Introducing clean coal technologies for reduction of greenhouse gasses emissions

Uvajanje čistih premogovnih tehnologij za zmanjšanje emisij toplogrednih plinov

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Abstract: Stabilization of climate depends on the balance between greenhouse gasses emissions and natural absorption of the earth. The longer the balance is not reached, the worse the climate will become. Playing a key role in the electricity production throughout the world, coal cannot be replaced during the next decades. Facilitating further coal use, acceptable to the market and the environment, is an important political task for the Europe.

Europe can efficiently explore the abatement potential of the carbon capture and storage technology (CCS) by expedited implementation of the demonstration program and appropriate commercial roll out of the most advantageous CCS technologies. A lot of uncertainties and barriers will have to be resolved in this process. The demonstration program of the CCS projects can explore the real potential of the technology, identify the risks and bring the public and industry confidence to this remarkable technology.

Regulatory issues related to responsibility for carbon storage, financing of demonstration projects, exchange of experiences can only be resolved by appropriate cooperation between industry, government officials, research institutions and universities. Public opinion and support should also be seen as to have an important impact on the final success of the process.

Original scientific paper

Izvleček: Za stabilizacijo klimatskih razmer se mora letna količina emisij izenačiti z zmogljivostjo Zemlje za absorpcijo toplogrednih plinov. Bolj kot bodo emisije presegale ta nivo, bolj se bodo klimatske razmere poslabševale in na višji točki (v slabšem stanju) bo potekala stabilizacija klimatskih razmer.

Premog je vedno igral ključno vlogo pri proizvodnji električne energije in takšno vlogo bo vsekakor imel tudi v prihodnje. Nikjer na svetu v naslednjih desetletjih premoga ne bo mogoče nadomestiti. Podpora pri nadaljnji uporabi premoga, sprejemljivost na trgu in v okolju pa bo pomembna politična naloga za Evropo. Za učinkovito izrabo potenciala tehnologije zajema in geološkega shranjevanja ogljikovega dioksida (CCS) v Evropi bi bilo treba hitro uvesti demonstracijski program in ustrezno načrtovati kasnejšo komercialno ekspanzijo tehnologije. Pri tem bo treba odpraviti kar nekaj negotovosti in ovir. Demonstracijski program CCS-projektov bi lahko dokazal pravi uspeh uporabnosti tehnologije, identificiral tveganja in dosegel zaupanje javnosti in industrije v tehnologijo.

Regulatorne zadeve, v prvi fazi predvsem glede odgovornosti za shranjevanje ter financiranja demonstracijskih projektov, kasneje pa tudi glede razširjanja izkušenj ter ustrezno koordinacijo na evropskem ali svetovnem nivoju, bo treba razrešiti v sodelovanju industrije, vladnih ustanov, raziskovalnih ustanov ter univerz. Pri tem ne smemo zanemariti vloge javnosti in njene podpore pri celotni rešitvi.

Key words: coal, clean coal technologies, carbon capture and storage, electricity, energy sources, competitiveness, security, reliability

Ključne besede: premog, čiste premogovne tehnologije, zajem in shranjevanje ogljikovega dioksida, električna energija, energijski viri, konkurenčnost, varnost, zanesljivost

INTRODUCTION

Energy use and energy generation represent the International Energy Agency's (IEA's) forecast that global electricity generation will nearly double from 2005 to 2030. The Agency says that fossil fuels will remain a significant part of the energy mix, comprising approximately 70 % of global and 60 % of European electricity generation.

One of the solutions being discussed to reduce greenhouse gas emissions from fossil fuel energy generation is capture and geological storage of carbon dioxide (CCS – Carbon Capture and Storage). CCS comprises technologies for capturing CO_2 emitted from power plants and industrial sites, compressing this CO_2, and transporting it to locations for suitable storing, e.g. deep underground. CCS technology is in a relatively early phase of development, with several key questions remaining, including about its costs, implementation timing, and the comparison of its suitability versus other low carbon electricity generation technologies. Public understanding of CCS is low, and there is some confusion regarding its true economics, particularly due a wide range of data on the price of technology implementation as well as due to a questionable accuracy and reliability of original information on the prices.

Greenhouse Gases and Atmospheric Warming

Greenhouse gas concentrations in the atmosphere nowadays amount to $430 \cdot 10^{-6}$ particles, expressed in CO_2 equivalent, compared to $280 \cdot 10^{-6}$ from the period before the industrial revolution. Until today, an increase in concentration has caused an increase in the Earth's temperature by more than half a degree Celsius and will, due to a sustained climate system, cause an additional temperature increase by at least half a degree Celsius over the next decades.

