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CO2 CAPTURING AND STORAGE TECHNOLOGY: FUTURE PROSPECT, CHALLENGES AND SUSTAINABILITY.

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ABSTRACT

With the growing population, there is growing demand of Fossil Fuels rate of replenishment of which is less than its consumption. This if not controlled would damage Earth's Climate. CO2 emissions have increased by more than 20% over the past 10 years. Considering present trends of Green House Gas emissions and expected energy efficiency gain and technological progress as mentioned in existing policies, including United Nations Framework Convention on Climate Change, the Kyoto protocol, Co2 emissions will continue to rise over the next 25 years. Due to burden on coal for power generation and increased emissions from transportation and human's consumption of non-renewable resources of earth the carbon emissions is forecasted to be over two and a half times the current level by 2050.

By portfolio of emerging and existing mitigation technologies like renewable energy, advanced hydrogen production for transportation, advanced bioenergy, energy efficiency, nuclear power generation and CO2 storage, the alarming climate change can be controlled to some extent. These technologies apart from reducing CO2 emissions, improves economic efficiency, competitiveness, and local environmental quality.

This paper discusses the development of CO2 capturing and storage as well as showing roadmap ahead in which there is future prospect of CO2 Capturing and its challenges and its sustainability.

1. INTRODUCTION

As seen in the changing pattern of climate over the past decades, environment is the major concern for the globe. The major root cause of this drastic change is attributed due to the emissions of Green House Gas (GHG) such as CO2, CFC etc. Nearly all the sectors are looking for avenues where they control such emissions especially power sector that is the biggest emitter of GHG. Legislatures are working around the policies to reduce CO2 emissions to save the future generations from the debacle of exhausted resources and repercussions of climate change calamities. Stringent rules are being implemented all over the world and as per the recent articles emissions of GHG has started reducing.

The Energy and Climate Change Package adopted in December 2008 by EU legislators represents a significant example of such legislation. It includes policies that facilitate direct investment towards renewable and low carbon technologies. European Energy Programme for Recovery to further effort has provided money for CCS and renewable projects.

2. BACKGROUND—TECHNOLOGY, POLICY, ECONOMICS

There are several technical solutions available to lower worldwide emissions of Greenhouse Gases. Carbon Capture and Storage is one of them. The longer effects of anthropogenic climate change are curbed by this technique. This alone is not the only challenge faced by the current generation, there is work needed to be done to eradicate the risk posed by human planet in unrest that might fall upon future generations if not rectified timely. Forest clearing, agriculture practices, building designs and operation, transport and electrical power generation are the sectors that need to take considerable measures to reduce carbon emissions. There are measures currently being implemented in these sectors those are technically viable and workable solutions.

All the policy-making and scientific community are conscious of the risks and methods available for solving them. Despite of awareness, on a global scale, the efforts towards lowering emission of Greenhouse Gases

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(GHG) are few. The energy consumptions has increased manifolds since last 30 years, in addition our energy mix has also remained unchanged over the years.

3. ADAPTATION

There is serious need of clean coal technologies, re-installation of existing power plants with the combination of environmental control systems to prevent climate change due to GHG emissions.

The foremost method to reduce CO2 emissions emphasizes on the technology combination. There is no one unique form of power generation that looks into both challenges of ensuring the supply of trust-worthy and affordable power supply and influencing a very fast transformation to a less carbon system of supplying energy .All kinds of power generating technologies such as nuclear, renewable are included in rapid transformation to a less carbon system . With the most complementary & and symmetrical combination of technologies of power generating unit in the market that includes reduction of existing pollutants.

Secondly, In today's scenario an area of increasing concern is the security of fuel supply and the less emissions it generates. The method is that of production efficiency(energy) vs. energy flow (fuel supply).By 2030 coming from the current existing plants will contribute to 60% of total CO2 emission, there must be continuous solutions development & in order to increase the efficiency ,CO2 reduction must be implemented. . The efficiency of the plant increases if the fuel consumption is less to produce the similar output.

Thirdly, to consider & act for the changing climate challenge is the application & usage of **Carbon Capture and Storage (CCS)** technologies. CCS has become a priority as fossil fuels accounts for more than 60% of electricity production in 2030.

