

1 **A Comprehensive Review on CO₂ Capture Process using Amine-**
2 **Ionic Liquids Mixtures**

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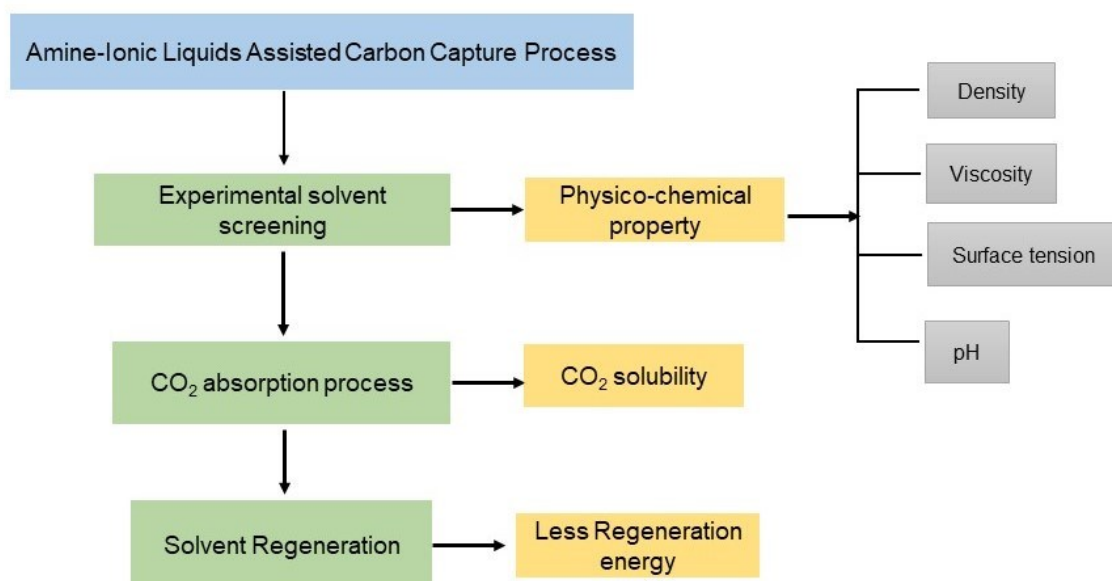
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22 **GRAPHICAL ABSTRACT**



23

24 **ABSTRACT**

25 In recent years, there has been an increase in the earth's temperature due to the emission of CO₂
 26 which causes global warming. With a 1.9°C temperature increase predicted by the
 27 Intergovernmental Panel on Climate Change, reducing of CO₂ is essential for all living species.
 28 Therefore, finding novel CO₂-capturing strategies is the only way to eliminate this life threat.
 29 From post-combustion coal-fired power plants, CO₂ separation is employed by a solvent-based
 30 chemical absorption method using Monoethanolamine (MEA) as standard solvent, which is the
 31 most practically proven and reliable process. The utilization of other solvents as absorbents in
 32 the CO₂ absorption process such as amine solutions, ionic liquids (ILs), and amine-ILs solvent
 33 blend mixtures were reviewed. This review provides an overview of the CO₂ capture process,
 34 emphasizing the importance of developing efficient and sustainable methods to mitigate
 35 greenhouse gas emissions. It also highlights the potential of using amine-ionic liquids mixtures
 36 as promising candidates for CO₂ capture due to their unique properties for effective removal of
 37 CO₂ by increasing CO₂ absorption capacity as well as minimizing energy consumption during
 38 solvent regeneration.

39 **Keywords:** CO₂ capture, Ionic Liquids, amine, CO₂ absorption capacity, Regeneration energy

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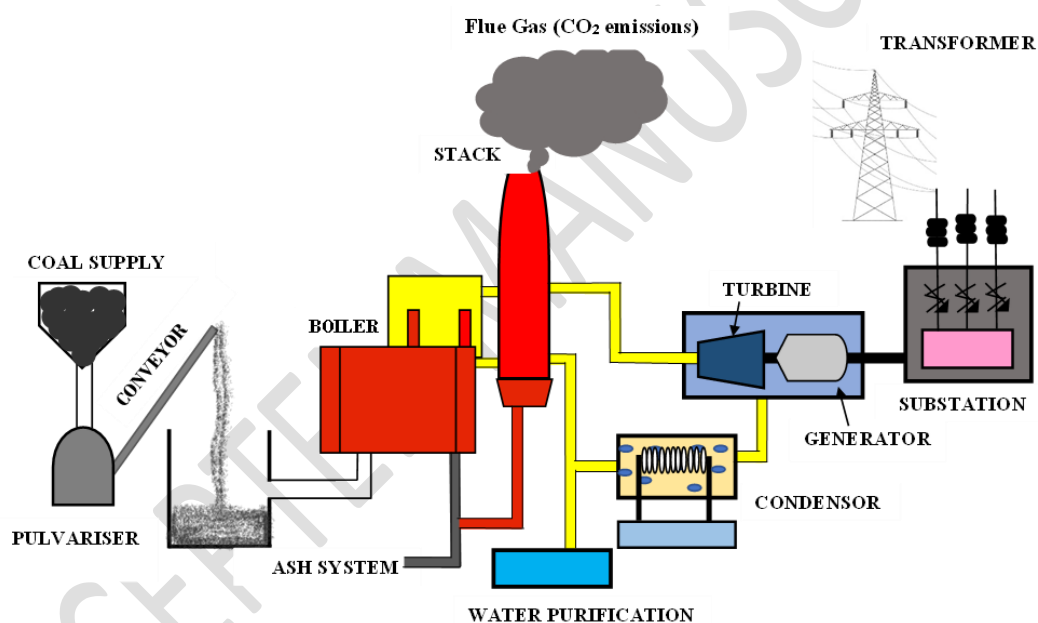
49 **1. INTRODUCTION**

50 The climatic challenges were caused by global warming, improper ecological cycle,
51 economic and technological issues. This average rise in the earth's temperature leads to global
52 warming. This temperature rise is due to the emission of Greenhouse Gases (GHG), mainly
53 CO₂. GHGs are caused by the fossil fuel, petrochemical, steel, transportation, and cement
54 sectors. Nearly 88% of the world's energy consumption is based on fossil fuels such as coal,
55 natural gas, and oil. The International Energy Agency (IEA) indicated in 2014 that coal and
56 crude oil are the leading sources of CO₂ emissions. Coal, a fossil fuel, is very inexpensive and
57 widely available (Aghaie *et al.* 2018; Kang *et al.* 2018). Rapid emission of GHG emissions
58 result's in increasing sea levels, melting polar ice caps, global warming, glaciers, and
59 catastrophic weather patterns in the atmosphere (Zhang *et al.* 2018). Among the different
60 pollutants, high GHG emissions cause the earth's temperature to rise. According to the Paris
61 Agreement, the atmospheric temperature should not exceed 2°C by 2100, with the goal of
62 lowering the temperature to 1.5°C. Based on the IPCC report (Intergovernmental Panel on
63 Climate Change), atmospheric CO₂ concentrations should be maintained at 450 ppm by 2100

64 to avoid global temperature rises of more than 2°C (Shivanna, 2022; Lv *et al.* 2020). Recent
65 research has shown that the global CO₂ emissions from fossil fuels are expected to reach 40.2
66 GT (gigatonnes) by 2030 through electricity generation as shown in Figure 1. (Xiao *et al.* 2019;
67 Chen *et al.* 2018). In order to overcome the issues, Carbon capture and storage (CCS) involves
68 capturing CO₂ emissions and storing them in geological formations, aiming to minimize their
69 release. Despite technical, regulatory, and economic challenges, developing efficient and cost-
70 effective CCS technologies, along with the promotion of carbon capture utilization and storage
71 (CCUS), offers a promising solution to mitigate CO₂ emissions and combat climate change
72 (Garba & Galadima, 2018; Fan *et al.* 2018). This CCS process has been performed using three
73 different methods namely pre-combustion, post-combustion and oxy-combustion. The pre-
74 combustion process, utilized in Integrated Gasification Combined Cycles (IGCC) for CO₂
75 removal before fuel combustion, faces challenges in industrial-scale implementation due to
76 complex equipment and high capital costs (Orhan *et al.* 2017). Oxy-fuel combustion burns
77 fossil fuels with pure oxygen to produce high CO₂ concentrations for easier separation, but its
78 high costs for oxygen separation and capital investment limit its economic viability compared
79 with other capture methods (Bajai *et al.* 2022). However, in the post-combustion process, CO₂
80 removal occurs after fuel combustion, particularly in coal, oil, and gas-fired power plants.
81 Solvent-based post-combustion technology offers the advantage of low-pressure CO₂
82 generation and easier integration into existing power plants, making it a potential solution for
83 reducing GHG emissions (Mukhtar *et al.* 2020). Some of the solvents used in CO₂ captures
84 process are amines, non-amines and ionic liquids. Monoethanolamine (MEA) act as benchmark
85 solvents for CO₂ but shows higher solvent degradation during regeneration. Hence, the
86 combination of amines and ionic liquids in CO₂ capture processes presents a novel approach
87 that addresses the limitations of traditional solvent-based methods. This solvent blend results
88 in enhanced CO₂ absorption kinetics and selectivity. The chemical and thermal stability of ionic

89 liquids also counteracts the degradation problems associated with amines, extending the
90 lifespan of the solvent system. This amine-ionic liquid mixture holds promise for more efficient
91 and sustainable CO₂ capture processes, paving the way for further advancements in the field.