Even if the emission inflow does not exceed the current level, the greenhouse gas concentration will reach $550 \cdot 10^{-6}$ by the year 2050 and continue to grow afterwards. This means it will more than double in comparison to the pre-industrial age. However, the annual CO_2 emission inflow is constantly growing due to investments into CO_2 emitting infrastructure, particularly in countries with rapid economic growth. Furthermore, both energy consumption and demand for transport are increasing globally. In such conditions, the CO_2 level of $550 \cdot 10^{-6}$ can be attained by the year 2035, with at least 77 %, or even 99 %, probability that an increase of global average temperature will exceed 2 ºC.

In a scenario without impacts on the course of events (BAU - Business As Usual), the greenhouse gas concentrations might exceed three times the amount by the end of the century, which would mean at least 50 % probability of global Earth's temperature increase by 5 ºC. Such warming would expose the human race to an entirely unknown environment. To illustrate the scope of consequences of such temperature increase, it should be considered that today's global temperature is higher only by 5 ºC compared to the last ice age.

The Impact of Global Warming on the Economy

In the past, the majority of economic models of global warming was based on the scenario of temperature increase within 2–3 ºC until the end of the century. The results of such analyses show that the costs of climate changes equals permanent loss of global GDP up to 3 %, considering the potential global product without climate changes. In such case, the developing countries would suffer a somewhat greater loss.

A breakthrough in thinking in this area was initiated in 2006 by the Stern Review showing evidence that with a preserved BAU trend, the global temperature will exceed 2–3 ºC by the year 2100. This presumption increases the probability of occurrence of other climate changes not considered so far. With an increase of global temperature up to 5 ºC, various economic models estimate the probability of average 5–10 % loss of global gross domestic product (GDP), with the loss in poor countries exceeding 10 % of GDP.

Lord Stern introduced risk economics in the global warming area as, according to his claims, averaging of various scenarios may conceal risks. He established that there is a very high probability of severe or catastrophic scenarios of event development. The probability of their occurrence cannot be entirely removed; they can only be significantly reduced. Furthermore, Stern indicates that the consequences of atmospheric warming should not be limited only to a direct impact on GDP; indirect impacts on GDP should also be studied and GDP's impacts on the inhabitants should be monitored as well.

If indirect impacts are added to direct impacts on GDP, they can be expressed as the following:

- 5 % reduction of GDP per capita due to human health deterioration and/or mortality rate increase as well as due to other environment changes,
- 3 % reduction of GDP per capita due to new scientific evidence according to which the climate system is much more responsive to greenhouse gas emissions than it has been thought so far, e.g. due to the methane release into the atmosphere or due to reduced activity of natural CO_2 sinks,
- 25 % reduction of GDP per capita due to an unproportionately larger impact of global changes on poor world regions where the percentual impact on GDP per capita is significantly larger than the percentual impact on GDP per capita in developed regions.

Hence the total impact of global changes amounts to 5–20 % reduction of GDP per capita. Stern estimates that without active interventions in emissions, the actual result will be somewhere in the upper section of this area.

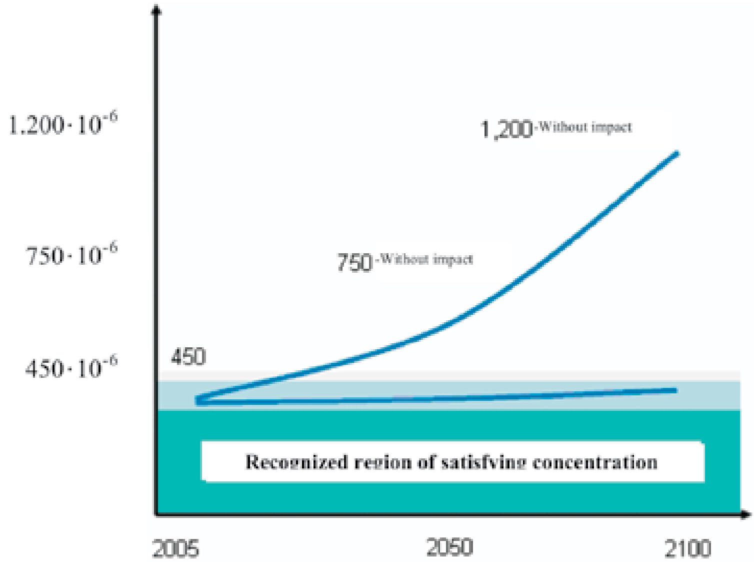

Figure 1. CO_2 prediction scenarious – scenario without impact (BAU) and stabilized concentration scenario (in 10^{-6} particles) (Katzer et al., 2007)

Stabilization of climate depends on the balance between annual amount of greenhouse gasses emissions and natural absorption capacity of the Earth. The longer the emissions keep exceeding this level, the more climate conditions will deteriorate and their stabilisation will take place at a higher level (worse condition). In a long term, annual global emissions will have to be reduced below 5 Gt CO_2, the amount absorbable by the Earth with no consequences for the atmosphere. To achieve this goal, a long-term emission reduction below 80 % of the current absolute emission level will be necessary. If we wish to stabilise CO_2 concentrations in the atmosphere at $450 \cdot 10^{-6}$ CO_2, the emission increase should stop in the next 10 years, followed by a reduction by more than 5 % per year, in order to fall to 70 % below the current level by the year 2050.

