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RESEARCH ARTICLE

Production and Use of Carbon Dioxide Gas in Turkey

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HIGHLIGHTS

- The current state of production, storage, handling and use of Carbon dioxide, which can be extracted from underground directly, from geothermal sources, or by chemical reactions, in Turkey is investigated.
- It is important to carry out research and conduct applications on feasibility of the use of carbon dioxide, which has the potential of being used as the carbon source in the production of fuels, carbonates, polymers and other chemicals.
- As a developing country, Turkey has an increasing demand for CO2 supply, but the domestic production, which is crucial, seems to not going to meet the demand in the near future.

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ABSTRACT

Carbon dioxide, which is also used in industry and agriculture, is the most important of the gases that cause global warming and climate change. Naturally extracted from underground reserves or extracted from the burning of fossil fuels, chemical reaction and fermentation in this gas industry in the food and cooling industry, firefighting, heat pumps, gas supply in various areas such as Used. Besides, carbon dioxide is an important food source for plant development and is necessary in the case of photosynthesis of plants. The presence of carbon dioxide levels in greenhouses at a certain concentration has been observed as a result of research estimating that it causes significantly increased yields in grown plants.

Natural carbon dioxide extracted from underground sources is derived mainly from Denizli Kızıldere, Niğde Kemerhisar and Aksaray basins in Turkey. These deposits are the richest natural carbon dioxide fields in the world together with central European countries. Geothermal resources also have a relatively high and continuous CO_2 oscillation. This causes high carbon emissions to be released into the atmosphere while energy is generated in geothermal power plants. To reduce CO_2 emissions that cause global warming and climate change, it is necessary to use it temporarily or permanently in the production of various products and ensure that they are stored. This study aims to investigate CO_2 production, production technologies, usage patterns, and economic potential.

Contents

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1. Introduction

In our growing population, energy demand is rapidly increasing, while fossil energy resources are being consumed extensively. Due to this consumption, our resources are decreasing and environmental pollution is increasing in parallel. It is clear that if the consumption rate continues in this way, the world will become uninhabitable. Therefore, each country takes various measures for a cleaner and more livable world and to take measures with various protocols by conducting studies to maintain ecological balance in parallel with scientific and technical studies they carry out.

The most important threat to our world is global warming. Due to global warming, the natural balance is deteriorating, increasing the severity and frequency of disasters such as floods, storms, etc. To prevent this deterioration, the Framework Convention on Climate Change was adopted at the World Summit in Rio De Janeiro in 1992 and entered into force in 1994. Turkey officially became a party to this agreement on 24 May 2004. According to this convention, the signatories agree to reduce greenhouse gas emissions to the levels of 1990 through various national programs and to transfer technological and financial resources to developing countries. The binding provisions of the Framework Convention are the preparation of national greenhouse gas inventories and the development of programs containing notifications and measures to be taken for emission reductions. The Kyoto Protocol is an agreement signed under this Framework Convention, which requires developed countries to reduce greenhouse gas emissions by 5.2% compared to 1990. This protocol was called in December 1977 in Kyoto, Japan. The main purpose of the protocol is to reduce the average emission values of greenhouse gases (carbon dioxide, methane, nitrogen, sulfur hexafluoride, chlorofluorocarbon (CFC), etc.) The protocol entered into force on 16 February 2005. As of December 2006, a total of 169 countries have participated [1].

The Kyoto Protocol includes improving energy efficiency, utilizing renewable energy sources, supporting sustainable agriculture, reducing hazardous greenhouse gas emissions and protecting and even spreading forests and vegetation that help reduce concentration of such gases in the atmosphere.

Among the gases that cause global warming and climate change, carbon dioxide is the biggest effect as mentioned above. This gas is used for different purposes, in a wide variety of fields of industry, such as food, and agriculture. Naturally extracted from underground reserves, derived from the burning or combustion of organic matter, obtained by chemical reactions and fermentation, this gas is used in a variety of fields of industry, ranging from food, cooling industry, firefighting, to heat pumps, gas supply, etc. [2, 3]. Carbon dioxide is an important source for plant development, which is essential in photosynthesis in the cycle of carbon. In researches, the levels of presence of carbon dioxide in greenhouses, at a certain concentration, has been observed to have caused significant increase in yields of grown plants. CO_2 fertilization at appropriate levels for increasing the yield of grown plants is of great importance [4].