92 The aim of this extensive review paper is to explore the potential use of amine-ionic
93 liquid mixtures as solvents for CO₂ absorption process. This work focuses on efficient and
94 sustainable methods to reduce greenhouse gas emissions, particularly CO₂, a significant acidic
95 gas that causes climate change. Addressing the overview of CO₂ capture methods and the
96 distinctive properties of amine-ionic liquids mixtures for enhancing CO₂ capture would
97 facilitate further research and advancements in sustainable carbon capture technologies.



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Figure 1. CO₂ emissions from coal fired power plants

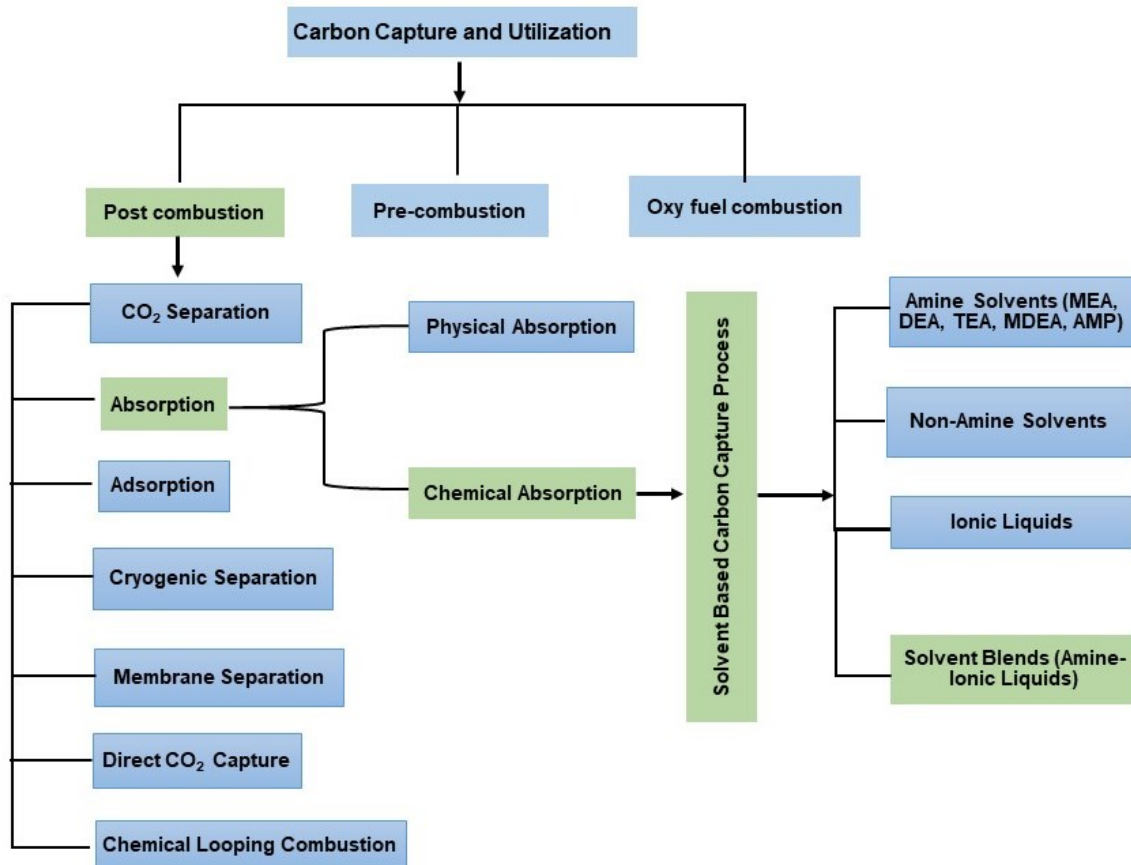
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100 2. REVIEW METHODOLOGY

101 Figure 2. indicates the review methodology adopted for the present work. In Figure 2, the
102 highlighted content represents the potential of use amine-ionic liquids mixtures as promising
103 candidates for CO₂ capture process because of their unique properties such as high selectivity,
104 low volatility, and tunable chemical structures. It also compares the performance of amine-
105 ionic liquids mixtures with conventional CO₂ capture methods. Carbon capture technology

106 involves methods to capture carbon dioxide emissions from coal fired power plants, mitigating
107 climate change by reducing greenhouse gas emissions. It includes post-combustion capture,
108 pre-combustion capture, and oxy-fuel combustion, aiming to store or utilize captured CO₂ to
109 prevent its release into the atmosphere. Post-combustion carbon capture technology holds
110 significant importance compared to other methods due to its ability to capture carbon dioxide
111 emissions after fuel combustion, particularly in existing coal, oil, and gas-fired power plants
112 (Bhavsar *et al.* 2023). This approach offers advantages such as lower implementation costs,
113 easier integration into existing infrastructure, and reduced risks associated with retrofitting. In
114 post-combustion carbon capture processes, CO₂ separation typically involves extracting CO₂
115 from the flue gas emitted by industrial sources after the combustion of fossil fuels which was
116 shown in Figure 2. Various methods are employed for CO₂ separation, including chemical
117 absorption, absorption, membrane separation, cryogenic separation, and chemical looping
118 combustion. Chemical absorption, using liquid solvents like alkanolamines, is a widely utilized
119 technique where CO₂ is chemically captured by the solvent, forming stable compounds that
120 can be separated from the flue gas. However, it shows some challenges such as high energy
121 requirements for solvent regeneration, equipment corrosion, and solvent degradation (Perumal
122 and Jayaraman, 2023). Recently, Ionic liquids (ILs) have garnered significant interest in CO₂
123 capture due to their unique properties, such as negligible vapor pressure, high thermal stability,
124 and tunable chemical structures. ILs can serve as promising solvents or sorbents for CO₂
125 capture processes, offering advantages such as low energy requirements for regeneration, high
126 selectivity, and the potential for reuse. But it has some bottlenecks such as high cost, viscosity
127 issues hindering mass transfer, potential toxicity, limited scalability, and stability. Many
128 researchers are able to find an alternative solution to capture CO₂ by overcoming the above
129 issues. Hence the present review focused on the use of solvent blends mainly amines with ionic
130 liquids act as a promising avenue for enhancing carbon capture processes. The solvent

131 combination may increase the CO₂ absorption capacity resulting in improved absorption
 132 kinetics and selectivity (Perumal *et al.* 2021). This blend also addresses limitations such as
 133 solvent degradation and corrosion, extending the lifespan of the solvent system.



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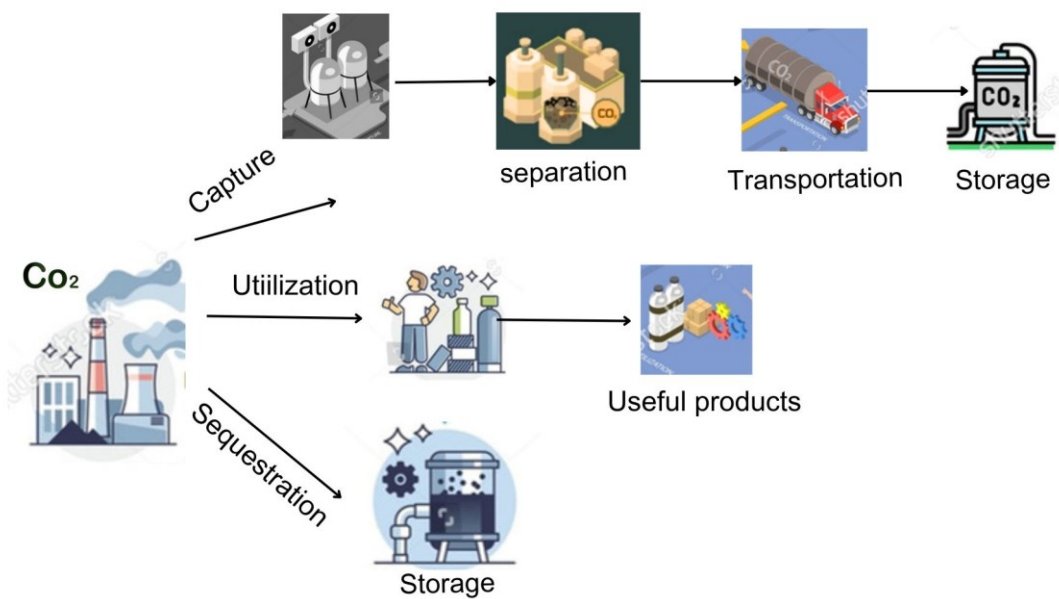
135 **Figure 2. Overview of CO₂ capture process**