Carbon Capture and Storage (CCS) Economics

CO_2 is produced during any kind of combustion of fossil fuels, both in electricity generation and elsewhere, e.g. in transportation. Certain industrial processes, such as steel production, cement manufacture or oil refineries, are significant CO_2 polluters as well. The CCS technology prevents CO_2 produced by large stationary sources, such as coal power plants, from entering the atmosphere. The technology attempts to capture 90 % of emissions from these sources and permanently prevent their entrance into the atmosphere. CCS is designed to achieve the above-mentioned goal in three steps. In the first step, CO_2 is captured in the facility and compressed. In the second step, it is transported to the storage location. The third step is a procedure of permanent geological storage.

Every of these three steps can be performed in various manners. Fossil fuel combustion produces CO_2, water vapour and a large amount of nitrogen. In the capturing process, CO_2 must be extracted from this flow. There are three basic methods for CO_2 capture in fossil fuel combustion.

The first method is called Oxy-Fuel. In this method, the fuel burns with pure oxygen instead of air, which minimises the nitrogen content in exhaust gases. From the remaining exhaust, CO_2 separation is relatively simple. The oxygen required for such CO_2 capture is produced in situ, from air. In another capturing method, Post-Combustion Capture, CO_2 is separated from exhaust gases by using absorption solutions. The third method is called Pre-Combustion Capture. Before combustion, the fuel is processed into a mixture of CO_2 and hydrogen from which CO_2 is separated. Electricity is then generated from pure hydrogen.

For CO_2 transport, the use of transportation pipelines is most probable, with an additional option of transportation by vehicles and ships.

CO_2 can be stored in various geological formations in exploited oil or gas fields. Natural underground saltwater deposits can be used as well.

Compared to regular power plants, the CCS technology is more expensive for four reasons. First of all, equipment for CO_2 capture must be installed in the power plant. Then, the capturing process needs power supply, which increases fuel consumption. Another cost is the construction of the pipeline for CO_2 transportation, followed by the cost of CO_2 storage. All above-listed costs mean increased investment and operation costs of a CCS power plant. The differences in price are relatively large. For example, construction of a regular 900 MW thermal power plant (without CCS technology) will in the year 2020 require approximately 1.5 billion EUR investment funds. A similar power plant equipped with CCS technology will cost approximately 50 % more. Investments in pipelines, storage and operation represent a relatively low additional cost.

Greenhouse Gas Emission Potential with the CCS Technology

Considering the current global share of fossil fuels in primary energy source consumption, the current increase in energy consumption in new markets as well as the importance of reliability and economics of electricity supply, the experts predict the current share of fossil fuels to remain the same until the year 2030 and beyond, despite an increased share of renewable resources. This applies both globally and to the European Community. Approximately 30 % of electricity in Europe is currently generated from coal. According to the IEA data, the share of electricity generation from fossil fuels will, in the event of realisation of predicted electricity consumption growth, actually double by the year 2030. The fuel with the largest share among fossil fuels is coal. It represents today 40 % of the entire global primary energy source consumption and it will increase to 45 % by the year 2030.

Currently, the CCS technology is the only known technology that can be used to reduce emissions from the existing CO_2 sources, not only from fossil fuel power plants representing nearly a half of all CO_2 sources in the European Community, but also from plants like steel factories, cement manufactures and refineries.

For that reason, the CCS technology has an important CO_2 reduction potential. Various reports indicate that the CCS technology might reduce 1.4–4 Gt of CO_2 emissions globally by the year 2030, 0.4 Gt of which in the area of the European Community, representing 20 % of all possibilities of CO_2 emission reduction in the European Community.

The CCS technology requires a longer implementation period before it is fully exploited. It involves highly demanding projects; with large investments in individual facilities. Consequently, every plant equipped with the CCS technology can achieve a large emission reduction potential. In individual power plant based on the CCS technology can satisfy electricity supply needs of 1.5 million European citizens. For comparison purpose, 1400 typical 2.3 MW wind turbines would have to be built to satisfy such needs. Nuclear and coal power plants are currently typical power plants for base power generation in Europe. Shutting down of coal power plants resulting from eventual failure of the CCS technology would have serious negative consequences for the reliability of electricity system operation.

Current Situation in the Area of CCS Technologies

Despite the fact that numerous components of the CCS technology are considerably mature and proven, we currently have very few experiences with comprehensively integrated commercially feasible CCS projects in operation. If we take a look at individual areas:

- The capture technologies are based

on mature applications in chemical and refinery industry, but an integration of such technology in power plants has not yet been commercially tested in practice.