4. CCS ABATEMENT POTENTIAL

Globally fossil fuels until 2030 would form a potential part of energy mix. This is in accordance to given current energy mix, energy demand growth in today markets and issues of energy security and prices. Some 30% of European electricity is generated from coal. As per the current demand of electricity, fossil fuel consumption for generating electricity is expected to be twice by this date.

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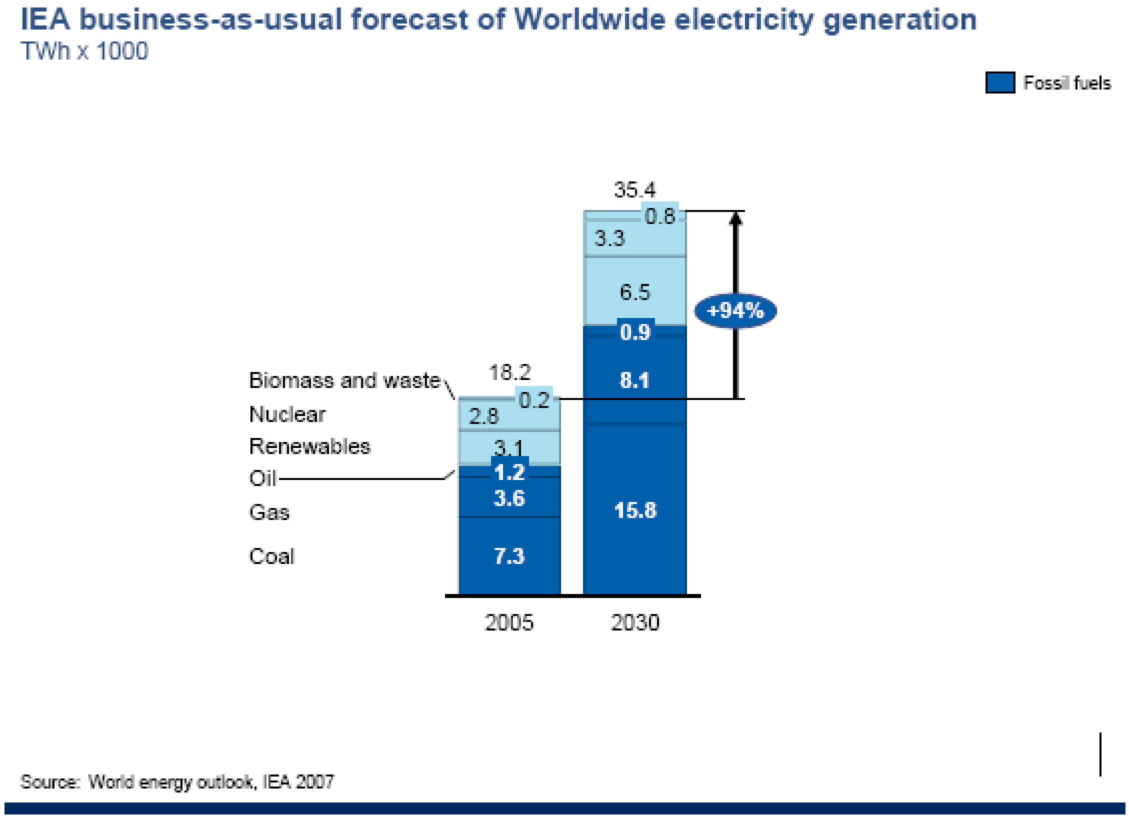

Graph 1: Forecast of Worldwide electricity generation

5. CCS IN PERSPECTIVE

The main target is to reduce the emission of GHG gases in atmosphere, CCS is one of the major contributor which helps to reduce the GHG emissions to the atmosphere. The major center area of CCS is government funded, R & D to study mobility of CO2 in different subsurface environment. The major components of CCS are:

- Capture
- Transport
- Geological sequestration.

The geological sequestration element is not well developed as compared to the other 2 components.

There have been several concerns raised by public for CO2 leakage from storage sites, as this will have greater risks imposed in long run. Although CCS has reduced the GHG impacts of coal which is used for electrical power generation. Due to all these efforts, government is various developed nations like Canada, USA, Australia and Europe fund projects which are well designed and cost efficient.

