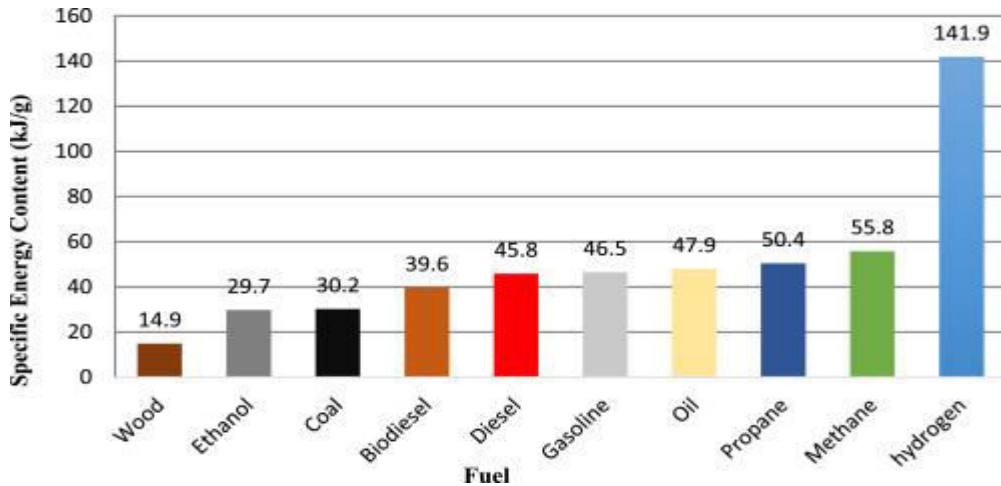
Coal gasification means the complete conversion of coal into gas using heterogeneous gas solid reactions. The main process is the reaction of the carbon of coal with steam, at pressures below 10 MPa and temperatures above 750°C, to form a "synthesis gas" containing mainly CO and H₂ with smaller amounts of CO₂ and CH₄, depending on process conditions. To perform this strongly endothermic reaction in technically feasible systems, the introduction of process heat is necessary, which is possible by transfer of heat from outside (allothermal processes) or by burning part of the coal inside the reactor using oxygen (autothermal processes). This latter process is the basis for the production of hydrogen, ammonia, methanol, hydrocarbons using the Fischer-Tropsch synthesis and methane using the so-called catalytic methanation reaction. Another method for converting coal into a gas is the direct exothermic conversion of coal with hydrogen into methane at a similar range of pressure and temperatures as mentioned above. This reaction can also be combined with the steam carbon reaction and in this way leads to a direct conversion of coal into SNG.[1]

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

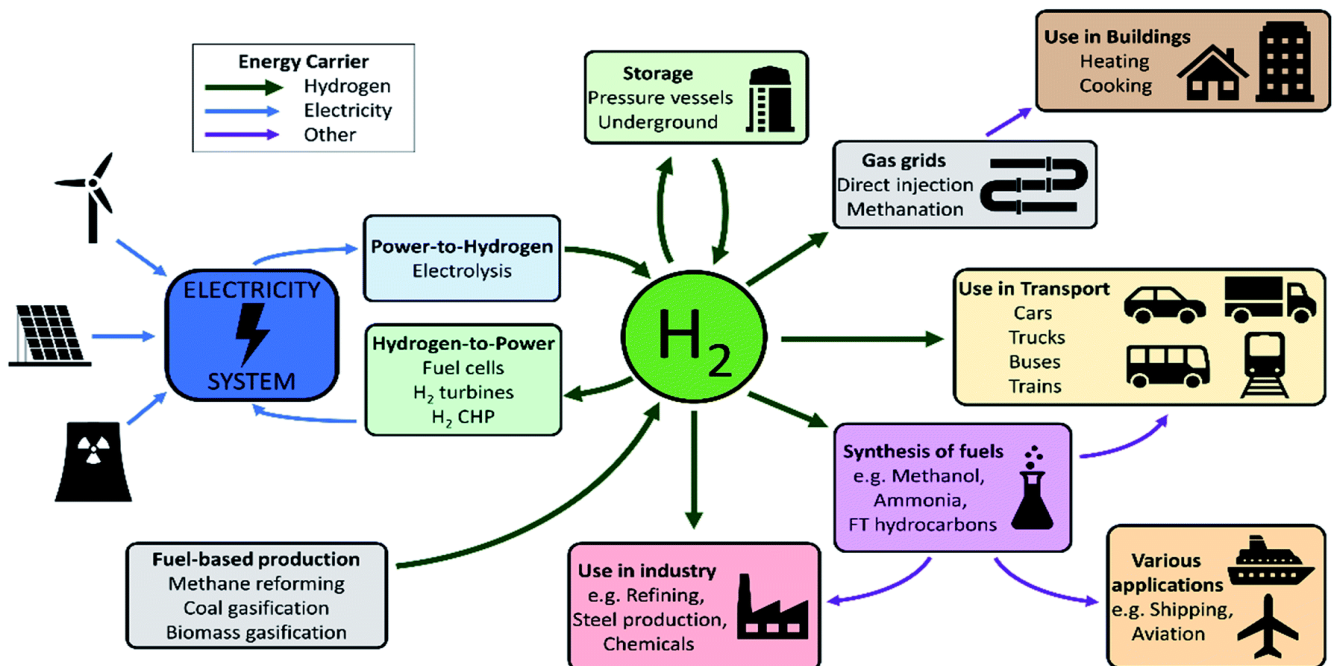
Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019