In order to reduce the release of carbon dioxide into the atmosphere, it is necessary to develop new processes in its production, to renew the necessary technologies and to ensure that this gas is used safely, also its properties and acquisition processes need to be well known.

2. Material and Methods

2.1. Carbon dioxide

Carbon dioxide is a molecule composed of one carbon and two oxygen atoms, a gaseous compound under normal conditions. The molecular weight is 44,009 g/mol. Colorless and odorless, this gas is chemically acidic, water soluble, corrosive, and has anti-combustion properties. Carbon dioxide gas is simultaneously found in solid, liquid and gaseous form at -56.6 °C and under 4 bar pressure. It can be stored at a pressure of 13 – 20 bar and at a temperature of -35 – 55 °C. If carbon dioxide dissolves in water in an oxygen environment at high pressures, it becomes carbonic acid [5].

There are four main sources of natural carbon dioxide extracted from underground.

2.1.1. Magmatic origin formation

There are very dense carbon dioxide outputs around young volcanoes in Turkey, around Kula, Erciyes, Hasan Mountain, Nemrut, Suphan, Tendurek volcanism, and these are of magmatic origin.

2.1.2. Sedimentary origin formation

These types of reservoirs are found in limestone traps within the anticlinal structure. Carbon dioxide deposits are available in sedimentary areas in Thrace region and Southeastern Anatolia Region. The largest reservoir is located in Dodan, in Siirt province of Turkey. This gas is used by The Turkish Petroleum Corporation (TPAO) for Oil Recovery (EOR). Dodan, Çamurlu and Yolaçan fields are those used by TPAO. Turkey's natural carbon dioxide fields are shown in Figure 1 [6, 7]. Gas ratios from natural CO_2 reservoirs extracted in Turkey are also given in Table 1[2].

2.1.3. Metamorphic formation

Copious amounts of CO_2 outputs exist in North Anatolia and Eastern Anatolia faults, and around grabens and active faults. Natural CO_2 sources of magmatic and metamorphic origin are based on many inactive volcanisms in Central Anatolia. In Table 2, CO_2 fields in magmatic and metamorphic sites are operated by private companies, and natural well manufacturers and production capacities are given [2].

Table 1 Characteristics of Turkey's natural CO2 reservoirs [2]

Reservoir	Total Gas (MS m^3)	Reusable Gas (MS m^3)	CO_2 (%)	N_2 (%)	H_2S (%)	Other (%)
Çamurlu	1,34	0,80562	73,37	5,22	0,11	21,3
Dodan	10,845	3,4	91	3,1	0,3-0,4	5,9
Yolaçan	0,232	0,1727	41,57	2,79	-	55,64

Table 2 Natural well manufacturers and production capacities in magmatic and metamorphic sites [2]

Company	Facility Location	Production Capacity (tCO2/day)	Product
Barit Maden	Kayseri-İncesu	100	CO_2 (Liquid)
MEGAŞ	Kayseri-Hacılar	120	CO_2 (Liquid)
Linde	Aksaray	120	CO_2 (Liquid)
Güney Doğalgaz	Niğde-Kemerhisar	120	CO_2 (Liquid)
Hisargaz	Niğde-Kemerhisar	100	CO_2 (Liquid)