- Long-range CO_2 transport in pipelines has been successfully used in the central region of the United States of America for over 30 years. More than 5000 km of such pipelines are used, enabling increased exploitation of oil wells. Using this technology, CO_2 is injected into oil wells, increasing the amount of pumped oil.
- Geological storage of CO_2 has been tested in operation mostly in the last 10 years. The industry could benefit from the knowledge acquired through geological storage of natural gas that has been carried out in practice for several decades.

Comparison of CCS Technology Costs in Three Development Phases

Costs of early commercial projects: these projects will be the first to reach the final dimension and technology implementation, their finalisation is planned for the first years after 2020 and they are estimated to 35–50 EUR per tonne of reduced CO_2 emissions.

Costs of initial demonstration projects: due to reduced size of plants and due to emphasis on proving the applicability of technology on account of optimal economic operation, these projects will

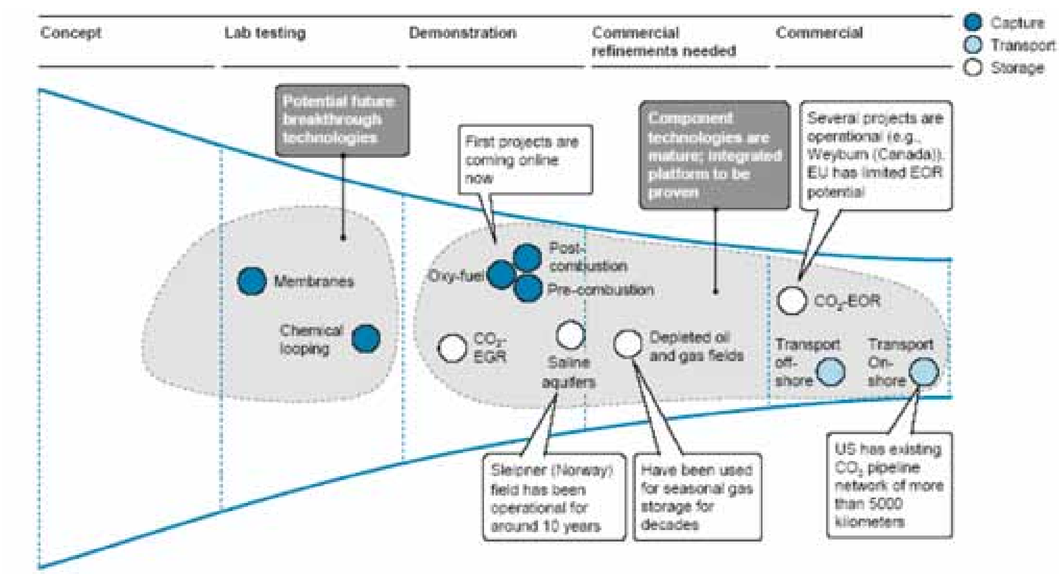

Figure 2. R&D situation of CCS technology (Carbon Capture and Storage: Assessing the Economics, 2008)

express costs between 60 EUR and 90 EUR per tonne of reduced CO_2 emissions. The costs here can vary significantly. Costs of some projects where borderline technological solutions will be tested, such as long-range transport, might also exceed the estimated framework. The finalisation of these projects can be expected in the years 2012–2015.

Cost development in the period following the early commercial phase: during this period, the costs will depend on numerous factors, such as additional experience of construction, plant expansion, availability of suitable storage location and actual breakthrough and/or mass use of CCS technologies. With a planned breakthrough involving 80 to 120 projects by the year 2030, the implementation of the CCS technology in new power plants might achieve 30–45 EUR/t of reduced CO_2 emissions. In case of larger global acceptance of CCS technologies reaching 500 to 550 projects by the year 2030, an additional cost reduction of 5 EUR/t of reduced CO_2 emissions could be gained on account of the technological breakthrough of new CO_2 capture technologies.

€/t of reduced CO_2 emissions; rounded to 5 €; considering the European scenario of CCS expansion.

Costs of other CCS technologies (e.g. modification of existing power plants into CCS, use of CCS in the industry) may significantly deviate from the above values.