Hydrogen production options

Coal contains not only carbon but also volatile matter, which is released during the heating up of coal in the gasification reactor by the so-called pyrolysis reactions. The interaction of pyrolysis and gasification of coal is mainly dependent on grain size and rate of heating of the feed coal. At low rates of heating, the pyrolysis products are released first and the remaining char reacts with the gasification agent later on at high temperatures, yielding gaseous products from the carbon. In this case, if a countercurrent of gas and solids in the gasification reactor is induced, the product gas contains pyrolysis products such as tar, phenols and higher hydrocarbons. At high rates of heating, the pyrolysis reaction is shifted to higher temperatures and in this way both–pyrolysis products at the outer grain shell and carbon–react with the gasifying agent to form the gasification products H₂, CO, CO₂, CH₄, and less or no pyrolysis products are found in the product gas.[1]



International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

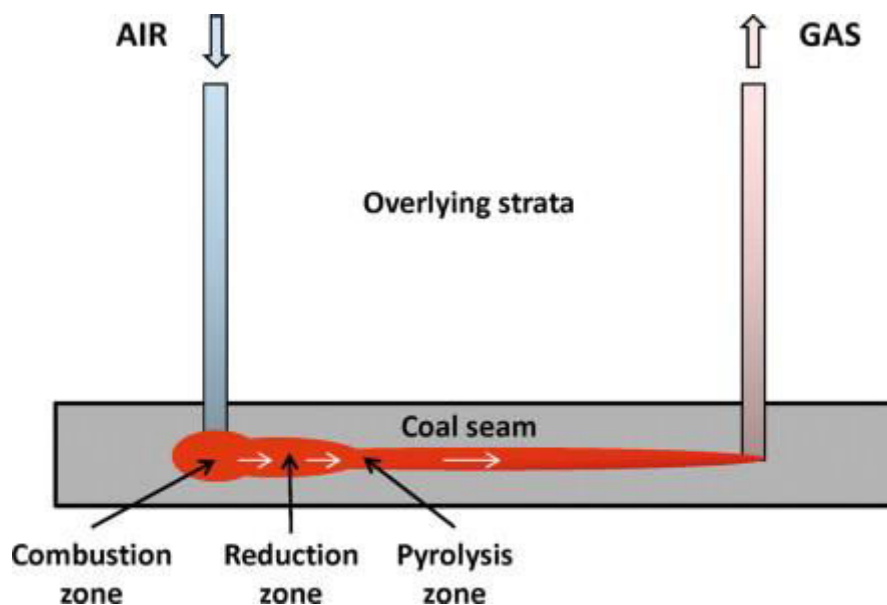
Vol. 8, Issue 11, November 2019

Role of hydrogen in sustainable energy scenario

The nature of the reaction products of coal gasification is primarily determined by the chemical equilibria which are established, especially at high temperatures, and sufficient residence times of coal and products in the gasification reactor. Thus a high pressure and a low temperature increase the methane yield and decrease the hydrogen and the carbon monoxide yield.[2]

II. OBSERVATIONS

Coal gasification can also be carried out on seams that are still in place, the coal being converted to gaseous fuels without an intermediate mining operation. This process, known as in situ or underground gasification, typically involves drilling boreholes to intersect the seam in at least two places, and providing a passage for gas through the seam from one intersection to the other. The coal is ignited at the base of one hole and a gasification agent, such as steam or compressed air, injected into the seam.[2] Heat from the zone of burning coal causes carbonization and gasification reactions in the coal around it, and the position of the reaction zone is controlled by advancing or withdrawing the end of the injection well. The injection process also drives the products of these reactions toward the other borehole (or boreholes), where they are taken off for use.