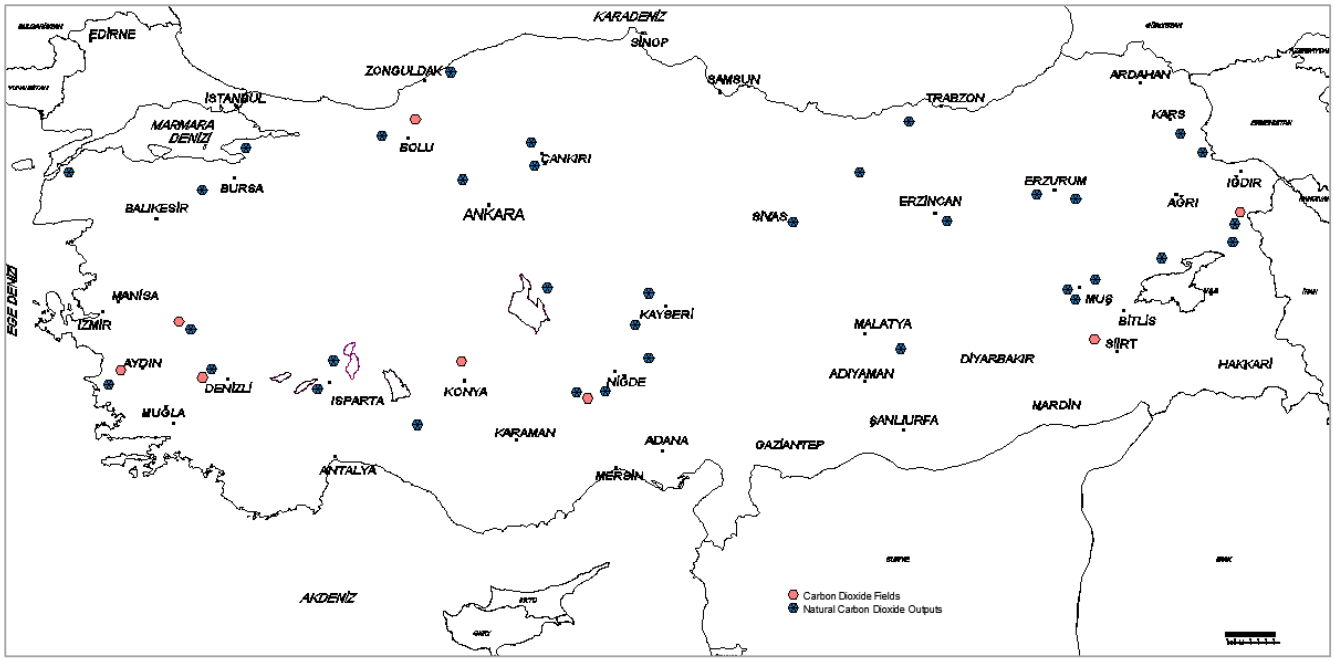

Figure 1 Natural Carbon Dioxide fields [6, 7]

2.1.4. Geothermal Based Formation

Carbon dioxide is also present in geothermal fields [2, 8]. There are over 227 geothermal sites in Turkey that can be used both for power generation and for direct use purposes. There are approximately 2,000 hot water and mineral water springs, temperatures of which are ranging from 20°C to 287°C [2, 7, 9]. CO_2 is obtained from geothermal fields as shown in Figure 2. Table 3 shows commercial CO_2 production capacity obtained from geothermal sources. These amounts may vary depending on the season and need. Table 4 provides an overview of commercial CO_2 manufacturers and production capacities in Turkey.

Table 3 Commercial Liquid CO_2 production capacity from geothermal sources [2]

Company	Facility	Facility Location	Production Capacity (tCO2/day)
BM Holding	Gümüşköy GPP	Aydın-Germencik	100
Linde	Kızıldere GPP	Denizli-Sarayköy	120
Linde	Dora I GPP	Aydın-Köşk	120
HABAŞ	Dora II GPP	Aydın-Köşk	120

GPP: Geothermal Power Plant

Table 4 Commercial CO_2 producers in Turkey [2]

Company	Production Source	Product	Production Capacity (tCO_2/day)
Barit Maden	Natural well	CO_2 (Liquid)	100
MEGAŞ	Natural well	CO_2 (Liquid)	120
Linde	Natural well	CO_2 (Liquid)	120
Güney Doğalgaz	Natural well	CO_2 (Liquid)	120
Hisar Doğalgaz	Natural well	CO_2 (Liquid)	100
BM Holding	Geothermal	CO_2 (Liquid)	25
Linde	Geothermal	CO_2 (Liquid)	360
Linde	Geothermal	CO_2 (Liquid)	100
HABAŞ	Geothermal	CO_2 (Liquid)	300
Torku	Biyoetanol (CCT)	CO_2 (Liquid)	80
Tezkim	Biyoetanol (CCT)	CO_2 (Liquid)	100
Barit Maden	Fermantasyon (CCT)	CO_2 (Dry ice)	50
Total Capacity			1575

CCT: CO_2 manufactured with Carbon Capture Technology

3. Place and Uses of Carbon Dioxide in Life

Carbon dioxide is used as a covering inert gas in metal welding. Oxygen and carbon dioxide are mixed into argon gas in MIG welding of steel, whereby it accelerates the formation of small amounts of easily melting oxides, weakens the surface tension of droplets falling from the melting electrode and thus provides a fine-grained metal transition. Gas Welding, which is made only under the CO_2 gas atmosphere, is called “Metal Active Gas” [MAG] Welding. This gas welding ingredient is mostly used in the welding of unalloyed steels [10].