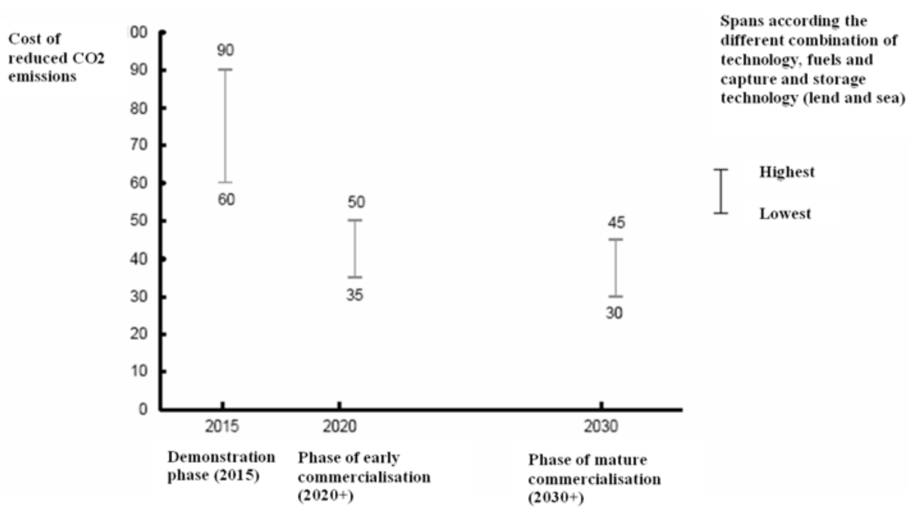

Figure 3. CCS total cost – reference case

The Technology of Coal Power Plants with Carbon Capture and Storage

A commercial realisation of clean coal technologies for capture and geological storage is currently not yet available. Several years of development and testing will be necessary to prepare a successful, widely planned implementation on a global scale. Premature attempts of implementation of clean coal technologies in the view of concern for climate changes could result in increased costs and additional environmental hesitations of local communities which might lead to delays in the final implementation of the technology.

Pulverised Coal Combustion

Pulverized Coal Combustion (PCC) is currently the most widely spread technology of coal combustion in thermal power plants. The technology is based on several decades of experience. In pulverised coal combustion, fine-ground coal is blown into the steam boiler where combustion takes place. The released is collected through water filled pipes of the boiler and through several further heat exchangers to receive high-pressure water steam for the steam turbine to power the electricity generator. Although PCC units can be built for various sizes, it can be assumed that PCC is appropriate for electricity generation in larger units (>300 MW).

Fluidised Bed Combustion

In the technologies of fluidised bed combustion (FBC), the coal is also first pulverised. The particles are somewhat larger in FBC technologies, and the velocity of blowing the air into the furnace is lower causing the coal in the furnace to float.

The FBC technologies have some environmental advantages compared to classical PCC technologies:

- The combustion temperatures are generally lower, around 427 °C, reducing the amount of nitrogen oxides,
- The cost of expensive flue gas desulphurisation (FGD) devices can be avoided by adding limestone directly to the fuel in the fluidised bed. By varying the amount of added limestone, combustion of coals with very different nitrogen content is made possible.

CO_2 Capture in Pulverised Coal Combustion Power Plants

CO_2 is separated from flue gases at low concentration and low partial pressure. One of possible approaches to separation is an amine-based chemical absorption. CO_2 separation from flue gases requires energy, mostly in the form of low-pressure steam for the amine solution regeneration. This causes lower steam parameters and net power at the turbine outlet. Therefore, generation of the same amount of power requires more coal, a larger steam boiler, turbine and other elements.

Thermal energy for CO_2 separation from amine solution reduces the power plant's utilisation rate by 5 %. Further 3.5 % of utilisation rate is used for CO_2 compression from 0.1 MPa to approximately 15 MPa (to supercritical fluid). All other requirements amount to less than 1 %.

CO_2 Capture with Oxygen Coal Combustion

The essential feature of CO_2 capture using this technology is coal combustion fired by oxygen instead of regular air. Such combustion results in high CO_2 content in flue gases, which enables a direct CO_2 compression. The air separation unit used for production of pure oxygen is the largest factor of utilisation rate reduction in oxy-fuel power plants. Therefore, the technology is only useful in combination with CO_2 capture.

Coal Gasification

Coal gasification technologies (IGCC - Integrated Gasification Combined Cycle) have been known for very long, but are only now becoming interesting for electricity generation. There are several technologically different options of coal gasification tested in large demonstration projects around the world. Gasification based on blowing pure oxygen in superpressure conditions into the sludge consisting of ground coal and water steam appears to be the most promising. In the superpressure reactor, the reduced atmosphere causes incomplete combustion, the primary product of which is a gas mixture consisting mostly of two gases: hydrogen and carbon monoxide, called syngas (synthetic gas):

$$2(CH_2) + O_2 \rightarrow 2CO + 2H_2 \qquad (1)$$

Prior to further use in a combined gas-steam process, the synthetic gas must be cleaned of solid particles, sulphur, mercury, possibly even carbon dioxide CO_2 and other admixtures. Acquired chemical compounds can be stored or used further in the chemical industry.

The coal gasification technologies have the following advantages:

- combustion of cleaned syngas has very low emissions of harmful substances in flue gases, compared to flue gas emissions from combustion of natural gas,
- with the use of the latest gas turbine technologies, high total utilisation rate of gas-steam processes (up to 48 %) can be achieved in combustion of syngas,
- coal gasification is also possible for coals with a very high sulphur content,
- the syngas combustion process sinter-glass ash locking in the majority of other chemical compounds in

flue gases
- syngas combustion offers a high potential for carbon dioxide separation and storage, and
- a potential for hydrogen generation.