Gasification process

More than 100 current and planned hydrogen production technologies are reported to date, with over 80% of those technologies are focused on the steam conversion of fossil fuels and 70% of them are based on natural gas steam reforming. However, in order to minimise carbon footprint emissions, a wider range of hydrogen extraction processes, must be addressed.[3]

III. DISCUSSION

Hydrogen is the most abundant element in the universe, and due to its reactivity, it only exists on earth in compounds such as water and organic materials. It is an odourless, flammable and colourless gas, which is leading to its safety

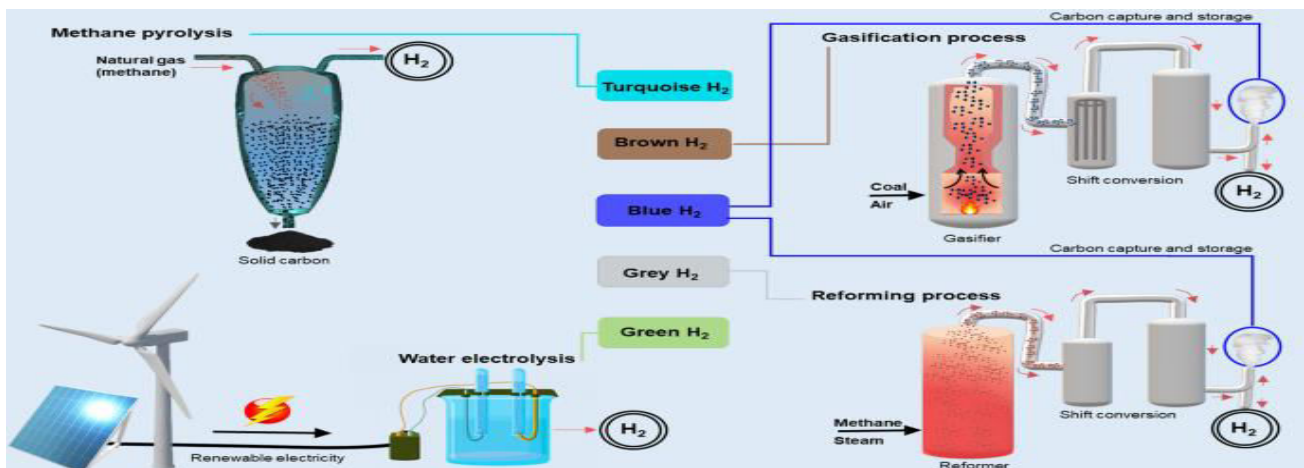
International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019

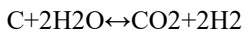
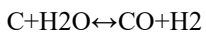
concern, especially if a leak is not detected and gas collects in a confined area; it can ultimately ignite and causes explosions.[4]



Hydrogen production

Hydrogen colour coding for various manufacturing processes. Green hydrogen is produced using renewable energy sources such as solar or wind energy, followed by water electrolysis. Grey and brown hydrogen are produced by methane steam reforming and coal gasification, respectively, and when combined with carbon capture and storage, blue hydrogen is produced. Turquoise hydrogen is produced through the pyrolysis of methane, with solid carbon as a by-product.

During the coal gasification process at high temperatures ranging from 800 to 1300 °C and 30–70 bar pressures, coal is partially oxidised in oxygen or air atmosphere into synthesis gas. The synthesis gas is typically composed of carbon monoxide and dioxide, hydrogen and unreacted methane, where the WGS process enriches the syngas further to recover additional hydrogen. Coal gasification is less efficient than steam methane reforming with 55%, although it has a larger single-train capacity.[5,6]