It is used in surface hardening works of steels, which is called cementation or carbureting, known as a type of “thermo chemical process”. It is one of the oldest surface hardening processes; carbon content below 0.2% is based on the issuance (absorption) of carbon in solid, liquid or gas environment to the surface of unalloyed or low alloy steels. After this process, the material is usually hardened by quenching in oil. The surface part is hard and corrosion-resistant, while the core part is soft but tough compared to the surface; i.e. a material that is resistant to impacts is obtained. Cementation is used in the manufacturing of steels, and several parts, such as gears, shafts, piston pins, valves, chain pods, chain gears, discs, bearings, some measuring and control tools [11].

In the chemical industry, the precipitation of salts such as ammonium bicarbonate, potassium carbonate, calcium carbonate, penicillin production is used as pH adjusting acid [8].

As a fire extinguisher gas, CO_2 is the most important in fire prevention, fire tubes and fire extinguishing systems. It removes the oxygen, which is required for combustion to proceed, from the environment or reduces it concentration. Under normal conditions, 0.03% of the air is CO_2. The

amount of CO_2 in the air in the external environment varies between 330 and 500 ppm depending on environmental characteristics. CO_2 is not a toxic gas, but it could be choking due to oxygen deprivation. When the concentration value exceeds 35,000 ppm, the central breathing nerve receptors are triggered and cause short breathing. Due to a lack of oxygen at higher concentrations, the central nervous system is unable to function [12]. In environments where concentration is 10% higher than the normal value, respiration can lead to sudden loss of consciousness and sudden death. Symptoms of suffocation are probably death after rapid and difficult breathing, nausea, vomiting and loss of consciousness [13].

CO_2, which is used in beverages such as fruit juices, cola, keg beer and mineral water in the food industry, regulates its use in the beverage industry according to the Turkish Food Code Index published by the Ministry of Food, Agriculture and Livestock. Accordingly, it defines the chemical components of the CO_2 product and with this regulation the minimum purity level in the beverage industry is set at 99% and limits on beverage participation [2]. During the production of carbonated beverages such as soft drinks, mineral soda and beer, carbon dioxide is used during carbonization due to its solubility in liquids. Carbon dioxide has the ability to limit or completely stop the reproduction of microbes that damage the drink. The most important issue in stopping the growth of bacteria is the amount of dissolved carbon dioxide in the product. The higher this amount, the greater the durability of the products. It also allows beverages to retain their taste for a long time and prolongs shelf life. Pizza, chicken, frozen food, all kinds of vegetables and fruits in the food industry ensures that the property remains unchanged for a long time.

Unlike conventional cooling methods, the loss of weight is minimal after decocting, as the loss of water in the product is minimized in carbon dioxide cooling. Product freshness remains; therefore, it is an economical, lucrative and effective cooling method. Dry ice occurs when liquid CO_2 gas is pressurized at 15 bar and -80 °C. For being colorless, odorless and not having no moisture content, it is highly preferred in the transportation of cold substances. Carbon dioxide, which has application areas in the chemical and food industry, is used as dry ice in cold grinding processes to remove unwanted heat from the environment owing to its low temperature.

CO_2 fertilization is called for the use of CO_2 in agriculture and the provision of CO_2 in various ways that plants need. In order to intake and use carbon dioxide in the plant and to start photosynthesis activity, CO_2 must be in the environment. In this case, CO_2 is absorbed by plant leaves through openings called stoma in leaf tissue. This absorption cycle accelerates as soon as the stomas begin to be reduced by CO_2 light energy and water that enters the leaf tissue and is stored in spaces between cells. The higher the CO_2 density in the environment, the faster this cycle will be. Increasing the amount of CO_2 will allow the plant to use excess water and energy stored in its leaves, causing a significant increase in growth [14, 15].