136 **2.1 Carbon Capture, Utilization and Storage**

137 CO₂ contributes significantly to global climate change. Capturing CO₂
 138 emissions from power plants, transferring them to an injection location, and storing them in an
 139 appropriate geologic formation for long-term storage is an effective approach for minimizing
 140 CO₂ emissions. In the 1920s, this CCS strategy was implemented to eliminate the carbon
 141 dioxide found in natural gas deposits from commercial hydrocarbons. Fossil fuel power plants
 142 remain the largest source of CO₂ emissions (Hospital-Benito *et al.* 2020). As a result, there is

143 a prospect of developing and implementing CO₂ capture, utilization, and storage (CCUS)
144 technologies to reduce CO₂ emissions (Jiang *et al.* 2020). Therefore, it is crucial to develop
145 efficient and economical technologies for CO₂ capture. CO₂ capture and storage (CCS) is
146 frequently a demanding and more viable technology for decarbonizing the global economy.
147 The use of CCS technology is considered a possibility for lowering anthropogenic CO₂
148 emissions. Collection of carbon dioxide from emitting sources, transferring it to a storage
149 location and depositing it in an appropriate subterranean geological formation (Bhavsar *et al.*
150 2023). The large amount of CO₂ flow might be delivered for underground storage upon capture
151 via the excavation of deep saline aquifers with no further practical application, as well as oil or
152 gas reserves. A stable geological circumstance, capping bedrock exhibiting excellent sealing
153 capacity, and reservoir stone with the proper porosity, width, and susceptibility are all
154 prerequisites for the geological storage of CO₂. The storage integrity of deep saline aquifers is
155 uncertain. Oil and gas reservoirs, whether active or depleted, have a history of reliable storage,
156 although they are not universally accessible. Furthermore, preserved carbon dioxide can be
157 used in various products, including firefighting gases, drinks, food, and refrigeration.
158 Implementation and popularization are effective methods for promoting carbon capture and
159 storage technologies. The utilization of CO₂ Capture and Storage (CCS) technology is one
160 solution that is utilized to minimize the release of carbon dioxide (CO₂). The use of gas and
161 biomass-based energy may also help lower carbon dioxide emissions. Technical constraints,
162 legal and regulatory barriers, economic barriers, and public perception barriers all impact CCS.
163 Considering the technological cost of developing and operating a CCS is a crucial topic that
164 must be considered. In addition, high CO₂ concentrations might have negative health effects
165 and increase safety and health hazards. Economic and environmental reasons necessitate the
166 use of efficient and appropriate CO₂ separation technology with minimal running costs and
167 energy consumption. Generally, three types of CO₂ capture and storage: post-combustion

168 (capture of CO₂ from exhaust gas), pre-combustion (collection of CO₂ from synthesis gas), and
 169 oxy-fuel combustion (oxygen combustion with exhaust gas recycling and CO₂ purification).
 170 Figure 3 indicates the overview of Carbon Capture Utilization and Storage (CCUS) technology,
 171 emphasizing the importance of capturing carbon dioxide (CO₂) emissions from industrial
 172 sources to mitigate climate change thereby reducing CO₂ levels by capturing, trapping, and
 173 converting CO₂ into useful chemicals (Fu *et al.* 2022). Furthermore, it explored the utilization
 174 and storage aspects of CCUS, discussing how captured CO₂ can be utilized in various
 175 applications such as enhanced oil recovery (EOR), as well as the potential for storing CO₂
 176 underground in geological formations.



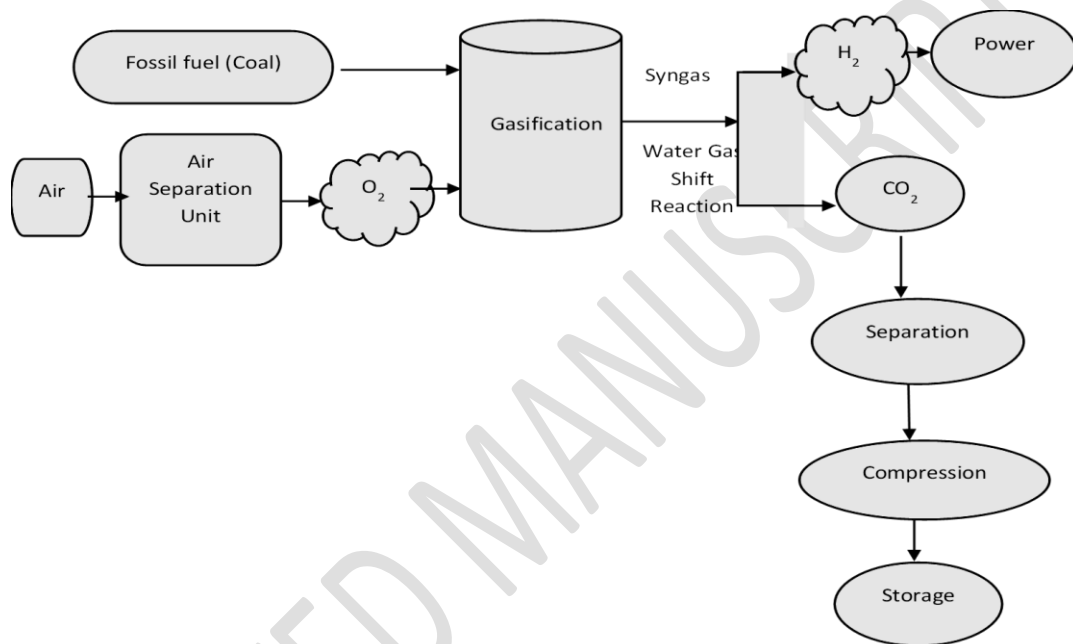
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178 **Figure 3.** Carbon Capture Utilization and Sequestration

179 **2.1.1 Pre-combustion process**

180 In this technique, removal of CO₂ takes place before the fuel is burnt. Coal, a
 181 fossil fuel, produces carbon monoxide instantly after reacting with air/oxygen. Carbon
 182 monoxide produced by the water gas shift process mixes with water to produce CO₂ and
 183 hydrogen gas (WGS) as shown in Figure 4. This method is used in several industrial processes,
 184 including the production of syngas, hydrogen, and natural gas. It is, nevertheless, extensively

185 used in Integrated Gasification Combined Cycles (IGCC). Pre-combustion capture is used in
 186 IGCC power plants, although the efficiency loss is roughly 7–8%. CO₂ concentrations in IGCC
 187 plants are generally 40-50 percent CO₂, and it can be separated from hydrogen. The separated
 188 hydrogen gas was then transformed into operational energy; however, this is not suitable for a
 189 comprehensive strategy. CO₂ removal is technically conceivable, but it is not yet ready for
 190 industrial scale.

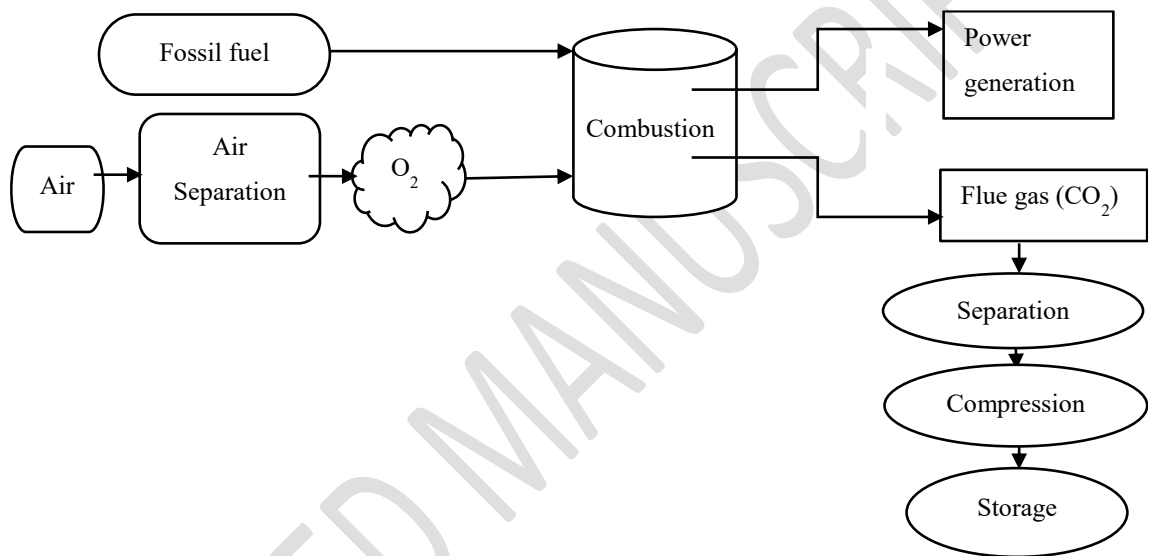


191
 192 **Figure 4.** Pre-Combustion Carbon Capture

193
 194 Because of the presence of significant concentrations of CO₂, high pressure gas permits
 195 the use of physical solvents to remove the CO₂. Physical solvent absorption is performed under
 196 high pressure conditions, namely with a CO₂ partial pressure greater than 10 bar (Orhan *et al.*
 197 2017). Solvent regeneration occurs through pressure reduction as opposed to heating. The
 198 benefits of the pre-combustion process include high working pressure, which lowers
 199 pressurization costs, and a separation approach that uses less energy. However, because of the
 200 complexity of the process, the capital cost is significantly higher. In addition, the use of a
 201 complicated high-pressure WGS reactor and air separation equipment increased the cost.