CO_2 Capture in Coal Gasification Power Plants

Carbon dioxide separation and storage in the IGCC process can be achieved by converting carbon monoxide into carbon dioxide (»CO shift«) during the syngas cleaning process. After that, syngas basically consists only of hydrogen. Doubling or tripling of oxygen production modules and reformers is necessary to provide adequate availability of the entire thermal power plant. In the future, additional improvements of the process are possible, which might contribute to improved utilisation rates up to 2 %.

Modernisation of Current Coal Power Plants for CO_2 Capture

Numerous countries around the world decide on the future of the existing power plants and on the limitation of CO_2 emissions. The following options are most often discussed:
- to significantly increase the power plants' utilisation rate,
- to continue operation and achieve emission reduction in other areas,
- to shut down power plants and replace them with new ones with an installed system for capture and geological storage of CO_2,
- to modernise the existing power plants for capture and geological storage of CO_2,
- to ignore the emission reduction and pay for CO_2 emissions.

In modernisation of the existing power plants and their facilitation for CO_2 capture, the technological selection is important, as well as the maturity of used technology, operation conditions and reliability, impact on the utilisa-

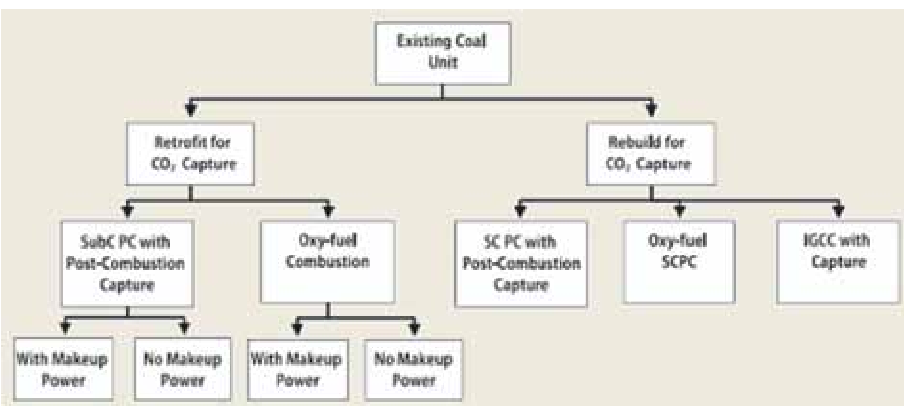

Figure 4. Thermal power plant process without CO_2 capture

tion rate and the complexity of modernisation. In the economic sense, the investment value is important, as well as the reduction of output power of the power plant and a change in price of power plant operation influencing the frequency of its operation.

Possible Realisation of Financing Mechanisms

Electric Industry Association in Europe defends the following options regarding the realisation of financing:

- financing from auction income,
- financing from the reserves of coupons for new investments related to auction mechanisms of coupon trading,
- financing from the reserves for new investments with a direct distribution of coupons

None of the listed mechanisms uses direct public funds. Emission coupons will be financed by the producers of electricity themselves or, indirectly, by the electricity consumers.

Financing of demonstration projects from auction income

In the third phase of the European emission coupon trading scheme, there will be a substantial generation of funds and their transfer from the producers of electricity to state treasuries of the EU member states. The European Commission suggests for a portion of these funds to be devoted for the development of clean technologies, including the development of demonstration CCS projects. Should these funds not suffice, they could be replaced by the funds from the reserves of coupons for new investments. In the European Community such financing mechanism has a strong support of the Electric Industry Association.

Financing from the Portion of Reserves of Coupons for New Investors

In the European emission trading scheme, 5 % emission coupons are to be reserved for new investors. In the period 2013–2020, it would mean 5 % of 14 800 million coupons, or approximately 740 million coupons. Independently of the CCS projects, it is the opinion of the Electric Industry Association that a 5 % reservation is too high, as it exceeds real expectations of new investments in the participating sectors.

A portion of the reserves for new investors could be reserved for new demonstration CCS projects, with an unchanged amount of emission coupons intended for trading by the member states. The European Commission would then elaborate a methodology for distribution of these coupons. The mechanism of coupon financing from the portion of reserves for new investors would:

- provide a coordination at the European Community level;
- create fund sources without affect-

ing the state treasuries of the member states;
- potentially avoid negative impacts on the European trading scheme; depending on a concrete proposition on the coupon allocation given by the European Commission.

Considering the amount of coupons to be reserved from the portion of reserves for new investors and intended for demonstration CCS projects, the estimates range around 500 million coupons. This proposition was recently presented in the European Parliament, the governing body adopting the amendments to the European emission coupon trading scheme.