In many countries CO2 pipelines have been laid and operated safely, generally in oil recovery operations. Amine systems are also used in gas industry to remove CO2 in raw gas.

If we see worldwide, the number of planned\active commercial integrated projects of CCS are 62, which contain capture, transport and sequestration (over 1 Mtpa CO2) elements. 7 projects out of total 62 are in operational stage; rest is in evaluation, definition, or execution stages.

In CCS, gas sector is the leader as the marginal cost to apply CCS is comparatively low than the other sectors, specifically coal-fired power generation.

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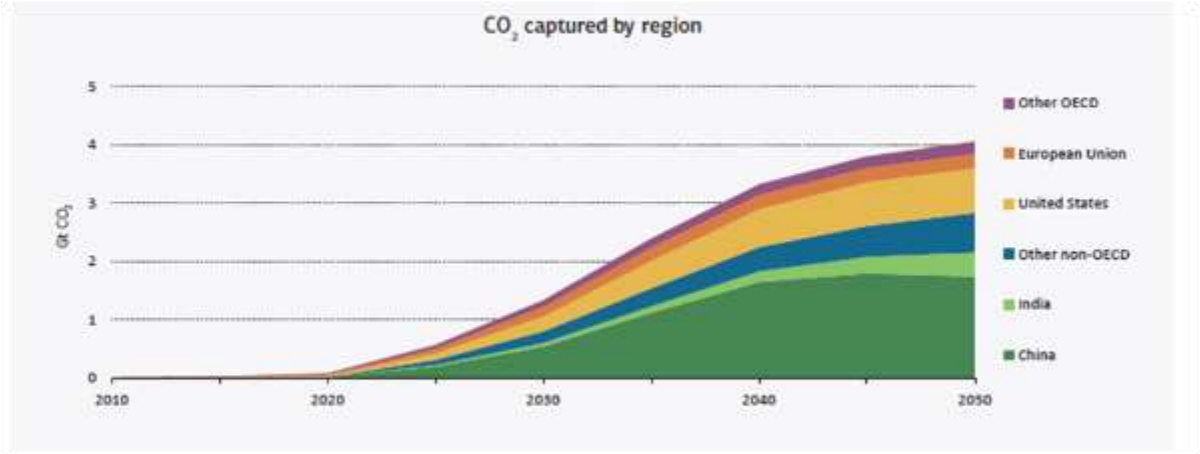
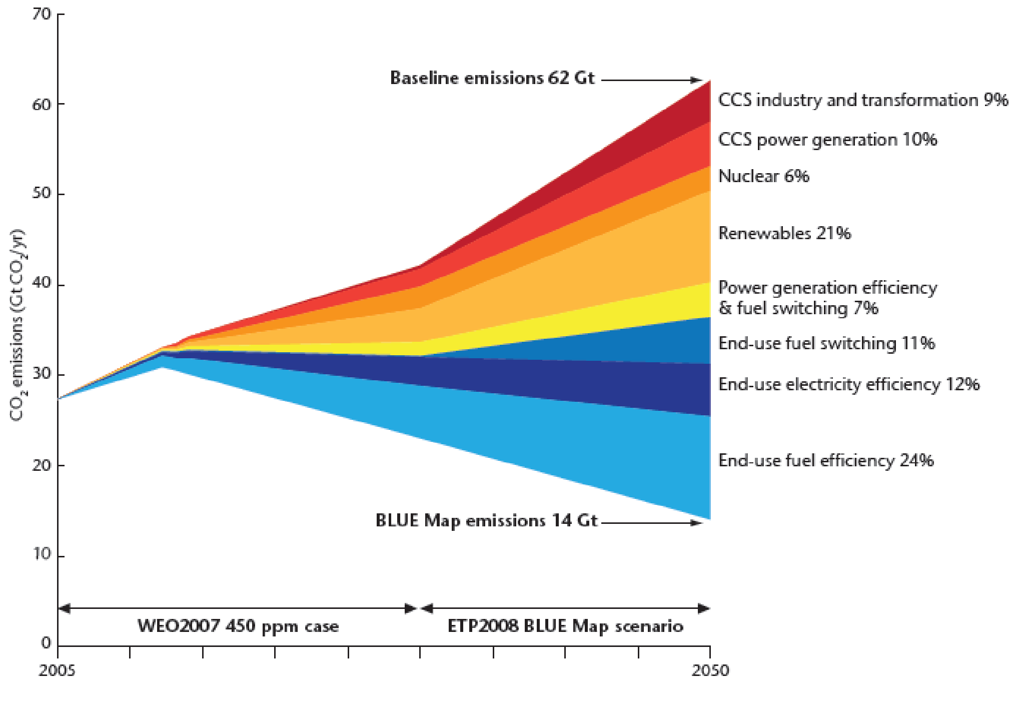


