ACCEPTABLE CONCEPT OF CARBON DIOXIDE STORAGE

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This article focuses on the assessment of the possibility of applying the already existing procedures of CO₂ storage and proposal of an acceptable new concept of storage (technical plantation) in accordance with natural resources and socio-economic and technological capabilities. The EU countries aspire to increase the share of renewables in total primary energy, as well as the efficiency of combustion of fossil fuels. Although there are new technologies that impact on reducing emissions of CO₂ in the atmosphere, it is estimated that its amount in the atmosphere will continue to rise and influence the greenhouse effect on a global scale. It is known that, in addition to developing new energy technologies and applications of Renewable Energy Sources, additional measures to reduce emissions of CO₂ are being considered, including possibilities of accepting, appropriations, transportation and storage of CO₂ in reservoirs in general. Since a part of the energy sector in most countries is focused on the burning of fossil fuels, it is necessary to consider the possibility of CO₂ storage from these plants. The basic premise of this approach is the environmental acceptability and economic viability.

Keywords: CO₂ emission, CO₂ storage, ecology, technical plantation

Fig. 1 presents further increase in the amount of CO₂ in the atmosphere, which will be of major concern and will have unpredictable consequences. The increase in concentration will cause further warming of the atmosphere which will be of major concern and will have the expected negative consequences for our civilization.

As further temperature rise projections assume that by 2100 the average annual atmospheric temperatures will have risen by more than 5 °C, the world’s concern is justified. According to some estimations, the Midwest United States, which is now the granary of the world, at temperatures higher than 3 °C will be converted into semi-deserts.

The planet maintained the environment in which life is possible by the carbon cycle. The cycle has four processes:
1) carbon dioxide modification between atmosphere and ocean,
2) circulation of deep ocean water (exchange of CO₂ between the surface and depth – Oceanic uptake),
3) photosynthesis by the vegetation on the earth and transforming the long-term carbon storage into wood and soil,
CO₂ + H₂O + energy → C₆H₁₂O₆ + O₂

4) net absorption or emission (deforestation, or otherwise).

These flows in the global carbon cycle can be summarized by the formula:

Atmospheric increase of CO₂ = Emissions from fossil fuels + Net emissions from changes in land use – Oceanic uptake – Missing carbon sink.

Human activities had various consequences: on one hand they caused the destruction of forest areas, and on the other hand the combustion of carbon. Both activities resulted in increasing concentration of CO₂ in the atmosphere. Nevertheless, it is desirable to have a so-called CO₂ sink, or the manner in which the CO₂ will be consumed or extracted from the cycle. The cycle of vegetation includes CO₂ emissions due to decomposition of organic matter and absorption of CO₂ for photosynthesis. Both cycles are balanced at about 120 billion tons of carbon per year, according to Fig. 2 [3].

Absorption and emission of carbon dioxide from the ocean are also balanced at about 180 billion tons of carbon a year, each. The evidence of balancing the natural balance of CO₂ has been shown through approximately constant concentration of this gas in the atmosphere for several centuries in the pre-industrial period. During 1980s, human activities led to more emissions into the atmosphere (above the one that follows from the natural processes) from 6.5 to 8.5 billion tons of carbon per year. Around half of this amount was absorbed into the natural processes, and the other half increased concentration of CO₂ in the atmosphere, [1].

The trend of increasing concentration of CO₂ in the atmosphere is shown in Fig. 3 [3].

Fig. 3 gives an overview of changes in CO₂ concentration since 1957 until now (measured by the meteorological laboratory Mauna Loa in Hawaii).