In agricultural pest control, it does not allow pests in its environment due to its suffocating properties and is therefore used in fumigation works. The use of carbon dioxide in the fumigation process against pests in greenhouses, in the silos where cereals such as wheat, corn and legumes are stored, is a harmless alternative to chemical drugs that have been proven to be harmful to human health and the environment. In open agricultural land applications, spraying efficiency increases by 2 times when CO_2 gas is used instead of air with the drug to be sprayed [8].

In fertilizer production, carbon dioxide is a source of urea production. The use of urea as fertilizer corresponds to half of the fertilizer used in the world. Urea is produced as a result of the chemical reaction between ammonia and CO_2 at high pressure and heat [16]. CO_2 has an important role to play in increasing urea yields. The only company producing urea in Turkey is IGSAS. The amount of nitrogen in urea is higher than other fertilizers, and the price is lower [2]. The amounts of urea produced in Turkey is given in Figure 2. Consumption distribution of urea compared to other fertilizers is shown in Figure 3. It is also understood from the amount of consumption that urea is a very important fertilizer [17]. Increasing urea yield using CO_2 is very important for Turkey.

For the purpose of Enhanced Oil Recovery (EOR), it has been used in oil production fields. The first stage of crude oil production is achieved by natural flow or through pumps. Oil extracted from the well becomes difficult to extract after a certain level. In these cases, water or gas is injected into the wells so as to the remaining crude oil is extracted. The gas used in gas injection includes the injection of CO_2, CH_4 and N_2 gases. All of these gases aim to reduce the viscosity of crude oil in order to extract it easily. The choice of the method also depends on the parameters of the reservoir and the availability of the gas source. To date, six advanced oil recovery have been carried out in four crude oil fields in Turkey. Since 1986, there has been a displacement CO_2 injection EOR project in the West Raman oil field. Steam injection and displacement CO_2 injection was performed at the Ikiztepe oil field. In addition, displacement CO_2 injection was carried out in Çamurlu and Western Kozluca oil fields. The results are promising for CO_2 injection projects. The EOR project in Western Kozluca was halted until the construction of the recycling unit in the field to prevent the depletion of CO_2 reserves. CO_2 projects in Çamurlu and Ikiztepe oil fields were stopped for technical and economic reasons [18–20]. However, it is possible for CO_2 derived from Turkey's natural and geothermal sources to feed these fields through pipes [2].

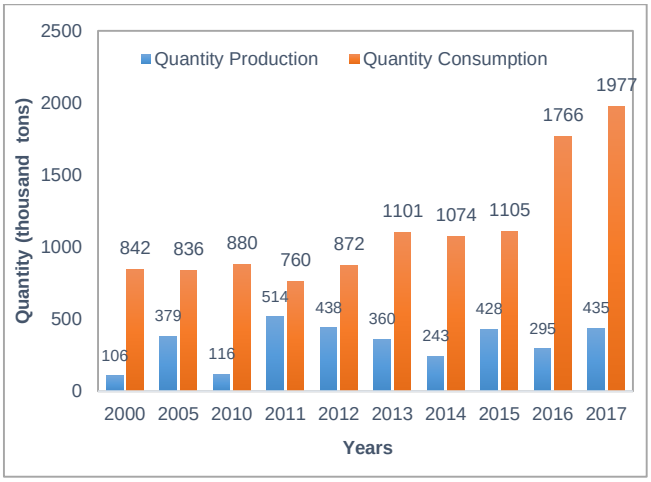

Figure 2 Urea quantities used and produced in Turkey [17].

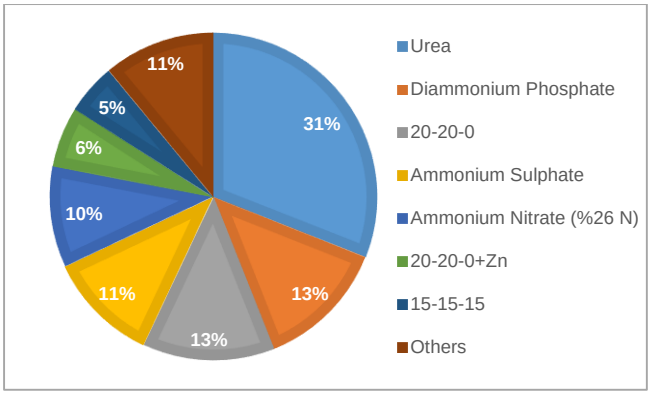

Figure 3 Consumption Distribution by Fertilizer Species for 2017 [17]