***Graph 2: Energy Technology Perspectives 2012**:*

From the graph it is clear that by the year 2050 China has a larger share of CO2 capturing and then US. India too has significant part to play in future clean energy technology.



Source: IEA, *Energy Technology Perspectives* (2008a).

KEY POINT: *Without CCS, overall costs to halve CO_2 emissions levels by 2050 increase by 70%.*

Graph 3: CCS delivers one-fifth of the lowest-cost GHC reduction solution in 2050

6. CCS FUTURE PROSPECT

As per the latest statistics, power plant accounts for more than 60% of the carbon capture potential in 2050.The main area of concern is to capture from power plants as in developing countries like India, the distribution of resources of coal based plants is rising fast. The evaluation of capturing cost from medium-scale units is currently being made by the International Energy Agency Greenhouse Gas R&D Programme.

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Potential for cost reductions from power plants

The major portion of the project cost is associated with the carbon capture The cost depends on several factors, such as oil price, extraction economics and reservoir performance the advantages from enhanced oil recovery that will offset part or all of the capture, transportation and injection costs. The cost of carbon capture from power plants generally ranges between 40$ - 90$ per tonne of Carbon captured and stored but it also depends on the power plant fuel and the technology used.. The cost can fall below $ 25 per ton of Carbon from Coal power plants if appropriate technologies are applied to the project timely.

The electricity production costs will get increased by US$ 0.02 to US$ 0.03 per kilowatt hour (kWh) when carbon capturing and storage new natural gas and coal-fi red power plants is implemented. But with the appropriate technologies are applied to the project timely By 2030,cost could fall to US$ 0.01 to US$ 0.02 per kWh. The costs of pipelines for CO2 transportation depend strongly on the volumes being transported and then it depends on the distances transported.

There are various parameters on which cost of carbon storage depends. The parameters are location and method of inoculation chosen, as well as the cost of monitoring. Storage costs are marginally low when compared to capture and transportation costs, at around US$ 1 to US$ 2 per tonne of CO2,. Therefore, taking in consideration long-term goals for costs controlling and confirmation of storage sites are not of prime importance. At an oil price of 45 USD/barrel, this translates into USD 30 to US$ 160 per tonne of CO2. This would place out of line all or an important portion of the capture cost; at higher oil prices, such projects could be in profitable mode.
Various factors such as how the technologies are used & implementation, how much the cost decrease as a result of R&D, market uptake and fuel prices. These factors will determine the cost in future of supplying, capturing and storing Carbon.

Retrofitting

Retrofitting is essential in coal fired plants as they have a longer life span & implementation of CO2 capture would need retrofitting. Additional capacity is still needed to counteract the capacity reduction caused due to Carbon capture. In perspective of coal-fired integrated gasification combined cycle IGCC plants, the design can be retrofit during the final stages.

This needs space for various assembly units such as coal handling units , bigger vessels & absorption units. As the gas composition would change in case of IGCC plants because CO2 capture would involve changes in the gas turbine,. Pulverized coal-fired plants could also be retrofitted. Currently in Germany and Australia Oxy-fuelling retrofits are under implantation phase.

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CO2 Capture

There are various CO2 projects under operating phase globally. Figure below shows globally main CO2 storage monitoring projects . Also, there are around 70 CO2 Enhanced Oil Recovery sites around the globe; the major chunk operates in N.America Many other countries are planning or operating in UAE, Australia, North America, China and major parts of Europe.