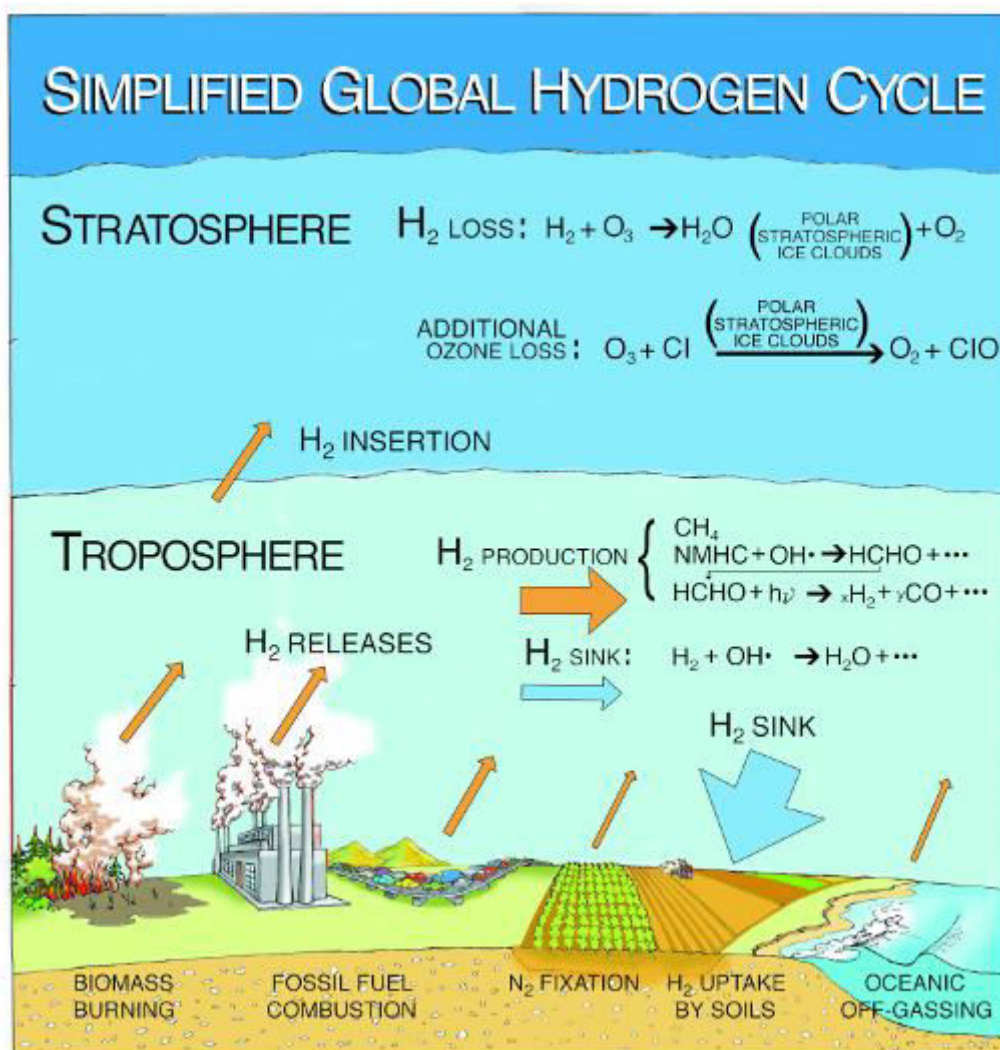


International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019



IV. RESULTS

The results suggest that because hydrogen reacts in the atmosphere with tropospheric OH radicals, the emission of hydrogen into the atmosphere would disrupt the distribution of methane and ozone, the second and third most important greenhouse gasses. Emissions of hydrogen lead to increased burdens of methane and ozone and hence to an increase in global warming. Therefore, hydrogen can be considered as an indirect greenhouse gas with the potential to increase global warming. The scientists have estimated that the potential effects on climate from hydrogen-based energy systems would be much lower than those from fossil fuel-based energy systems. However, such impacts will depend on the rate of hydrogen leakage during its synthesis, storage and use. The researchers have calculated that a global hydrogen economy with a leakage rate of 1% of the produced hydrogen would produce a climate impact of 0.6% of the fossil fuel system it replaces. If the leakage rate was 10%, then the climate impact would be 6% of that of the fossil fuel system. The current study suggests that a future hydrogen-based economy would not be free from climate disturbance, although this may be considerably less pronounced than that caused by the current fossil fuel energy systems. Careful