202 **2.1.2 Oxy-fuel combustion**

203 The oxy-fuel method refers to the combustion of fossil fuels using pure oxygen.
204 The purpose of the oxy-combustion process is to collect CO₂ from the flue gas stream and
205 create high CO₂ concentrations using pure O₂ as an alternative to air for combustion as reported
206 in Figure 5. The goal is to increase combustion efficiency to generate high quantities of CO₂
207 that can be easily separated. Flue gas with a CO₂ content of 70-95 percent generated by
208 combusting the fuel with pure oxygen (Bajai *et al.* 2022).



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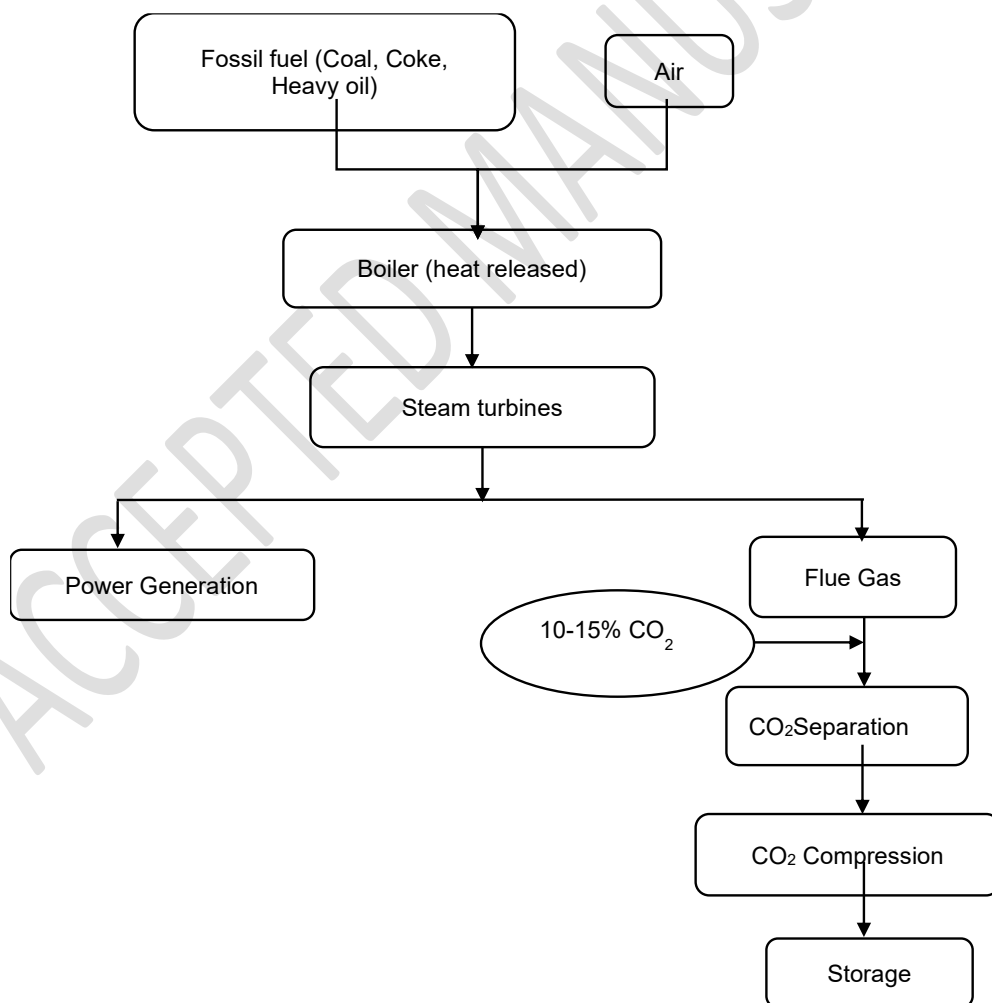
210 **Figure 5.** Oxy-Fuel Combustion Carbon Capture

211 At the end of the process, large concentrations of CO₂ and flue gas components, such
212 as CO₂ and water vapor were generated. Hence, the water vapor is removed from the gas stream
213 by cooling and compression. Finally, separation technologies are used to remove the high
214 concentration of CO₂ released from flue gas. The merits of this process is that the flue gas flow
215 rate is relatively modest, resulting in a smaller capture unit with a cheaper capital cost. In
216 addition, as compared to other procedures, the NO_x level in flue gas is lowered by 60-70
217 percent. This method is critical in power plant pre- and post-combustion procedures. The
218 expense of purifying O₂ using an air separation device is more involved and costly. This raises
219 the cost of O₂ separation as well as the energy demand. The large air separation unit enhances

220 the plant's capital cost when compared to alternative capture technologies. This approach is
221 costlier than other capturing methods (Orhan *et al.* 2017).

222 2.1.3 Post-combustion process

223 In this process, the fossil fuel (coal, coke, and heavy oil) is combusted in fired
224 power plants to create electricity. The fossil fuel was burnt in the existence of air for this
225 purpose. Heat was released during combustion to form the high-pressure stream that powers
226 the steam turbines. Flue gas was released through the combustion of fossil fuels. Particulate
227 matter, SO₂, and CO₂ are all components of flue gas was shown in Figure 6. Scrubbing
228 techniques and other particle materials collected by vacuum cleaning can be used to remove
229 SO₂.



230

231 **Figure 6.** Post-Combustion Carbon Capture

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233 The cleansed flue gas from a natural gas-fired power plants constitutes 3-15%
234 CO₂, whereas coal-fired power plants emit 10-15% CO₂ to the environment. To lower the
235 growth of CO₂ concentrations in the atmosphere. The removal of CO₂ is critical for reducing
236 greenhouse gas emissions. Therefore, post-combustion technology was demonstrated on a
237 limited scale, with the quantity of CO₂ collected averaging roughly 800 t/day (Mukhtar *et al.*
238 2020). This technology was used to remove CO₂ from the exhaust flue gases of fuel combustion
239 plants namely as coal, oil, and fuel-fired thermal power plants. In terms of economics, the CO₂
240 absorption/desorption phase, which is largely a solvent regeneration phase, is the most
241 expensive component of the CCS process at post-combustion. Furthermore, as compared to
242 sequestration requirements, the post-combustion capture technology generates CO₂ at low
243 pressures and can be easily fitted to an existing power plant (Haider *et al.* 2016).

244 **2.2 CO₂ Separation Process**

245 Post-combustion flue gas from a coal-fired power plant typically includes 12-
246 15% CO₂. Absorption, adsorption, membrane separation, direct air capture, chemical looping,
247 and cryogenic are all methods for CO₂ separation. The details have been discussed below.

248 **2.2.1 Adsorption**

249 Adsorption is a separation technique utilized in the PCCC procedure (Post
250 Combustion Carbon Capture). This adsorption method employs a packed column loaded with
251 solid sorbents in CO₂ collection. The solid sorbent should have high regeneration capacity,
252 excellent selectivity, and a large specific surface area. Carbons and carbon nanotubes, clays
253 and oxides, microporous zeolites and mesoporous molecular sieves and microporous metal-
254 organic framework materials (MOFs). Adsorbent refers to the use of a solid material for CO₂
255 separation, while adsorbate refers to the gas that is adsorbed. Adsorption is based on the
256 attraction of CO₂ molecules to solid sorbents via intermolecular forces. As a result, CO₂ is

257 drawn to the sorbent and attaches to its surface. Following that, the solvent (solid sorbent) is
258 regenerated in order to strip the CO₂ by temperature/pressure swing adsorption and reuse the
259 solvent for further adsorption. The mechanism of desorption used to regenerate the adsorbent
260 in CO₂ capture from post combustion flue gas can be characterized through a rise in
261 temperature (temperature swing adsorption) or a decrease in pressure (pressure swing
262 adsorption). CO₂ capture incorporating adsorbents in the pre-combustion phase helps enhance
263 hydrogen gas production. The main disadvantage is that there is relatively little CO₂ adsorption
264 capacity and selectivity for accessible solid adsorbents (Olajire, 2017).