The four major CO2 storage projects: which are operational projects are

A. Sleipner in the North Sea : Injects 20 M tonnes of CO2
B. Weyburn in Canada : CO2 is separated from recovered oil and re-injected along with the anthropogenous stream.
C. In Salah in Algeria;
D. Proposed Gorgon project in Australia : Maximum capacity to inject 120 Mn tonnes of CO2.

Using Variable amounts of CO2, The projects plan to insert CO2 in number of geologic creations, which includes depletion of hydrocarbon reservoirs, coal seams and saline formations.

Major target of these projects is long term storage CO2 & eventually no venting to take place post project completion.

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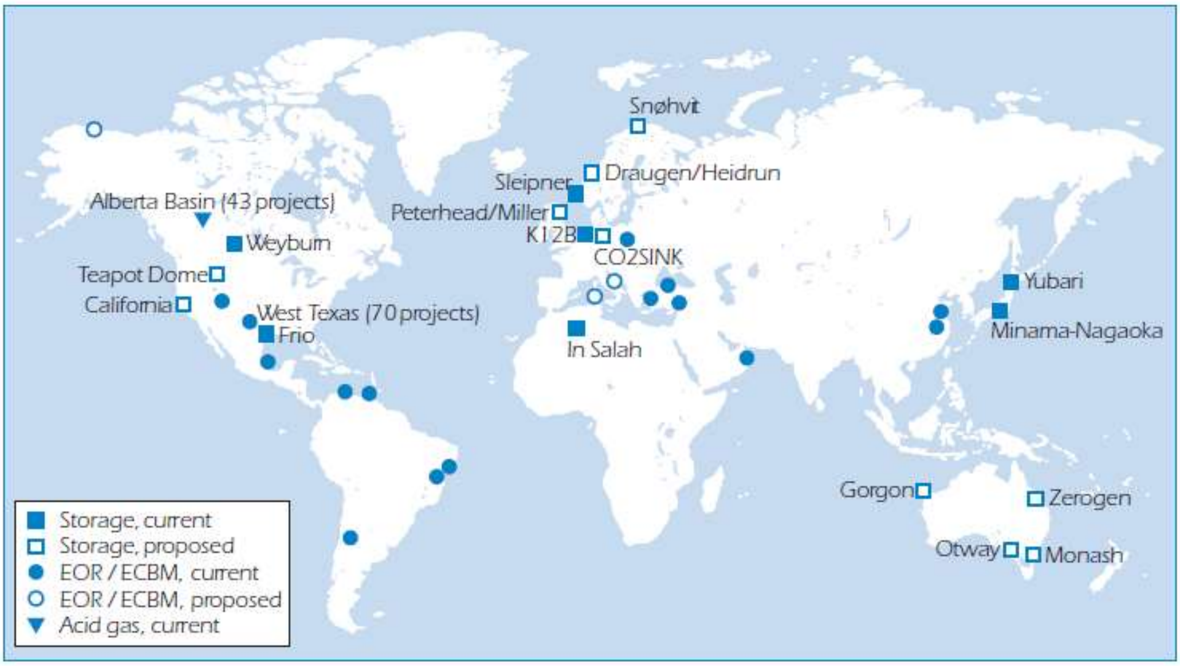

Source: IPCC, 2005.

Graph 4: Current and proposed CO2 Storage Projects

7. CCS ROADMAP

CCS is the major contributor to reduce GHG emissions; its growth path is quite ambitious.
Its global target by 2020 is around **100 projects** and more than **3,000 projects** by 2050. It will require an extra investment of approx. USD 2.5-3 trillion from the year 2010 to 2050, which is approx. 6% of the total amount which is required to attain 50% decrease in GHG emissions by 2050.As per these figures, one-fifth of GHG emissions reductions will be contributed by CCS.

For attaining the above target, funding for CCS projects will be required for USD 3.5 to 4 bn from the year 2010 to 2020 annually by OECD (Organization for Economic Co-operation and Development).

Moreover measures to be taken to reduce GHG emissions and CCS like activities should be given benefit in the form of tax rebates or government funding.