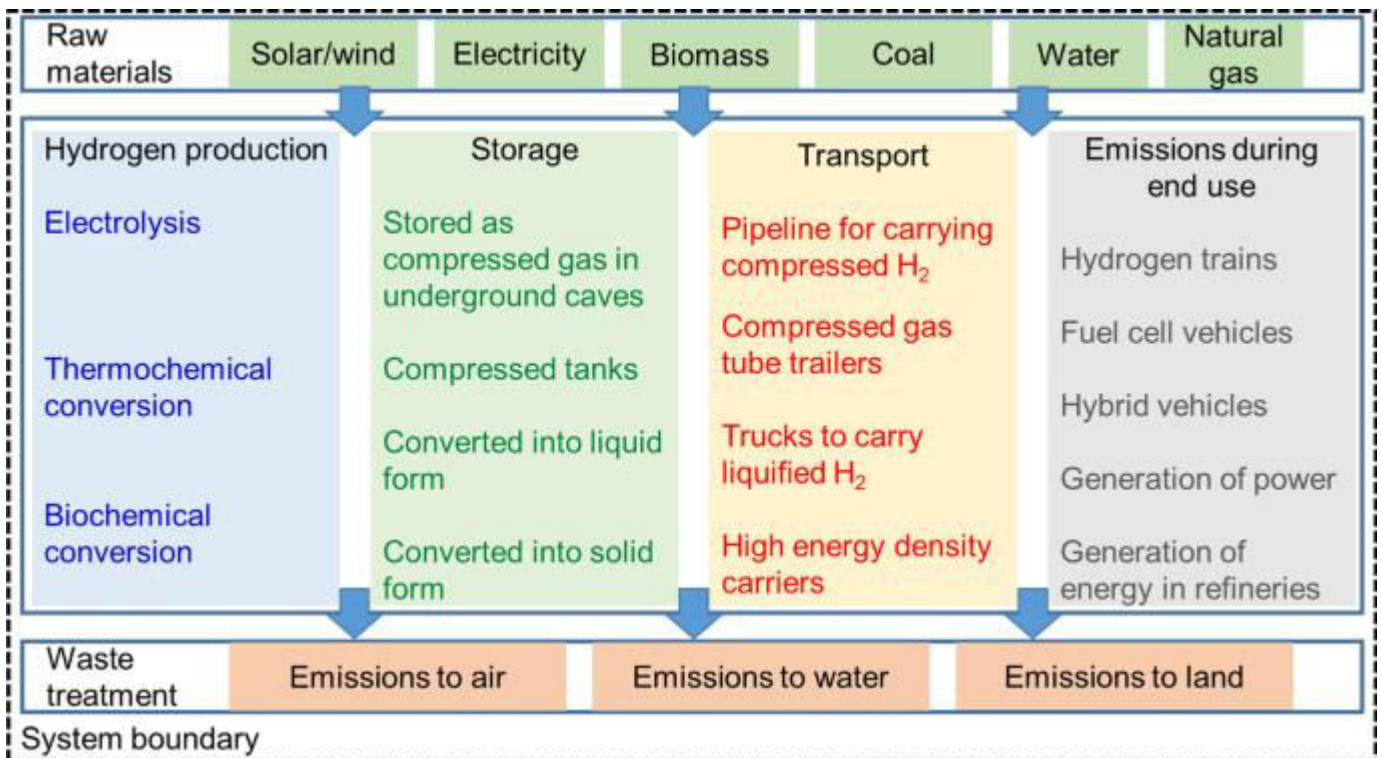
International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019

attention would have to be paid to reducing hydrogen leakage to a minimum if the potential climate benefits of a future global hydrogen economy are to be realised.



Generalised system boundary used for conducting life cycle assessment of hydrogen production and consumption. This includes various raw materials such as solar, wind, biomass, coal, water and natural gas.