Fig. 4 shows CO₂ emissions trends from 1960 to 1995, and emissions projected by economic models (EPPA, GTEM, POLES and PRIMES) to 2020 in the European Union. Higher emissions in EPPA are thus due primarily to higher GDP (gross domestic product) growth rates for this region (the average GDP growth rate for Europe in EPPA-EU is 3.6 % between 1995 and 2010, 2.5 % in POLES and PRIMES, and 2.7 % in GTEM [4].
2 Carbon dioxide storage technologies – advantages and disadvantages

It is understood that the capture, isolation and transport of CO$_2$ are resolved by the known suitable technical interventions that are generally similar for all cases of storage. As these procedures are described in the literature, the rest of this paper gives an overview of methods of storing CO$_2$ in order to highlight the concept which would be suitable for use in Croatia. There are several basic ways of storing CO$_2$, Fig 5:

1) storage in depleted oil or natural gas deposits and storage in deep saline aquifers.
2) ocean storage at depths below 3000 m.
3) industrial absorption in the green areas.

The second method also requires investments in equipment and energy but also represents a major risk to the environment due to potential impact on ocean ecosystems.

The third type does not require excessive investments in equipment, the location can be more flexibly chosen in the environment of the facility that emits CO$_2$, and for the storage process mainly solar energy (photosynthesis) is used.

This type will be considered below, as well as the concept adapted to it.

3 Concept of long-term CO$_2$ storage – technical plantations

It is known that it is possible to achieve accelerated growth of plants by enriching the greenhouse atmosphere with carbon dioxide, the main food for plants and vegetables. Carbon dioxide is used to improve productivity, quality and quantity of plants. It is suitable for cold climates and can be used to accelerate the growth of practically all kinds of vegetables (e.g. tomatoes, asparagus, celery, lettuce...), fruit from the greenhouse (e.g. strawberries), ornamental plants, etc. As one of the sustainable concepts of storing CO$_2$ in Croatia is proposed the injection of CO$_2$ into the technical plantation - greenhouses for crop production (common food or ornamental plants as well as hydroponic or aeroponic), where, as described above, CO$_2$ would be stored.

This concept is oriented toward that amount of CO$_2$ that is not absorbed by natural processes, but increases concentration. This procedure not only stores, but also consumes CO$_2$, a schematic diagram in Fig. 6.

It is understood that the balance of CO$_2$ absorption in the plants should be higher than the CO$_2$ emissions during their degradation - the fallen timber should be collected, which will be long-term stored in other ways than burning or rotting.

These plantations would have vegetation that increases spending of CO$_2$ to the fullest extent possible for its growth, according to agro-technical properties (CO$_2$ absorption, water, etc.). Properties of vegetation provide covering of the entire plantation with plastic foil, without building a special bearing structure.

During the growth of vegetation (CO$_2$ spending), the foil is easily added only on the edges of the plantation, since growth of vegetation in the central plane of the foil performs a parallel shift of the ground. CO$_2$ is brought under the foil where it mixes with the air present, thus raising the level of concentration. As CO$_2$ is heavier than the air, it remains at the soil and thus avoids unwanted effects (breathing, etc.).

In addition, the foil physically prevents access to plantation. In the case of treatment of vegetation (crop, harvest, etc.), the foil is simply removed from the part of plantation. CO$_2$ can be transported via pipeline to the ground and emitted dosed at pipe ends, analogous to the principle of irrigation "drip".
4 The concept analysis of technical plantation in the example of power plants

The average adopted temperature under the foil is 33 °C (year round) as the optimal temperature for the growth and yield of plants, with 1500 ppm of CO₂ in the air. In the case of open forests, the amount of CO₂ ppm would be slightly lower due to inability to control the temperature, [7].

It is generally necessary for such a concentration of 0,015 m³ of CO₂ per 1 m³ of space. For the bulk concentration the main mass concentration can be found. Fig. 7 shows the CO₂ density in dependence on temperature.

For the chosen temperature, CO₂ density is 1,7 kg/m³ respectively, the required weight of CO₂ is 0,0255 kg in a volume of 1 m³.