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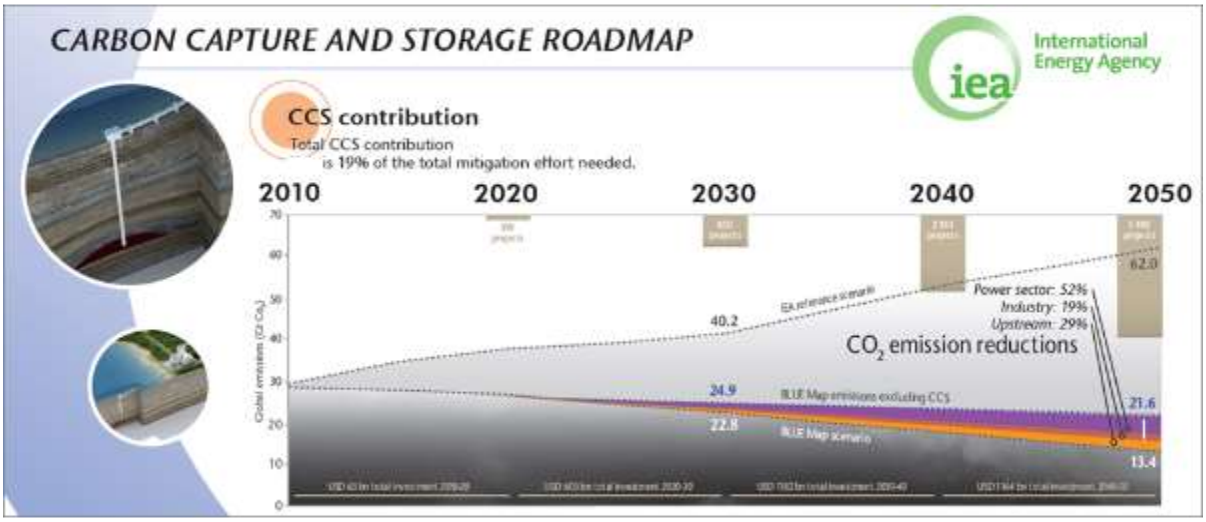

Graph 5: Carbon Capture and storage Roadmap

- *Carbon Capture and Storage is an important part of the lowest-cost greenhouse-gas mitigation portfolio. Without CCS, costs to halve emissions by 2050 rise by 70% in the electricity sector. This roadmap envisions 100 projects globally by 2020 and over 3,000 projects in 2050.* [3]

- *This roadmap's level of project development requires an additional investment of over USD 2.5 to USD 3 trillion from 2010 to 2050, which is about 6% of the overall investment needed to achieve a 50% reduction in greenhouse-gas emissions by 2050.* [3]

- *The developed world must lead in the next decade by investing an average of USD 3.5 to USD 4 billion annually between 2010 and 2020. However, CCS technology must spread rapidly to the rest of the world through expanded international collaboration and financing for CCS demonstrations in developing countries at an average annual level of USD 1.5-2.5 billion between 2010 and 2020.* [3]

- *Carbon Capture and Storage is more than a strategy for "clean coal". CCS technology must be adopted by biomass and gas power plants, in the fuel transformation and gas processing sectors, and in emissions-intensive sectors like cement, iron and steel, and chemicals manufacturing.* [3]

- *CO2 capture technology is commercially available today, but the associated costs need to be lowered and the technology still needs to be demonstrated at commercial scale. Additional research and development is also needed, particularly to address different CO2 streams from industrial sources and to test biomass and hydrogen production with CCS.* [3]

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8. CCS & SUSTAINABILITY

CCS (carbon capture and storage), should deliver reliable green environment which should benefit society, environment and economically. It will lead to climate change which must be sustainable. All these benefits must protect human from health hazards in long run, so that it can be deployed on a significant scale. With all its benefits there is a cost attached to it, as CCS is costly and challenging technology.

CCS is preferred in comparison to other technologies available as it is optimally competent, sustainable and cost-effective improvement plan. While evaluating other options available cost per tonne of CO2 is one of the tradeoff along with other factors as water, NOx, SOx, biodiversity, energy, and human health and safety.

Major industries benefitted from CCS:

- *Stationary fossil-fuel powered energy*
- *Large scale petroleum industry operations*

The CCS technology would be more expensive and technically challenging for retrofitting existing coal-fired power plants and is required to be compared to newly build plants on portfolio basis.