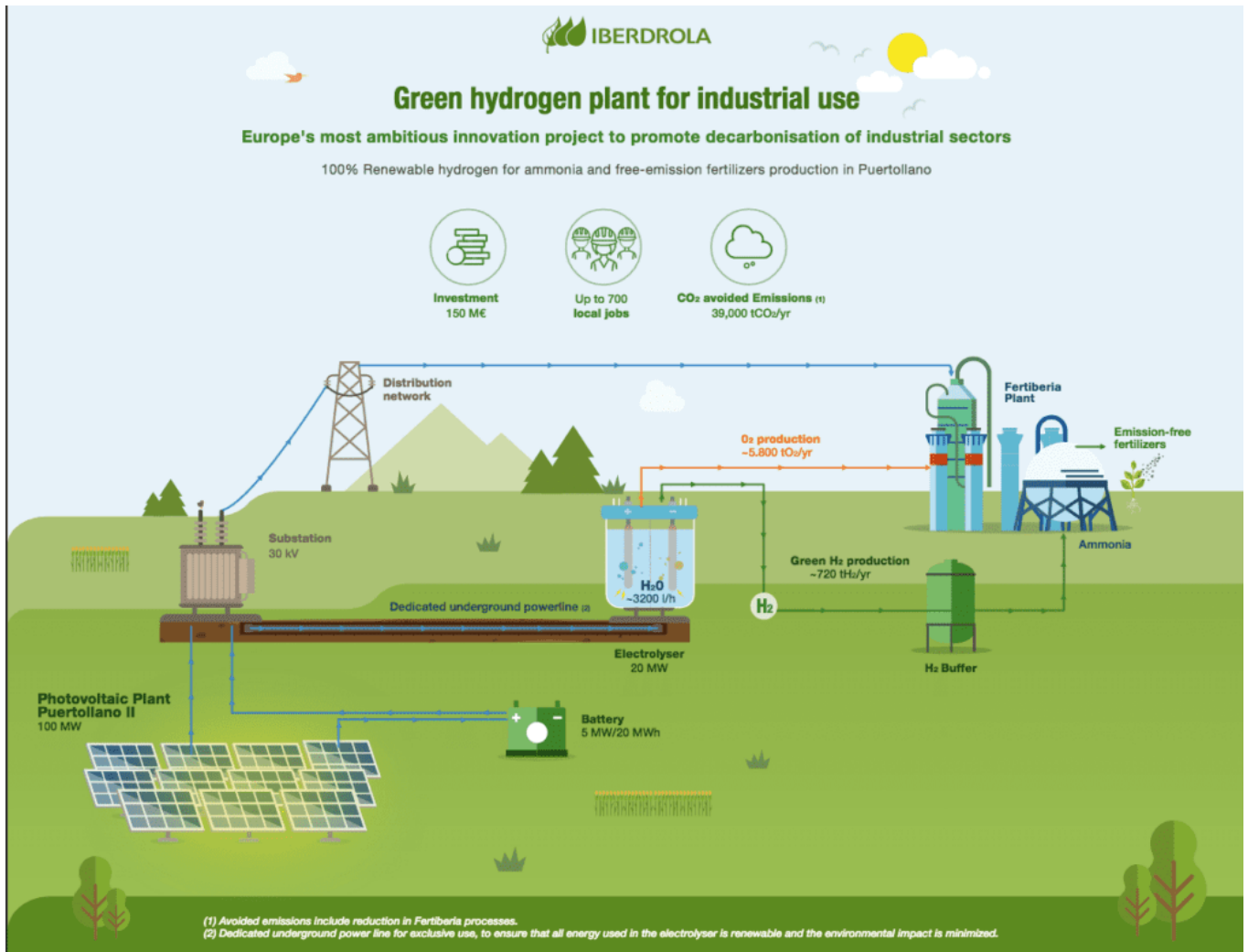
Global warming potential due to emissions of greenhouse gases and depletion of fossil fuels was the centre of the attention in the environmental indicators for hydrogen production, with 100% of the studies accounting for either of these two categories.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019



The by-products of coal gas manufacture included coke, coal tar, sulfur and ammonia; all useful products. Dyes, medicines, including sulfa drugs, saccharin and many organic compounds are therefore derived from coal gas.[7,8]

Coke is used as a smokeless fuel and for the manufacture of water gas and producer gas. Coal tar is subjected to fractional distillation to recover various products, including

- tar, for road surfacing
- benzole, a motor fuel
- creosote, a wood preservative
- phenol, used in the manufacture of plastics
- cresols, disinfectants

Sulfur is used in the manufacture of sulfuric acid and ammonia is used in the manufacture of fertilisers.