4. Transportation of Carbon Dioxide

Carbon dioxide can be transported in gas or liquid form to places where it is needed. In Turkey, commercial transportation is usually done in liquefied or as a refrigerant in foods in the form of dry ice. Where gas needs are high, pipeline transport can be carried out for oil recovery from CO_2 production sites or for use in greenhouses. In order for CO_2 to be safely transported in liquid form and a two-phase flow regimen not to occur, the pressure must be greater than 80 bar. The liquid covers less volume due to its high concentration of CO_2, which reduces the cost of transport. Transport with land and rail tankers is a preferred method for small quantities of liquid CO_2. These systems carry CO_2 at -20°C and 20 bar pressure. The carrying capacity of the land tanker is between 10-25 tons. A single car can carry 60 tons of CO_2. However, these methods are not economical compared to pipeline and sea freight, except for small-scale distributions. It is reasonable for land and rail tankers to be used only for land deliveries [2, 21].

5. Discussion

Turkey is a region rich in geothermal resources. CO_2 obtained during the extraction of geothermal resources and CO_2 obtained from natural CO_2 wells are used in large commercial terms in the above mentioned uses. This usage reduces emissions from geothermal plants and decreases the harmful effect on the environment. In addition, Turkey is a transit route from the Caspian and Middle East to Europe. There is potential for oil exploration and unconventional oil and gas in the Black Sea and Mediterranean [2]. CO_2 is a very important gas for oil recovery (EOR) in order to extract oil from oil wells that are not efficient in terms of rising oil prices and reducing foreign dependence.

Industrial CO_2 can be used in urea production to increase efficiency. In order to improve the agricultural sector in our country and to reduce the dependence on agricultural products by increasing the yield, cheap fertilization is very important, which can only be achieved with the production of urea with increased yields. It will increase urea efficiency thanks to the use of CO_2. The use of CO_2 in greenhouses in the south and southwest of Turkey will again increase productivity, making product prices competitive with the world. In addition, the use of CO2 is important in order to ensure that the quality of the product is maintained for a longer period of time by using dry ice in the food industry.

6. Conclusion

Consequently, CO_2, which has the most important share of gases causing global warming, is used commercially to increase oil production, to keep food fresh, to increase the yields of various products, to protect against harmful pests, in fire-fighting, welding and heat treatment etc. It is one of the most important gases. It should be noted that excessive carbon dioxide emissions play an important role in the acidic properties of the earth's waters. We have to use every option we can to reduce carbon dioxide emissions to leave a livable clean world for future generations.

In Turkey, the total capacity of carbon dioxide producing companies is 1,575 tCO_2/day. The development of the refrigeration industry, the increasing importance of the cold chain for food quality, the use of carbon dioxide injected into oil wells for oil recovery (EOR) to increase the efficiency of the oil deposits in the Southeastern Anatolia Region; use in greenhouses is expected to become widespread. This capacity will gradually increase with the development of industry and increasing needs. It is estimated that CO_2 production and transportation costs will decrease and its use in industry will increase rapidly in the upcoming period.

Ayrıca karbon kaynağı olarak CO2, yakıt, karbonat, polimer ve kimyasalların üretiminde de kullanılma potansiyeline sahiptir. Bu amaçla kullanılacak CO2 için yeni bir ekonomiyi temsil etmektedir. CO2 kullanımı, orijinal hammadde tüketimini azaltırken ve bunlarla ilişkili diğer maddelerin atmosfere salınımını engellerken, atmosfere karbon salınımını geciktirmesi dikkate alınması gereken bir husustur.

It also has the potential to be used in the production of CO2, fuel, carbonate, polymers and chemicals as carbon sources. In this regard, CO_2 stands out as a new economy. The use of CO_2 in intermediate use will help reduce the consumption of original raw materials, such as oil, and prevent the release of carbon dioxide by increasing its consumption, as well as reduce the emission of other process-related harmful substances into the atmosphere. Increased use of carbon dioxide, along with innovative CO_2 capturing technologies which will enable the capture of CO_2 in the atmosphere could offer a solution to fight against global warming.

There are major international companies that conducts research and development programs on Carbon Capturing Technologies, and it must be urged for the domestic players, too.

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