There is a substantial and wide variety of cost required for CCS technology to process natural gas, LNG, and coal-fired power generation sectors. Environment and social benefits are considerable; it depends on the way how and where it is applied. Some CCS applications are more cost efficient and sustainable in comparison with others. CCS is among one of the effort which companies follow to improve energy efficiency which helps to eliminate GHG emissions.

9. CCS CHALLENGES

The future adoption of CO2 capture and storage technologies have challenges which includes the following:

A) Technology and costs,
B) Legal and regulatory issues,
C) International mechanisms,
D) Financing, and
E) Public acceptance.

Without CO2 incentive the CCS technologies are not expected to be accepted, except for cases of enhanced oil recovery, ECBM (Enhanced Coal Bed Methane recovery), and related extractive techniques where there is substantial benefit. Similarly using low carbon electricity option, the countries relying heavily on coal for power generation use of nuclear energy, renewable energy, CO2 capture and storage seems a relatively low cost option to mitigate CO2 emission. As a result, EOR (Enhanced Oil Recovery) technologies are going to play an important role in the commercial adoption of CO2 storage technologies in the future.

CCS Legal & Regulatory Issues

The safe and effective use of CCS technologies brings many regulatory as well as legal issues. The International Energy Agency (IEA) supports CCS legal and regulatory development for member and non-member countries by adopting CCS legal and regulatory information and experience on neutral forum, by analyzing the issues related to regulatory design and by undertaking targeted engagement with each countries.
The IEA (2010 & 2011) CO2 and Storage Model Regulatory Framework and the London Protocol are included in recent IEA CCS legal and regulatory analysis. and options for allowing CO2 technology transfer among the countries.

The principles developed for solving 29 key regulatory issues were proposed by model framework which was based on work done by early movers in this category especially Australia, Europe and the United states.
CO2 storage faces similar Intellectual property (IP) issues to the oil and gas sectors. There are three main issues in terms of IP rights in relation to ensure the acceptance of CO2 storage.

➢ Firstly assurance of rate of return and non erosion of rights to IP owner because without these assurance the owner will be reluctant to transfer his knowledge to others

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- Secondly the issue of mechanisms by which the technology transfer will take place and finally put in practice.
- Thirdly capacity of country or economy will be tested if they can handle the receiving of knowledge transferred which can be done through capacity building. For CO2 storage, overall policy and regulation will also play a vital role along with technology.

International Cooperation on CO2 capture and Storage

The CCS technologies being promoted and developed by a number of public and private international initiations. Many major on-going projects have a strong international collaboration component.

The framework for CO2 capture and storage has been developed by the International Energy Agency (IEA) through:

- *IEA Implementing Agreements, in particular, the IEA Greenhouse Gas R&D Programme (GHG Programme) that has worked since 1991 on generation of technologies, promotion and outcome of results and data from its evaluation studies and facilitating practical research, development and demonstration activities; the IEA Clean Coal Centre also works on CO2 storage technologies;*

- *Working Parties, including in particular the IEA Working Party on Fossil Fuels (WPFF) that pursues the Zero Emissions Technologies for Fossil Fuels Initiative; the WPFF's Subcommittee on Legal Issues prepared this study and organized the 2nd Legal Aspects of CO2 Storage Workshop;*

- *The IEA Coal Industry Advisory Board and its Zero Emissions Technologies Working Group; and*

- *The IEA Secretariat*[7]

The G8 request to accelerate the development & commercialization of CCS technologies are response work which are included in the Secretariat's work. To complete this, in August 2006, a workshop of first kind was organized by IEA on nearby opportunities for carbon capture along with the IEA WPFF, CSLF and industrial partners in San Francisco. Next workshops in the series on nearby Carbon capture and storage opportunities are planned in Oslo, Norway in June 2007 and Canada in december 2007.

IEA also conducts the work on a concept storage-ready power plant with GHG Programme together with the IEA Secretariat (Gale, 2007). An update to the 2004 IEA publication on CCS is planned for the end of 2007.

Financial Issues

The provision for funding and insuring for post-closure costs and/or liabilities are included in financial issues. These costs comprises of site rehabilitation & remediation, cost of plant decommissioning, monitoring and leakage cost and liability of CO2 stream.