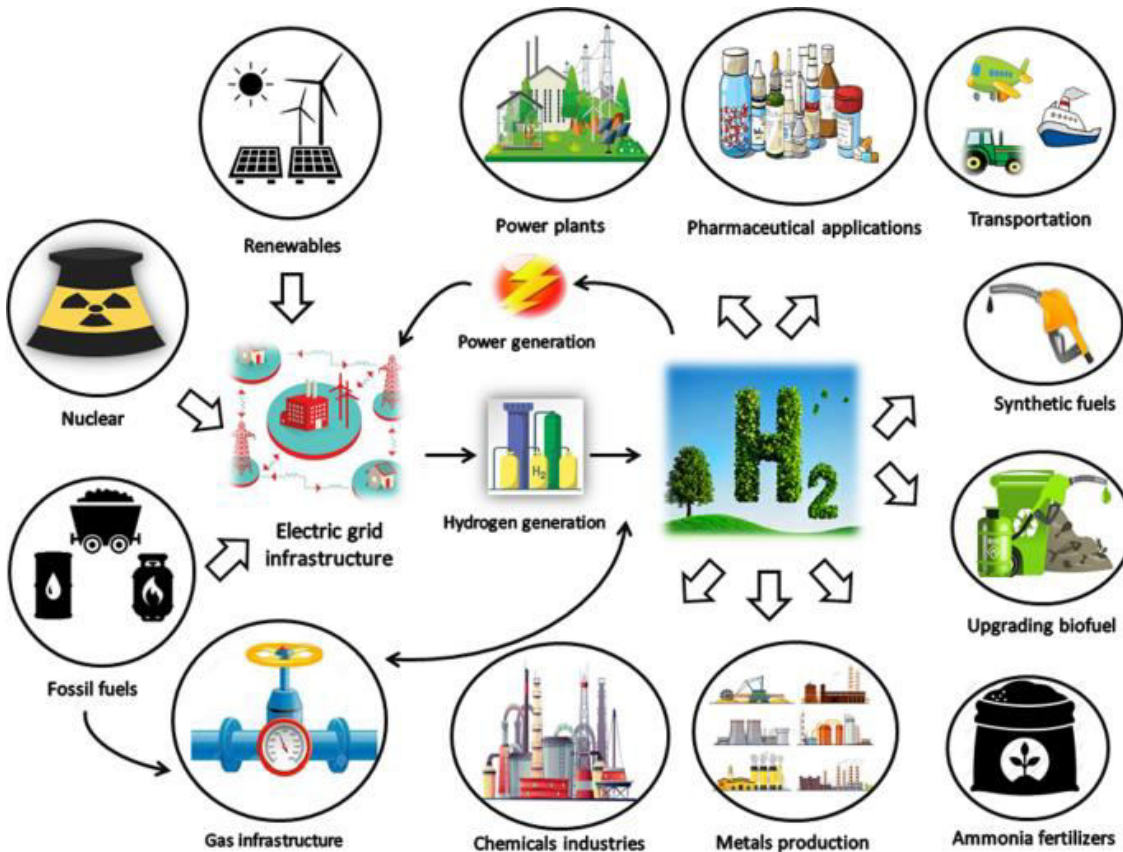
International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019

Coal gasification processes require controls and pollution prevention measures to mitigate pollutant emissions. Pollutants or emissions of concern in the context of coal gasification include primarily:



- Ash & slag

Non-slugging gasifiers produce dry ash similar to that produced by conventional coal combustion, which can be an environmental liability if the ash (typically containing heavy metals) is leachable or caustic, and if the ash must be stored in ash ponds. Slugging gasifiers, which are utilized at many of the major coal gasification applications worldwide, have considerable advantage in that ash components are fused into a glassy slag, capturing trace heavy metals in the non-leachable glassy matrix, rendering the material non-toxic. This non-hazardous slag has multiple beneficial uses such as aggregate in concrete, aggregate in asphalt for road construction, grit in abrasive blasting, roofing granules, etc. [9]

- Carbon dioxide (CO₂)

CO₂ is of paramount importance in global climate change.

- Mercury
- Arsenic
- Particulate matter (PM)

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019

Ash is formed in gasification from inorganic impurities in the coal. Some of these impurities react to form microscopic solids which can be suspended in the syngas produced by gasification.

- Sulfur dioxide (SO₂)

Typically coal contains anywhere from 0.2 to 5 percent sulfur by dry weight, which converts to H₂S and COS in the gasifiers due to the high temperatures and low oxygen levels. These "acid gases" are removed from the syngas produced by the gasifiers by acid gas removal equipment prior to the syngas being burned in the gas turbine to produce electricity, or prior to its use in fuels synthesis.

- Nitrogen oxides (NO_x)

(NO_x) refers to nitric oxide (NO) and nitrogen dioxide (NO₂). Coal usually contains between 0.5 and 3 percent nitrogen on a dry weight basis, most of which converts to harmless nitrogen gas. Small levels of ammonia and hydrogen cyanide are produced, and must be removed during the syngas cooling process. In the case of power generation, NO_x also can be formed downstream by the combustion of syngas in turbines.