If the vegetation consumes about 0,4 kg CO₂/m² per day, then in 10 hours it consumes 0,04 kg CO₂/(m²/h) (average insolation). This means that the active layer in the canopy during photosynthesis is about 1,6 m in height. If the plants passed semipermeable film (drainage) below it would be possible to insufflate CO₂ collected. This foil would largely maintain a layer of gaseous CO₂ in the presumed amount of the active part of the canopy during photosynthesis.

<table>
<thead>
<tr>
<th>Year</th>
<th>CO₂ emissions in 1000 t</th>
</tr>
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<tbody>
<tr>
<td>2000</td>
<td>450</td>
</tr>
<tr>
<td>2001</td>
<td>578</td>
</tr>
<tr>
<td>2002</td>
<td>864</td>
</tr>
<tr>
<td>2003</td>
<td>981</td>
</tr>
<tr>
<td>2004</td>
<td>451</td>
</tr>
<tr>
<td>Average</td>
<td>664,8</td>
</tr>
</tbody>
</table>

If the annual CO₂ emission is 664 800 t, this means that the average daily power plant emission is 1821 t CO₂, assuming that the vegetation in the technical plantation absorbs an average of 0,4 kg/m² per day or an average of 0,04 kg CO₂/(m²/h) (the sunny part of the day); it follows that it takes approximately 4 553 425 m² of the surface vegetation for its absorption.

In other words, an imaginary square of the technical area of vegetation should have sides 2,14 km in length in order to be able to absorb the average emission of this power plant.

For practical reasons, it would be desirable to establish technical CO₂ plantations as close as possible to the plants that have increased CO₂ emissions, to reduce storage and transportation costs. CO₂ gas could be brought directly by the pipeline and thus heavy containers (bottles) of gas could be avoided.

If the prices of emission permits by contracts (in future) are on the level of 20 €/t CO₂, from [9], if we take care of 1821 tons per day that means a daily income of 36 427 € or 13,3 M€ a year.

For a comparison of this income with the income from the production of electricity, the thermal power plants in the example produce a daily average of 2,5 million kW·h; according to the framework market price of 0,086 €/(kW·h) it makes 215 000 € a day.

The cost of CO₂ capturing only should be estimated to 1/3 of total CCS cost (capture + transportation + storage) or 1,3 eurocents/(kW·h), [6, 11]. This means around 32 500 € a day for the price of capturing only.

To this price the costs of the proposed technical concept should be added. In the following text the cost of the project of building technical plantations will be discussed. It is assumed that the costs of the project documentation, insurance, land for industrial plantations, development of CO₂ pipeline transport and dispersal on the ground, then the cost of planting and initial vegetation cover of the planned territories with the plastic wrap resistant to UV radiation are the most significant investment costs.
The foil adapted to greenhouses should be applied, [10], whose price, as the largest project cost expected, amounts to an average of 0.7 €/m² (from various commercial sources) and only the installation costs additional 0.13 €/m².

The total cost of the technical sheet for the plantation of 4,553,425 m² rises to 3,800,000 €. Having taken the cost of the project documentation for about 20 % of the foil, then the pipeline about 30 % and other costs of about 10 %, we obtain the total project cost estimation of around 6.1 MEUR.

With a moderate cost of capital and 10 years for return of investment, it follows that the procedure should be financed from about 0.085 eurocents/ kWh or 2100 € a day. This should be added to the price of capturing 32,500 € a day, that gives 34,600 € a day cost. The difference between income from prices of emission permits and last cost gives

\[ 36,427 - 34,600 = 1827 \text{ € a day of profit}. \]

5 Conclusion

Technical plantation can be located near CO₂ sources, or a bit further, depending on available space. Considering the purpose and effect, it is completely environmentally friendly.

With minimal annual maintenance costs and maximum rates of emission allowances, investment in technical plantation should give to basic income from electricity production about 1 % more income from prices of emission permits, or 667,000 € a year.

In addition, as a by-product, plants can have at their disposal wood mass that has been created (production of furniture, carpentry, construction, etc.).

6 References

[7] https://forums.vutra.org/content/130-Carbon-dioksid-CO2