265 **2.2.2 Membrane separation**

266 A membrane acts as a selective barrier, allowing different components from the
267 flue gas stream to infiltrate at different speeds. Separation processes can be classified based on
268 membrane structure. Simple process design, easy scaling, minimal energy use, and a lesser
269 investment cost. The membrane separation process requires five distinct methods of separation,
270 comprising molecular screening, Knudsen diffusion, solution and surface diffusion, capillary
271 condensation. Beginning in 1970, carbon membranes are used to separate gases. It is
272 considered a watershed moment in the field of membrane technology. Membrane performance
273 is classified by two primary factors: selectivity and permeability. Selectivity and permeability
274 were lowered during membrane production by increasing polymer concentration, temperature,
275 and pressure. When membranes were combined with inorganic materials, significant chemical
276 and thermal stability was discovered. The membrane functions as a semi-permeable filter in
277 the separation of CO₂ from flue gas streams. It has various advantages, including low
278 regeneration energy requirements, easy operation, no waste streams, and dual benefiting. Due
279 to the higher surface area for molecular sieving properties at the gas-liquid interface, which are
280 essential for gas separation, membrane technology process efficiency is quite high compared
281 to conventional process (Haider *et al.* 2020). High-purity CO₂ separation may necessitate the

282 use of many membranes with various properties. In order to combine the greatest qualities of
283 membranes and solvent scrubbing, solvent aided membranes are being created. Much research
284 is necessary before membranes can be employed on a broad basis for capture in power plants.
285 Membrane technology is easy to use and small, making it ideal for large-scale CO₂
286 applications. However, it requires a high degree of separation for recycling, is particularly
287 sensitive to sulphur compounds, is a high-cost module, suffers from membrane degradation, is
288 not appropriate for removing huge amounts of CO₂ gases, and is not long-lasting.

289 **2.2.3 Cryogenic separation**

290 Cryogenic separation is referred as low-temperature distillation. It is employed
291 to separate CO₂ from flue gas effectively. Various gas components from the atmosphere may
292 be separated using this approach. The cryogenic separation technique comprises gas mixture
293 separation by fractional condensation followed by low temperature distillation (-73.3°C). The
294 percentage of CO₂ in flue gas is often greater than 50% and is easily separated. The benefits of
295 this method include great dependability, no need for chemical reagents, an easy scale-up
296 procedure, and the recovery of pure CO₂. The key disadvantages of this technique are the
297 significant energy demand for cooling as well as the solidification of CO₂ at extremely low
298 temperatures, as well as the cost inexpensive for the cooling process (Font-Palma *et al.* 2021).

299 **2.2.4 Chemical looping combustion**

300 Chemical looping combustion (CLC) is a potential method for avoiding CO₂
301 emissions by diluting flue gases. This strategy eliminates the direct contact of air and fuel
302 combustion. It is also a viable alternative to traditional fuel combustion. It was discovered,
303 however, to be helpful for CO₂ collection applications (An *et al.* 2023). In this approach,
304 instead of air, oxygen carriers, typically metal oxides, are injected between fuel reactors,
305 obviating the necessity for an Air Separation Unit (ASU). The main advantages of this
306 technology are low energy loss and simplicity of CO₂ separation. However, maintaining reactor

307 pressure to reduce air leakage in the fuel reactor and metal oxide deactivation due to unburned
308 carbon accumulation on the surface of metal oxides is a challenge with this approach.

309 **2.2.5 Direct capture of CO₂ from air**

310 The CO₂ removal from the atmosphere using direct air capture is a technique
311 (DAC). It has recently grabbed scientists' interest because it has the potential to relieve the
312 issues associated with enormous quantities of CO₂ transfer from point-source emitters.
313 Traditional capture methods focus on large point sources, reducing the pace of CO₂ buildup in
314 the earth's atmosphere. This process is comparable to adsorption-based CO₂ collecting.
315 Aqueous hydroxides, namely calcium hydroxide, sodium hydroxide and potassium hydroxide
316 solution, as well as solid materials such as alkali and alkali-supported carbonates, metal oxides,
317 and anionic-exchange resins, are used in this process (An *et al.* 2023). Temperature Swing
318 Adsorption (TSA) and pressure swing adsorption (PSA) are used for CO₂ removal in the DAC
319 process. According to thermodynamic research, TSA is more efficient than PSA for this
320 technique since the heat of adsorption affinity grows at low CO₂ concentrations. However, the
321 estimated cost of DAC is significantly higher than that of other major point sources.
322 Furthermore, for this technology to be widely used, high durability of low-cost materials is
323 essential. The disadvantages of the DAC method include significant energy usage during CO₂
324 separation.

325 **2.2.6 Biological process**

326 High CO₂ concentrations stimulate the creation of high-value biomolecules. At high
327 CO₂ levels (often greater than 50%) and in the presence of SO_x and NO_x, green algae strains
328 expanded rapidly. When algae species with high CO₂ fixing and solar energy conversion
329 efficiency are utilized, the technique's commercial and environmental effectiveness can be
330 maximized. These organisms must be capable of converting solar energy into H₂ and producing
331 many useful proteins (Okeke et al. 2022). To employ solar energy for H₂ generation rather of

332 creating biomass, photosynthesis is a little hindered. The retention duration of fixed CO₂ in
333 agriculture is expected to be 50 to 100 years. In the lab, 260 mg l⁻¹ h⁻¹ of CO₂ fixation efficiency,
334 or 26 kg per hour of CO₂ capture in a 100 m³ bioreactor, was achieved. Because bio reactors
335 are prohibitively expensive, this approach is not frequently employed.

336 **2.2.7 Absorption**

337 Absorption is the most cost-effective and commercialized separation strategy
338 utilized in coal-fired power stations for post-combustion CO₂ collection (PCCC). By
339 depressurizing or heating, the liquid sorbent absorbs CO₂ from the flue gas, and the CO₂ can
340 be removed or the solvent regenerated. The CO₂ gas combines with the liquid sorbent, resulting
341 in absorption from the gas to the liquid phase. The flue gas (including CO₂) is chilled (between
342 318 and 323 K) and delivered into the absorption column (scrubber), wherein the solvent
343 absorbs CO₂. The CO₂-rich solution is pumped through a heater to raise the temperature of the
344 solution, and into a stripper column to liberate the CO₂. The CO₂ that has been released is
345 compressed, and the recovered absorbent mixture is chilled and transferred to the absorber
346 column. The quantity of energy needed for post-combustion CO₂ collection is an essential
347 factor. Thus, present investigations show that lowering the cost of this capture might be
348 accomplished by developing appropriate solvents that can remove more CO₂ for a given mass
349 while using less energy for stripping stage (Mukhtar *et al.* 2020). Flue gas relates to an
350 absorbent during the process of absorption, and CO₂ is absorbed by this solvent. The absorbent,
351 on the other hand, would possess an acceptable capacity for CO₂ intake, a high kinetic rate for
352 CO₂ absorption, limited vapor pressure, great chemical and thermal resistance, as well as be
353 safe for humans. There are mainly two types of solvents employed in CO₂ absorption: physical
354 and chemical absorption.

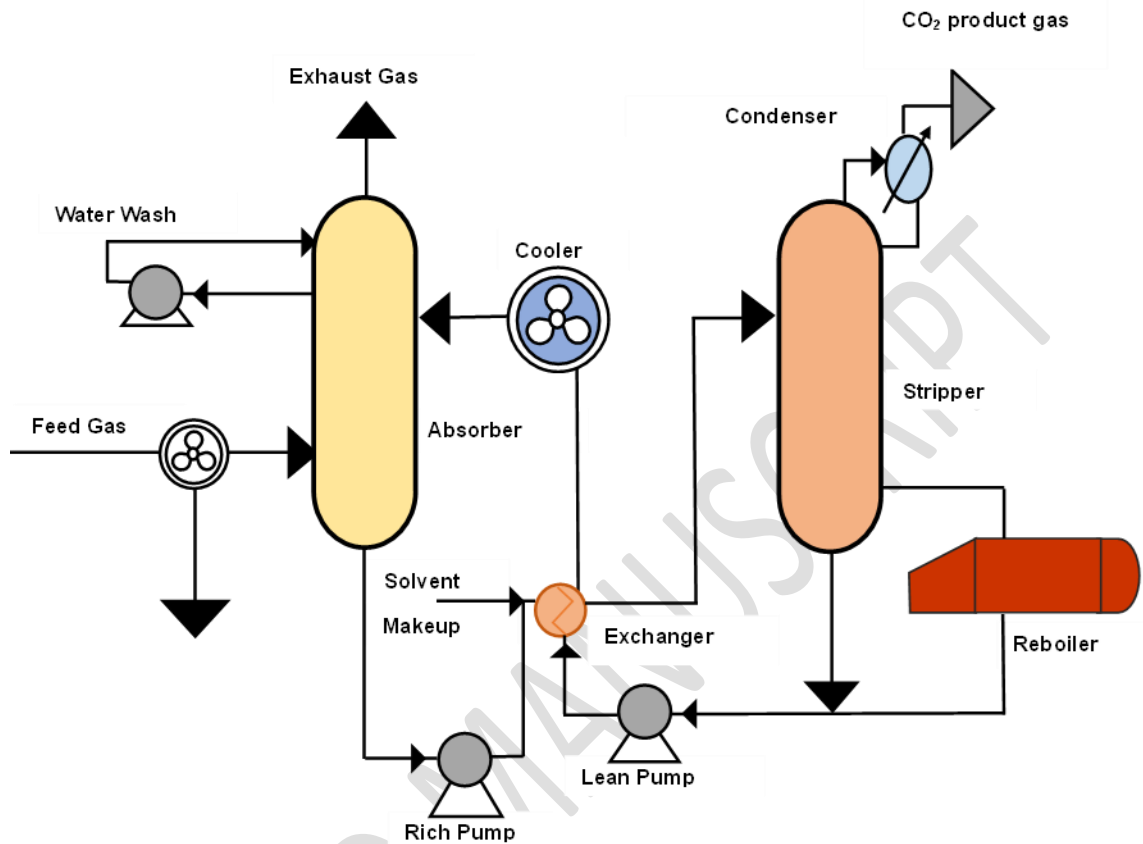
355 **2.2.7.1 Physical Absorption**

356 Physical solvents like Selexol, Rectisol, and N-Formylmorpholine (NFM) absorb acid
357 gas components, primarily CO₂, through physical interactions rather than chemical reactions.
358 These solvents offer advantages such as requiring less energy for regeneration due to their
359 physical solubility interactions, but they come with drawbacks including low CO₂ capacity,
360 high capital and operational costs, solvent loss, and larger equipment. Physical absorption is
361 suitable for removing acid gases from natural gas and synthesis gas used in hydrogen,
362 ammonia, and methanol production. Despite its effectiveness at high CO₂ partial pressures,
363 physical absorption may not be cost-effective for gases with CO₂ partial pressures below 15%
364 vol due to energy demands related to flue gas pressurization and equipment complexity.
365 Additionally, while physical solvents exhibit great selectivity for hydrogen sulfide over carbon
366 dioxide and can extract carbonyl sulfide, they require low temperatures and high vapor
367 pressures, necessitating gas chilling before absorption and contributing to operational costs
368 (Vega *et al.* 2018).