For assuring financial responsibility for CO2 storage projects many options can be think off, including the various establishments like insurance bonds, government trust bonds, public, private or semi private partnerships.

The criterion's which should be followed when taking a suitable financial instrument which can assist in managing potential long-term liability, including:

- Establishment of a project baseline;

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- Suited with the timeframes of the above chosen phases of CO_2 storage activities, including both decommissioning and post closure;
- Flexibility to the site-specific nature of CO_2 storage activities;
- Advancement of 'leading practice' in CO_2 storage;
- Matching with legal, regulatory, IP and taxation requirements.
- Ability of the parties to bear the risk and adequacy of compensation for risk taking; and
- Risk cost associated with CO_2 storage.

Technology and Cost

For cost calculation a reference case is taken. The expected price of full scaled project in the range of Euro 35 to 50 per tonne CO_2 abated. As experience and scaling effects enhances, it is expected that these costs are going to drop to Euro 30 to 45 per tonne CO_2 abated around 2030.These costs would make CCS installations economically self-sustaining at a carbon price of Euro 30 to 48 per tonne CO_2 as forecasted by many financial institutions. The potential for even lower costs are foreseen if a global roll-out of CCS takes place, or if some disruptive technologies, which are still in the laboratory stage, comes in picture.

Due to smaller scale and low efficiency the early phase projects which are in demonstration stage will be more costly (Euro 60 to 90 per tonne CO_2 abated), as their focus is on technology proving rather than optimizing it commercially. [4]

With differing capital costs, operational costs, energy requirements, and performance demands wide variety of capture technologies. [3]

Obama Offers $6 Billion Investment for Clean Energy Infrastructure in Asia-Pacific

For sustainable energy future president Obama is going to offer a $6 billion investment package in the Asia pacific region for clean energy infrastructure under the US – Asia Pacific Comprehensive Partnership It is being formed to enhance investment in the region, and also to have a ready export market for US companies and their technologies. There are four regional priorities:

1. Cleaner and renewable energy
2. Globalization.
3. Natural gas and its emerging role
4. Sustainable development

The plan is to engage the private as well as partner with countries in the given region to make specific projects on 4 priority area

"With an estimated $9 trillion needed in investment in electricity alone through 2035 to meet growing demand in the region, there is enormous potential for U.S. industry to play an important role in the region's energy future."[6]

Public Acceptance

As change in climate has effected globally so it is a global issue and is beyond any country's boundary. It's every individual's issue and shall not be distinct on gender or nationality. We know the cause and solution. The lacking aspect, so far, is the **political**, **social**, and **economic will** to start these existing technologies in mass production. The actions which are done have been slow and insufficient as nobody wants to pay the price of action.

10. CONCLUSIONS

CCS sustainability mainly the environmental and economic is a function of many factors, which includes the **timing of deployment**, the **value placed on carbon**, **fuel and energy prices**, the costs of disruptions to the business during retrofit, and the **externalities** and possible releases from storage sites.

The externalities and benefits involved must be taken into consideration if the real value, and therefore the environmental and economic sustainability, of the action are to be considered. [3]

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The future prospect and challenges shows that in near future the onus will be on CCS technology to reduce carbon emission by employing it on existing as well new power plants and other industry emitting carbon.

The countries have to make a tradeoff between clean technology and higher cost & less efficient plant.
The clean technology of CCS shall also be sustainable in long run.
The milestones of 2050 will only be achievable by wider international collaboration.
Newer ways to transfer technology to developing countries
Industries having global reach should enhance their Carbon capture and storage collaborative efforts.
Dealing with climate change may come at a relatively high price. But what matters are the benefits that result from that expenditure, not only to the emitters, but to society as a whole

11. RECOMMENDATIONS

CCS unit's installation increases the initial capital expenditure (capex) and operational and maintenance (O&M) running costs. The overall size of plant increase and efficiency reduces by 10% around and overall cost increases by 25%.

The future fuel energy requirement in India and China shows that the load of clean technology will be more on China and India along with the developed countries and also onus will be on CCS technology as roadmap shows that one fifth of the clean technology will be solved by CCS.

The new power plant installation shall be of higher efficiency as well of higher power generation like ultra critical power plant which are under construction under NTPC and other companies.

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