V. CONCLUSIONS

Gasification-based processes for power production characteristically result in much lower emissions of pollutants compared to conventional coal combustion. This can be traced to the fundamental difference between gasification and combustion: in combustion, air and fuel are mixed, combusted and then exhausted at near atmospheric pressure, while in gasification oxygen is normally supplied to the gasifiers and just enough fuel is combusted to provide the heat to gasify the rest. Since air contains a large amount of nitrogen along with trace amounts of other gases which are not necessary in the combustion reaction, combustion gases are much less dense than syngas produced from the same fuel. Pollutants in the combustion exhaust are therefore at much lower concentrations than the syngas, making them difficult to remove. Moreover, gasification is usually operated at high pressure (compared to combustion at near ambient). The inherent advantages in removing syngas contaminants prior to utilization of the syngas¹ emerge as follows:

1. Relatively high concentration of pollutant species and pollutant species precursors (most notably hydrogen sulfide (H₂S) in syngas which would form sulfur oxides (SO_x) upon syngas combustion), versus much lower concentration that would be found in the combustion flue gas, improves removal;
2. High-pressure gasifier operation significantly reduces the gas volume requiring treatment;
3. Conversion of H₂S into elemental sulfur (or sulfuric acid) is technically much easier and more economical than capture and conversion of SO₂ into salable by-products;
4. The higher temperature and pressure process streams involved in gasification allow for easier removal of carbon dioxide (CO₂) for geological storage or for sale as a byproduct;
5. The oil and gas industries already have significant commercial experience with efficient removal of acid gases (H₂S and CO₂) and particulates from natural gas.
6. Removal of corrosive and abrasive species prevents potential damage to the conversion devices such as gas turbines, resulting from contamination, corrosion, or erosion of materials.[10]

VI. FUTURE SCOPE

Coal gasification has inherent advantages over combustion for emissions control. Emission control is simpler in gasification than in combustion because the produced syngas in gasification is at higher temperature and pressure than the exhaust gases produced in combustion. These higher temperatures and pressures allow for easier removal of sulfur and nitrous oxides (SO_x, and NO_x), and volatile trace contaminants such as mercury, arsenic, selenium, cadmium, etc. Gasification systems can achieve almost an order of magnitude lower criteria emissions levels than typical current U.S. permit levels and +95% mercury removal with minimal cost increase.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 11, November 2019

REFERENCES

- [1] Navarro Torres; V.F. And Dinis Da Gama; C. The Milos Declaration And Sustainable Development (In Portuguese). Journal Ingenium Ii Series, Number 84 November/December 2004, Pp. 56 – 59.
- [2] Navarro Torres V.F, Modelling And Optimisation Of Underground Coal Gasification And Co2 Capture And Sequestration For Clean Energy In Europe. Proposal Of European Young Investigator Awards – Euryi Awards 2005
- [3] Green, M., Overview Of Worldwide Field Activity And The Future Of Ucg. 4th International Conference On Underground Coal Gasification. Ucg Partnership, London, February 10-11, 2009.
- [4] Dinis Da Gama, C. And Navarro Torres V.F, A Mathematical Model To Assess An Environmental Sustainability Index For The Underground Coal Gasification Process. 4th International Conference On Underground Coal Gasification. Ucg Partnership, London, February 10-11, 2009.
- [5] Caldeira, K. And Wickett, M.E, Ocean Model Predictions Of Chemistry Changes From Co2 Emissions And Ocean To The Atmosphere. J. Geophysical Research, 110, C09s04, Doi 10.1029/2004jc002671. 2005.
- [6] Schlumberger Carbon Services, Integrated Solutions For Long-Term Co2 Storage. London. 2007.
- [7] Walker, L., Underground Coal Gasification: A Clean Coal Technology Ready For Development. The Australian Coal Review, October 1999.
- [8] Rogut, J., Eu Project Huge - The Role And Value Of Virtual And Experimental Approaches. 4th International Conference On Underground Coal Gasification. Ucg Partnership, London, February 10-11, 2009.
- [9] Kempka, T.; Schluter, R.; Aeckersberg, R.; Tian, H. And Krooss, B., Carbon Dioxide Storage In “In Situ” Concerted Coal Seams – Experimental Studies. 4th International Conference On Underground Coal Gasification. Ucg Partnership, London, February 10-11, 2009.
- [10] European Technology Platform For Zero Emission Fossil Fuel Power Plants (Zep), Co2 Capture And Storage (Ccs), A Key Solution For Combating Climate Change. 2005.