369 **2.2.7.2 Chemical Absorption**

370 In the absorber, the flue-gas meets the solvent, which absorbs the CO₂ and forms
371 weakly intermediate chemicals through chemical processes. These chemical reactions are
372 reversed by using heat to extract CO₂ from the solvents and regenerate them. In chemical
373 absorption processes, the rate at which CO₂ is absorbed by the solvent is an essential
374 characteristic. Because a higher CO₂ absorption rate reduces not only the capital costs of CO₂
375 collection, but it is also viewed as an asset for an absorption process that will be conducted on
376 an industrial scale represented in Figure 7. The key benefits are the high CO₂ absorption
377 capacity, greater absorption and response rate (Aghaie *et al.* 2018). According to the survey on
378 separation approaches, absorption in PCCC plays a critical part in the CO₂ collection process.
379 Solvents are used to carry out this absorption. Amine-based solvents, carbonate-based solvents,
380 aqueous ammonia, and ionic liquid-based solvents are examples of chemical absorption

381 solvents (Salvinder *et al.* 2019). As a result, a post-combustion carbon capture technology
382 based on solvents is preferable.



383

384 **Figure 7.** Flow diagram of chemical absorption process for post-combustion carbon
385 capture (Zheng *et al.* 2022)

386 2.3. Solvents Based Carbon Capture Process

387 The solvent-based post-combustion carbon capture process involves the use of liquid
388 solvents to selectively absorb CO₂ from the flue gas emitted by power plants and industrial
389 facilities. This method typically employs a chemical absorption process where the flue gas
390 comes into contact with the solvent, allowing the CO₂ to be absorbed while other gases pass
391 through. After absorption, the CO₂-rich solvent is then regenerated, releasing the captured CO₂
392 for storage or utilization. Solvents commonly used in this process include aqueous amine, non-
393 amine, ionic liquids and solvent blends, which have high affinity for CO₂ molecules (Perumal
394 and Jayaraman, 2023).

395 2.3.1 Amine solvents

396 Several alkanolamines are often used as absorbents in CO₂ collection methods. Because
397 of its strong reactivity with CO₂ molecules, superior thermal stability, and cheap cost, it is less
398 costly and has a larger absorption capacity. Solvent performance in absorption should have
399 three major characteristics: (i) high solubility of gas compounds in the solvent; (ii) strong
400 reactivity of gas compounds with the solvent; and (iii) absorbent cycle capacity. Because of
401 their high chemical stability, which favors mass transfer kinetics, Monoethanolamine (MEA)
402 and Diglycolamines (DGA) are the most often utilized main amines in PCCC. DGA need a
403 high solvent concentration for a better absorption process (Vega *et al.* 2018)

404 MEA was revealed to be a benchmarking solvent for CO₂ absorption, that has an
405 absorption efficacy of greater than 90%. The low price, high responsiveness, and rapid
406 absorption all contribute to this. Nevertheless, it has certain drawbacks throughout operation,
407 such as a high energy required for CO₂ removal, a higher entropy of reaction, equipment
408 corrosion, and oxidative and thermal deterioration (Jang *et al.* 2021). Secondary alkanolamines
409 have hydrogen atoms which bond directly to nitrogen atoms, such as Diethanolamine (DEA)
410 and diisopropanolamine (DIPA). While DIPA consumes fewer energy during the recovery of
411 solvent than MEA, DEA produces less heat of reaction, is more resistant to solvent degradation,
412 and is less corrosive. Finally, tertiary amines having a high equivalent weight, like
413 triethanolamine (TEA) and methyl diethanolamine (MDEA). Despite their high chemical
414 stability, TEA and MDEA have a slow reaction rate and absorption capability (Vega *et al.*
415 2018). The primary difficulties in amine-based absorption technology for CO₂ separation are
416 the solvent loss, degradation of solvent due to the presence of NO₂, SO₂, HCL, and HF in flue
417 gas streams, volatile compound production, essential equipment deterioration, and high
418 utilisation of energy throughout high temperature absorption. The zwitterion ion mechanism
419 regulates CO₂ uptake in amines. When CO₂ combines with a primary or secondary amine,

420 carbamate is generated as an intermediate product. Afterwards, the carbamate is hydrolyzed
421 and separates into carbonate and bicarbonate. Khan *et al.* (2016) evaluated the CO₂ capture
422 capability of four distinct aqueous solvents, including MEA, AMP, MDEA, and PZ. It was
423 determined by altering the solvent content (10, 20, and 30 wt%), temperature (293-313K), and
424 pressure (10-15KPa). According to the specific absorption rate, it was shown that MDEA-
425 AMP-MEA-PZ's absorption performance shows a growing trend. The above solvents like
426 MEA, DEA, and MDEA exhibit high CO₂ absorption efficacy, but it shows drawbacks such as
427 high energy requirements for CO₂ removal, equipment corrosion, and solvent degradation due
428 to the presence of contaminants in flue gas streams.

429 On the other hand, the sterically hindered amine such as 2-amino-2-methyl-1-
430 propanol (AMP) function as alternative conventional amines for CO₂ collection procedure.
431 Because sterically hindered amines were unable to produce stable carbamate intermediate
432 compounds during absorption. Karlsson *et al.* (2019) investigated the CO₂ absorption using the
433 2-amino-2-methyl-1-propanol (AMP) mixed with organic solvents. The obtained results were
434 compared with the N-methyl-2-pyrrolidone (NMP). From the findings it was showed that the
435 organic solvents with AMP, these solvents showed similar CO₂ absorption capacity to the
436 AMP-NMP blends. The use of this amine reduces the energy consumption than amine based
437 solvent regeneration, good absorption capacity, high selectivity but it has low absorption rate
438 (Vega *et al.* 2018, Salvinder 2019).

439 **2.3.2 Non-amine solvents**

440 Non-amine-based solvents are chemical solvents that do not integrate with an
441 amine group. Some examples are sodium hydroxide (NaOH), ammonia (NH₃), potassium
442 hydroxide (KOH), sodium carbonate (Na₂CO₃), and potassium carbonate (K₂CO₃). MEA has
443 a lower carbon concentration than Na₂CO₃. Sodium carbonate, on the other hand, absorbs CO₂

444 at a slower pace, resulting in a higher absorption column height. As a result, promoters are
445 required to boost its absorption rate more than primary amines.

446 K_2CO_3 is used as solvent due to its cost inexpensive, less energy demand, high
447 resistance to solvent degradation and low toxicity. But it has poor absorption capacity. Hence,
448 it acts as a promoter in CO_2 capture process with amines due to its low absorption capacity
449 Ammonia used as a solvent in CO_2 absorption process. It has higher reaction rate with
450 minimum regeneration energy than baseline MEA (Vega *et al.* 2018).

451 Piperazine (PZ) is an organic molecule having two nitrogen atoms in opposing
452 places inside a 6-member heterocyclic ring that is used to absorb CO_2 . The reaction between
453 piperazine and CO_2 increases absorption capacity compared to MEA and promotes the fast
454 production of carbamates. However, it is a more volatile and expensive procedure than the
455 baseline MEA (Salvinder 2019).

456 **2.3.3 Ionic liquids**

457 Ionic liquids (ILs) have recently developed as a novel type of physical solvents that
458 are preferred over conventional physical solvents in CO_2 absorption. Ionic liquids are used
459 as substitute solvents in the CO_2 capture process because of their beneficial characteristics,
460 such as designability, non-flammability, low vapor pressure, good chemical and thermal
461 stability, and comparatively low regeneration energy (Zhao & Baker, 2023; Li *et al.* 2021).
462 When considering technological and economic issues, IL-based CO_2 collection is costlier than
463 MEA. However, IL can save energy and utility costs throughout the regeneration phase
464 (Salvinder 2019).

