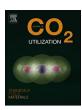
ELSEVIER

Contents lists available at ScienceDirect

Journal of CO₂ Utilization

journal homepage: www.elsevier.com/locate/jcou



Advances in CO₂ utilization technology: A patent landscape review

R.S. Norhasyima^{a,b,*}, T.M.I. Mahlia^{a,c}

- ^a Department of Mechanical Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
- ^b PETRONAS Research Sdn Bhd, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia
- ^c School of Systems, Management and Leadership, Faculty of Engineering and Information Technology, University of Technology Sydney, NSW 2007, Australia



ARTICLE INFO

Keywords:
CO₂ utilization technology
CO₂ utilization patent
Enhanced oil recovery (EOR)
Mineral carbonation
Biological algae cultivation
Enhanced geothermal system (EGS)

ABSTRACT

There is rising concern on the increasing trend of global warming due to anthropogenic CO2 emission which steers progress of carbon capture and storage (CCS) projects worldwide. However, due to high cost and uncertainties in long term geological storage, there is a growing inclination to include utilization, which re-use the CO2, hence carbon capture utilization and storage (CCUS). Additionally, it is expected to generate income to offset the initial costs. This study methodically review patents on CO₂ utilization technologies for CCUS application published between year 1980-2017. It was conducted using the Derwent Innovation patent database and more than 3000 number of patents was identified. The patents identified are in the field of enhanced oil recovery (EOR) and enhanced coal-bed methane (ECBM), chemical and fuel, mineral carbonation, biological algae cultivation and enhanced geothermal system (EGS). Over 60% of these patents were published since the last 10 years, and a sharp increase in patents were seen in the last 5 years (~38%). The top major patent types are patents granted in the United States (US), China (CN) and Canada (CA) which makes of 3/5 of the overall patent type found. Recent patents published include enhancements to the state-of-the-art technologies and hybrid concepts such as in photo-bioreactor in algae cultivation, chemical reaction and EGS. From this study, it was found that further research for the best CO2 utilization method which fulfil the need of an economic, safe, nonlocation dependent and environmentally friendly whilst efficiently mitigate the worldwide global warming issue is much needed.

1. Introduction

Limiting the increase of anthropogenic carbon dioxide (CO2) emissions in the environment is a major challenge facing the world today. Hence, there is a vital need to assess the growing worldwide concern about global climate change. CO2 generally originated from flue gas from fossil fuel combustion, biogas from anaerobic digestion, product of coal gasification and natural gas streams [1-4]. According to BP energy statistics, in the year 2016 there were 33,432.04MT of CO2 emission worldwide [5]. An assessment conducted by The Intergovernmental Panel of Climate Change (IPCC), concluded that the CO₂ emissions should be decreased by at least 50% to limit the escalation of the global average temperature to 2 °C by 2050. International Energy Agency (IEA) presented models of technology mix which are essential to meet the 2 °C scenario. The model shows that in order to achieve the targeted scenario, CCUS will need to contribute at least one-sixth of global CO₂ emission reductions by 2050, as well as 14% of the cumulative emissions reductions from 2015 to 2050 as compared to a business-as-usual [6].

CCUS is a methodology to separate CO2, then utilize CO2 to produce valuable products and techniques to store produced CO2, commonly from power generation, industrial processes and even high CO2 gas fields. The IPCC report stated that without CCUS implementation, the overall cost required to mitigate global climate change may increase up to 138% and there is great challenge to achieve the targeted 2 °C scenario [7]. Various international agreements have been established to ensure that CCUS will play an important role for an economically sustainable route for CO₂ emissions cut required to limit the global climate change rise [8]. More recently, the Paris Agreement of 2016 was established to further accelerate the worldwide response to the threat of climate change by keeping a global temperature rise this century by limiting the temperature rise even further to 1.5 °C [9]. This effort requires even more effective actions to combat climate change, especially on the mitigation for CO2 emission reduction worldwide. Therefore, new technologies are needed to be developed as one of the critical methods to mitigate the global warming issue [10]. Apart from international agreements, a global competition was introduced to combat CO2 emission. NRG Canada's Oil Sands Innovation Alliance (COSIA)

^{*} Corresponding author at: Department of Mechanical Engineering, Universiti Tenaga Nasional, 43000, Kajang, Selangor, Malaysia.

E-mail addresses: norhasyima.rahmad@petronas.com.my, PE20454@utn.edu.my (R.S. Norhasyima), indra@uniten.edu.my (T.M.I. Mahlia).