Below are listed some possible solutions to the question of how to distribute the reserved coupons. The coupons can be sold at the central auction and the acquired income can be distributed among the projects. Another option is to hand over the coupons directly to the managers of demonstration projects to sell them at auctions by themselves.

FINANCING OF INVESTMENTS BY AUCTION SALE OF RESERVED COUPONS

Auction Sale of Reserved Coupons

A certain amount of coupons could be distributed by the commission or any other authorised body at a special auction, thus creating an investment fund put at the disposal of the commission or a special committee made of representatives of member states.

Funds Distribution among Competitors

As already stated in the chapter on basic principles of financing, the allocation of funds must be based on rules of competition in order to provide the highest possible value of the money spent in the programme and enable the demonstration project programme to achieve its purpose. The European Commission, the member states and organisation must define terms and conditions for the acquisition of financial funds; they must include a series of criteria. The CCS projects can, on the basis of terms and conditions, prepare competitive offers including the demanded scope of funds and the time necessary for the realisation of projects. The financial support may be given for both investments and operation of the demonstration CCS project; therefore, the competitor must define both the amount of necessary funds and the dynamics of funds' spending. The projects must be comprehensive and must comprise the entire chain of the process of CO_2 capture and geological storage; therefore, the offers can also be prepared by consortiums of managers of several different components of the demonstration CCS project. The offer price must include costs of all elements in the chain.

The fund manager may establish the best offers on the basis of the scope of the demanded funds and on the basis of a comprehensive complying with the selection criteria. The fund manager should distribute the financial funds in a manner to provide a variety of demonstration projects according to the technologies used in the capture areas, CO_2 transport and storage, and a wider geographical coverage, in the most cost-effective way.

The advantage of this method compared to direct distribution of coupons is that the funds are provided from the European coupon trading scheme, causing the least disruptions in this market. From the point of view of funds acquired for the projects, the mechanism is clear and reliable, with a minimum risk of too low or too high level of subsidisation. The mechanism is in accordance with basic principles of ETS, as it does not give away free coupons for CO_2 not released to the atmosphere. The projects are not subject to uncertainties in the emission coupon market.

Financing of Investments by Direct Coupon Distribution

In such case, the demonstration project bidders would either determine the amount of coupons that are, in their opinion, necessary for economic eligibility of the project, or provide a calculation of additional investment and operating costs. The acquirers of projects would then receive the coupons from the fund of reserved coupons, with the right of selling them at any time at the ETS market. By selling the coupons, the bidders of demonstration projects would acquire additional funds for the realisation of their projects. In order for the investors to receive timely assurance for the realisation of the projects, the projects could, during their first phase, already before the year 2012, receive a credit note and begin with the realisation. The credit notes would later be converted into actual coupons.

Advantages compared to the financing by auction sale of coupons:

- fast realisation,
- a simple system with low administrative costs,
- risks related to the emission market are carried by the projects themselves.

Criteria for Project Evaluation

In addition to economic criteria, the following elements should also be considered when defining criteria for acquisition of financial funds in the framework of European demonstration programme of CCS:

- consistency and maturity of the technological concept,
- potential for achieving long-term commercial goals,
- technical and commercial competences of partners in the project

providing a successful realisation and further commercialisation of the project,
- a commitment to a long-term management of the demonstration CCS project,
- variety and integrity of the entire programme in the following items:
  a. fuel,
  b. the size of the unit,
  c. the capture technology,
  d. transportation method,
  e. technology of geological storage,
  f. business plan,
  g. geographic dispersion.
- commitment to an exchange of acquired experience.

CONCLUSION

There are several ways how to reduce the risks appearing from climate changes. Appropriate solutions are to be determined only by suitable stimulations. Stability of concentration of greenhouse gasses in atmosphere is realizable, although the costs are rather high but can be mastered. Stimulations needed for modification of present investment samples and motion of resent global economy on reducing greenhouse gasses emissions can also be supported by various legal measurements. Activities for reducing greenhouse gasses emissions should be intensified and adopted to consequences of climate changes which can not be avoided anymore.

Reducing risks of climate changes can only be achieved by a coordinated action which means international cooperation, through international networks which support common targets. It can be achieved as a partnership between public and private sector, working class, civil company and individuals. It is still possible to prevent from the worst consequences of climate changes but only by a strong and urgent common action. Any delays would be very expensive and dangerous.

Latest respectable reports as IPCC report, Stern report and IAE report represented technology of capturing and geologic storage (CCS) as a basic potential for reduction of greenhouse gas emissions. Fossil fuels will continue to be an indispensable energy source at least till 2050, CCS represents an important factor of emissions reduction on stationary energy sources which are based on using fossil fuels. CCS technology is also one of the most important agents for reducing CO_2 in steel factories, cement factories and refineries. Their share in emission is about 15 %.