465 It is typically formed by the combinations of cations (Imidazolium,
466 pyrrolidinium, pyridinium, phosphonium, ammonium) and anions (Fluorinated anions such as
467 PF_6 , BF_4 , TF_2N , non-fluorinated anions such as acetate (OAC), bromide (Br), chloride (Cl),
468 hydroxide (OH) etc. The anion serves the principal role, whereas the cation plays a minor part.

469 As a physical solvent, these ILs reacted with CO₂. As a result, the CO₂ solubility of ILs follows
 470 Henry's rule and necessitates high pressure and temperature. Amine functionalized ILs, on the
 471 other hand, boost absorption capacity with primary or secondary amine via the zwitterion idea.
 472 ILs are employed in the CO₂ capture process to minimize solvent loss and need less
 473 regeneration energy than baseline because to their chemical and thermal stability. MEA (Zeng
 474 *et al.* 2017). Despite their benefits, several disadvantages of ILs include high viscosity, which
 475 inhibits mass transfer kinetics. The development of a strong hydrogen bond between IL and
 476 CO₂ enhanced the viscosity following CO₂ absorption. It is overcome by adding organic
 477 amine/water to IL, which reduces viscosity without affecting absorption capacity. Green
 478 solvents, such as Ionic Liquids (ILs), have currently gained more interest for the carbon capture
 479 process than alkanolamines due to attractive qualities such as cation and anion tuning, high
 480 chemical and thermal stability, non-volatility, minimal vapour loss, and non-flammability
 481 (Halim *et al.* 2018). The cations and anions of ILs have an influence on CO₂ solubility. As
 482 compared to the cation of ILs, the anion has a greater impact on CO₂ dissolution. Several
 483 research on the CO₂ solubility of IL have been published in peer-reviewed journals shown in
 484 Table 1.

485 **Table 1.** Absorption of CO₂ using Ionic Liquids

S. No	Ionic liquids	Pressu re	Temperature	CO ₂ Solubility	References
1	Tributylammonium heptanoate	20 bar	298.15 K	0.74 mole of CO ₂ /mole of solvent	[Rahim <i>et al.</i> 2023]
2	Triethyl (2-(2- methoxyethoxy)ethoxy)ethy lammonium bis(trifl	1bar	303K	0.55mole of CO ₂ /mole of solvent	[Zhao <i>et al.</i> 2023]

uoromethane)sulfonimide

3	Bis-(2-ethylhexyl)ammonium heptanoate ([BEHA][C7])	20 bar	298.15 K	0.78 mole of CO ₂ /mole of solvent	[Zailani <i>et al.</i> 2022]
4	Bis(2-ethylhexyl)ammonium butyrate [BEHA][BA]	29 bar	298.15 K	0.486 mole of CO ₂ /mole of solvent	[Yunus <i>et al.</i> 2019]
5	Ethanolammonium butyrate [EtOHA][BA],	29 bar	323.15K,	0.35 mole of CO ₂ /mole of solvent	[Halim <i>et al.</i> 2018]

486

487 2.3.4 Solvent blends

488 The high-energy demand, low absorption capacity related to solvent degradation
489 of amine, ILs and non-amine regeneration are the serious issue as mentioned in previous
490 section. As a result, an attempt was made to employ solvent blends to improve absorption
491 capacity while also regenerating the solvent with reduced energy usage represented in Table 2.
492 In general, solvent regeneration is a high-energy process. Furthermore, CO₂ extraction from
493 carbon-rich amine requires a greater amount of energy.

494 **Table 2.** Absorption of CO₂ using Ionic Liquids mixed with amine in atmospheric pressure

S. No	Ionic Liquids	Amine	Temper ature	CO ₂ Solubility	References
1	TetraButylAmmonium Acetate [TBA][OAC]	Monoethanolamine (MEA)	303K	0.459 mole of CO ₂ /mole of solvent)	[Perumal and Jayaraman, 2023]
2	TetraButylAmmonium Hydroxide [TBA][OH]	Monoethanolamine (MEA)	303K	0.502 mole of	[Perumal <i>et al.</i> 2021]

				CO ₂ /mole		
				of solvent		
3	Dimethylamino-1-propylamine ([DMAPAH]-[OAc]) acetate	Ethanediamine (EDA)	323K	0.295 g CO ₂ /g absorbent	[Li	<i>et al.</i> 2021]
4	N-butylethylenediaminium bis(trifluoromethanesulfonyl)amide, [HButylen][Tf ₂ N]	Ethylenediamine	308K	0.95 mmol CO ₂ /g IL	[Voskian	<i>et al.</i> 2020]
5	1-butyl-3-butylimidazolium tetrafluoroborate [BBIM]BF ₄	Methyldiethanolamine [MDEA]	298K	0.0168g/C O ₂ g absorbent	[Xiao	<i>et al.</i> 2019]

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The addition of a small amount of tertiary amines (MDEA, TEA) to either primary or secondary amines (MEA, DEA) generates solvent blends that improve overall solvent behavior with regard to of absorption capacity, less demand on energy for solvent regeneration, and resistance to solvent degradation.

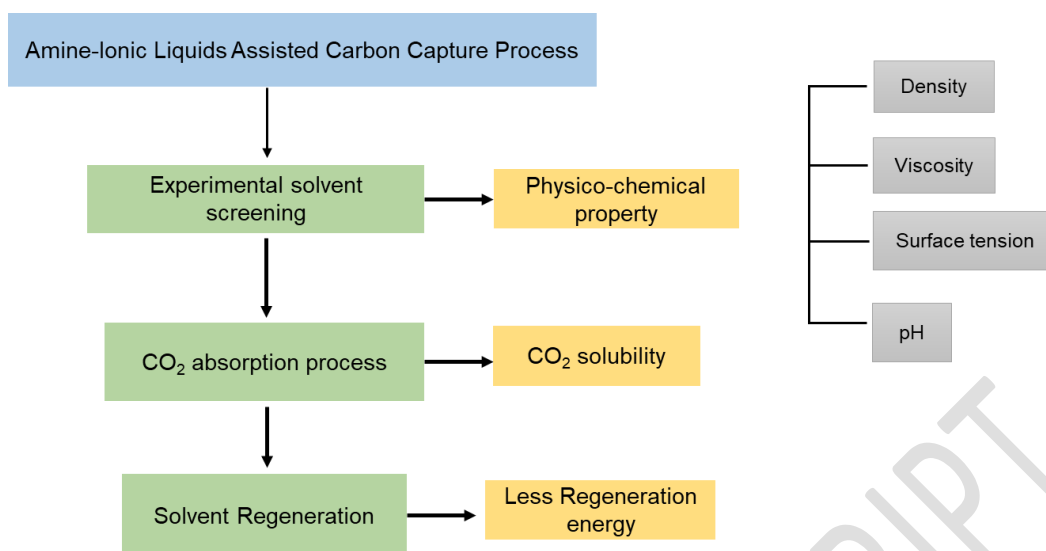
MEA mixes with TEA, AMP, and MDEA are some of the other solvent blends used in the CO₂ collection process. It is feasible to speed up the reaction rate of these mixes when compared to separate solvents. MEA is the fastest solvent; however, its absorption rate is 50 times slower than that of PZ. As a result, a small amount of PZ boosts MEA absorption. Similarly, potassium carbonate boosted with PZ and AMP mix with PZ are regarded as potential solvents. Recently, IL-amine blends have improved absorption capacity and rate while using minimal energy for solvent regeneration (Haider et al. 2016). Because IL-amine

507 mixtures absorb CO₂ fast, higher temperature and partial vacuum are required to desorb CO₂
508 (Camper *et al.* 2008). The addition of tertiary amine to ILs increases the solubility of CO₂. The
509 addition of ILs to an amine/non-amine solvent resulted in a high CO₂ cyclic capacity and a
510 30% reduction in the enthalpy of CO₂ dissolution (Gao *et al.* 2015). These amines and ILs
511 mixes have excellent absorption and thermodynamic efficiency, a high absorption rate,
512 minimal solvent degradation and corrosion, and low energy needs for solvent regeneration. ILs
513 were coupled with amine, which has a lower regeneration energy than pure ILs and amine
514 solvent, to increase CO₂ solubility with a faster reaction rate.

515 CO₂ absorption and desorption by aqueous solvent blends has received a
516 significant consideration in the past few years. Similarly, in the case of amine with ILs blends
517 have received a great attention. Hence, in this section, a detail review of literature performed
518 regarding the aqueous amines, ILs and solvent blends as absorbents for CO₂ capture is
519 presented. Finally, the conclusion that has been received based on the literature survey is
520 specified.

521 **3. AMINE-IONIC LIQUIDS ASSISTED CARBON CAPTURE PROCESS**

522 The mitigation of CO₂ emission has been achieved through solvent based post combustion
523 carbon capture process. The experimental screening of solvent plays a vital role in the
524 development of potential solvent mixtures for efficient and sustainable CO₂ capture process.
525 The screening has been performed through physico-chemical analysis namely density,
526 viscosity, surface tension and pH as shown in Figure 8. This screening process enables the
527 suitable selection of solvent blends especially amine-ionic liquids with high CO₂ absorption
528 capacities and less energy needed for solvent regeneration.