Renewable sources as wind and solar energy and other measurements as improvement of energy efficiency represent a chance to reduce emissions, but it would be too optimistic to expect that

Europe would achieve its targets on reducing greenhouse emissions only this way.

Various studies expect the potential of reducing emissions by CCS technology by 2030 will be between 1.5 Gt to 4 Gt CO_2 a year, in Europe 0.4 Gt CO_2 a year or 20 % of all the emission potential. Beside the reduce of CO_2 CCS technology can also help covering increasing energy demands and sustain energy supply in Europe. In case of using ecologic acceptable coal the dependence of imported gas would be reduced. CCS technology would also have effect on electric energy production, environmental acceptance of new technologies would be improved like using hydrogen or electric vehicles.

Today actually on meetings of large corporations, ministries and governments, where decisions about the kinds, types and characters of future coal power plants. Investments are huge, over 1000 million of USD a plant. Power plants, build today will be in use over next 60 years or more. International Energy Association (IEA) expects for the next 25 years on new power plats over 5 000 000 million USD will be spent. Considering these calculations the capacity of these new plants by 2030 will be 1800 GW. That means about 3000 large coal power plants or approximately 10 power plants each month for the next 25 years. New capacities represent a 1.5-times of all active power plants at present worldwide. It is amazing that seven of ten power plants planned to work in 2030 are still not built yet.

However, the facts listed above represent a great opportunity – in case of further investment into efficient energy use, many coal power plants can be replaced by clean renewable sources and not at last, new built power plants should be built the way that we could capture the CO_2 from them. This new concept would be different from the plants built by our ancestors.

If all the 3000 coal power plants of the new generation were built without equipment for CO_2 emission control, their emission would represent an enormous ecologic burden for our children and grand children. Through the planned life time these plants would produce over 750 billion of tones of CO_2. Consequences of these decisions would be omissions which in the next 25 years would exceed all the omissions ever done from the start of using coal till today for 30 %.

Unfortunately, improving technologies on power plants built without CCS technology according to MIT study are rather senseless due to the fact of large technical modifications even if the technology of supercritical dust or gasified coal combustion had been used.

New power plant built in 2030 – CCS technology costs are to be between 35 EUR/t and 50 EUR/t of reduced emissions CO_2. The price level is equal to expected price of CO_2 coupons during that period. The costs of early demonstration projects would be expected much higher, between 60 EUR/t and 90 EUR/t of reduced CO_2 emissions. CCS technology costs could even be more reduced in case of global spread of the technology or in case of completely new technologies, which are still being tested in labs.

Costs of sample projects can vary from a reference power plant, depending on their specific characteristics. At present, costs of diverse technologies of CO_2 capture are rather similar, but the costs of reconstruction on existing power plants will be rather much higher than on new coal facilities. Costs of reference power plant can also vary depending on the size of the plant, its location or technology. Transport distance can raise the price for approximately 10 EUR/t at 200 km distance. Relatively equalized prices of diverse capturing technologies effect on testing diverse technologies at the same time.

Building CCS into existing power plant will be economical acceptable only on new facilities with a basic high share of conversion efficiency.

There are practical realizable passages from demonstration phase to early commercial phase in 2030, but first a problem of storage and a business model should be solved. To reduce emissions of CO_2 for 0.4 Gt CO_2 by CCS technology in Europe by 2030 there should be between 80 and 120 commercial power plants built. They will probably form clusters of new and old, renewed CCS power plants and industrial projects, gathered into the same transport network and common location for storing CO_2. The speed of the expansion of CCS projects will effect on reducing emissions of CO_2 coming from the objects with CCS technology by 2030. But if the first commercial projects are not accepted soon after the demonstration phase or if delays in projecting occur because of gaining certain permissions, CCS technology will hardly be accepted before 2030.

Storage of CO_2 is probably one of the main insecurities, which could affect on advancing of CCS projects. Despite of all, experts are convinced that there is enough potential on storing CO_2 for many decades to come. Abandoned oil and gas fields are important possibilities, but they are mostly located in north sea, underground locations of salt water are more spread but less researched. It would be ideal if each main emission bunch would have its own underground reservoir of salt water, but it is also possible that transport lines to sea wells will have to be made.

For effective use of CCS technology potential in Europe demonstration program and appropriate planning of further commercial expansion of the technology should be started as soon as possible. There will be a few obstacles and doubts which will have to be abolished. Demonstration program with integrated CCS project could approve usefulness of technology, identify the risks, get public and industry trust into technology. It is necessary to open several demonstrative projects to test diverse capturing technologies and storage characteristics on diverse geologic locations connected to abandoned fuel deposits. Considering high costs for demonstration projects there is an economic difference between expected price CO_2 costs of building and operation of power plant in range of 500 mio. to 1000 mio. EUR/project. In coincidence with these demonstration projects or partly in connection with them, feasibility of storing CO_2 in underground deposits of salt water should be proved.

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