529

530 **Figure 8.** Carbon capture process using amine-ionic liquids

531 3.1 Solvent Screening through Physical and Chemical Properties

532 The determination of physical and chemical characteristics is critical for
 533 screening of sustainable solvents for design optimization and a better absorption process.
 534 Solvent physical parameters like as density, viscosity, and surface tension will vary during the
 535 absorption and desorption process. One of the physical characteristics that has a considerable
 536 impact on the kinetics of mass transfer and CO₂ solubility is density. When designing
 537 equipment and optimizing industrial processes, viscosity is a crucial factor. It is used to forecast
 538 diffusivity of CO₂ in a solution using a modified Stoke-Einstein equation. This equation
 539 establishes a fundamental relationship between diffusion coefficient, viscosity, and
 540 temperature. It also helps to know, how quickly CO₂ molecules diffused in the solution with
 541 influencing mass transfer rates. Therefore, this Stokes-Einstein equation facilitates the design
 542 and optimization of CO₂ capture processes by providing a quantitative understanding of CO₂
 543 diffusion behavior (Apaiyakul *et al.* 2021). It is also required to calculate mass transfer and
 544 kinetic characteristics. Understanding the chemical interactions that take place in solvents
 545 requires knowledge of surface tension. Additionally, it has a sizable effect on mass and heat

546 transfer at the liquid-gas interface during distillation and absorption. For the physicochemical
547 behavior of solvents in CO₂ absorption, it is therefore crucial.

548 Changes in these physical qualities will impact mass transfer at the bottom of
549 the absorber and reaction kinetics in the stripper, raising the energy requirement of CCS. In
550 order to determine the physical characteristics of absorption and desorption, it is required to
551 measure them (Karunarthane *et al.* 2020). The following are some examples of
552 physicochemical analyses related to CO₂ capture processes:

553 The study investigated the effects of fluorinated and non-fluorinated ionic liquid
554 blends on surface properties. In comparison to non-fluorinated IL ([C,C,Im][PF]), the
555 incorporation of 9 mol% of fluorinated IL ([PFBMIm][PF]) enhanced viscosity and dropped
556 surface tension, exposing nanosegregated structures at the surface.

557 Halim *et al.* (2018) investigated the four ammonium-based ILs
558 (Ethanolammonium Acetate [EtOHA][AC], Ethanolammonium Butyrate [EtOHA][BA],
559 Tributylammonium Acetate [TBA][AC] and Tributylammonium Butyrate [TBA][BA]). They
560 measured temperatures ranging from 293.15K to 373.15K. According to the findings, when the
561 temperature rose, the density and viscosity of ILs reduced due to an increase in IL volume. The
562 presence of additional OH groups in [EtOHA][AC] and [EtOHA][BA] resulted in increased
563 viscosity, which facilitates hydrogen bonding with H₂O molecules. Because of its decreased
564 viscosity, [EtOHA][BA] attained the maximum CO₂ absorption.

565 Aqueous Tetrabutylammonium Hydroxide [TBAOH], piperazine [PZ], and an
566 aqueous-blend of [TBAOH] and [PZ] viscosities and densities were also tested at a temperature
567 range of 303.15K to 333.15K. According to Safdar *et al.* (2015), all physical attributes dropped
568 as temperature increased. At temperatures ranging from 298K to 350K, the surface tension of
569 ammonium-based Room Temperature Ionic Liquids (RTILs) was determined. It was
570 discovered that when the temperature rises, the surface tension of RTILs decreases. Changing

571 anions has a negligible influence on surface tension during carbon loading. An increase in
572 cation alkyl-chain length reduces surface tension in ammonium-based RTILs due to an increase
573 in the Vander Waals to coulombic force ratio for an interaction between RTILs and CO₂ during
574 absorption. In contrast, ILs with hydrocarbon tails on the cation showed an increase in surface
575 tension. (Zailani *et al.* 2022; Ab Rahim *et al.* 2023)

576 For a temperature range of 303.15-343.15 K and at varying mass fractions, the
577 physical characteristics of amine with ILs blends were investigated experimentally for 16
578 distinct absorbents. According to the findings, the CO₂ capture procedure has significantly
579 improved the solubility of CO₂. With different IL-amines and temperatures, the density and
580 viscosity of the IL-MEA hybrid solvent were measured. The outcomes showed that the density
581 and viscosity of hybrid solvents increased as ionic liquid concentration was increased.
582 According to Nookuea *et al.* (2017), the temperature effect has a tendency that is opposed to
583 these characteristics.

584 3.2. CO₂ Absorption using Amine- Ionic Liquids

585 For a variety of solvents, CO₂ absorption was conducted. Amines, ionic liquids,
586 and solvent mixes are among the solvents employed. Amines use the zwitterion ion process.
587 As an intermediate product of CO₂ reactions with primary or secondary amines, carbamate is
588 formed. The carbamate next undergoes hydrolysis and dissociates into carbonate and
589 bicarbonate. ILs were combined with amine to increase CO₂ solubility with a quicker reaction
590 time. Previous study has also demonstrated the effectiveness of CO₂ collecting using Amine-
591 IL mixtures (Perumal and Jayaraman, 2023). The combination of alkanolamine and Ionic
592 liquids promotes CO₂ capture even at low pressure since alkanolamine can dissolve and interact
593 with CO₂ in ionic liquid mixtures (Huang *et al.* 2017).

594 Therefore, the combination of alkanolamine and ILs in the CO₂ capture process
595 might address a number of disadvantages, including high viscosities, corrosion rate, and energy

596 consumption for solvent recovery & reuse (Perumal *et al.* 2021). Another study found that at
597 higher pressures, CO₂ dissolution is stronger in aqueous blends of MEA and ILs. CO₂
598 absorption was investigated using amine and IL mixtures at different partial pressures, and it
599 was revealed that the activation energy of blends is lower compared with that of pure amine
600 (MDEA).

601 Safdar *et al.* (2018) investigated the CO₂ absorption and physical characteristics
602 of aqueous TBAOH blends incorporating Piperazine (PZ). A lower blend concentration (5%
603 TBAOH and 5% PZ) demonstrated better solubility than a higher one (11.11% TBAOH and
604 11.11% PZ). Higher concentrations of TBAOH tend to have greater interactions between the
605 cation and anion of IL, resulting in fewer interactions with CO₂, which leads to lower solubility
606 (Safdar *et al.* 2015).

607 **3.3. Solvent Regeneration**

608 The regeneration efficacy of Amino Acid Ionic Liquid (AAIL) activated N-
609 methyl-diethanolamine (MDEA) solutions was examined to determine the impact of solution
610 composition, recovery temperature, and regeneration rate. The solvent mixtures were prepared
611 by varying IL and MDEA concentration comprises of 15 wt % [N1111] [Gly] + 30 wt %
612 MDEA, 10 wt% [N1111] [Gly] + 30 wt% MDEA, and 10 wt % [N1111] [Gly] + 40 wt %
613 MDEA were regenerated at 363 K, 373 K, and 378 K. According to the findings, thermal
614 regeneration at around 378 K causes the majority of CO₂ in the liquid phase to be released
615 before solution boiling. Additionally, the rates of CO₂ absorption in the regeneration solutions
616 are increased by higher regeneration temperatures. Yang *et al.* (2014) investigated CO₂
617 desorption utilizing amine-IL blends to reduce energy usage. The solvent blends consumed
618 37.2% less energy than the aqueous MEA solution. In addition, the limitations of ILs, such as
619 high viscosity and high cost, can be resolved in the CO₂ capture process by utilizing amine-IL
620 blends.

621 **3.4. Solvent Degradation**

622 Fouling, foaming, and waste disposal are all challenges caused by solvent deterioration.
623 The presence of chemicals that because solvent degradation can also increase pipework
624 corrosion. In addition to the operating concerns, amines can be expelled with the cleaned gas
625 because of their instability and may react under ambient circumstances via photo oxidation to
626 generate nitrogen compounds. These chemicals have recently been recognized as possibly
627 carcinogenic and hazardous to human health and the environment (Vega *et al.* 2016). As the
628 deterioration rate increases, so does the amount of make-up solution that must be applied during
629 the campaigns. Solvent degradation may be systematized into two primary types of reaction:
630 1) amine oxidative degradation through autoxidation pathways, and 2) oxidation in the
631 presence of metal ions. At high temperatures and in the presence of CO₂, thermal degradation
632 predominantly occurs during solvent regeneration. Thermal degradation byproducts and some
633 oxidative degradation byproducts are frequently more flammable than the amines themselves
634 and therefore more prone to evaporate in the absorber. In amine scrubbing technique, MEA is
635 the most often utilized amine (Voskian *et al.* 2020). Carbamate formation is the primary
636 thermal breakdown mechanism for amines. Over a long period of time, the influence of acidic
637 gases on amine deterioration should be considered. The MEA solutions combined with IL
638 [bmim][BF₄] need less energy for regeneration and have less solvent loss, according to Yang
639 *et al.*'s 2014 research. Pure MEA solutions showed a greater rate of absorbent loss and energy
640 consumption due to oxidative degradation and high reaction heat. In collaboration with IL, they
641 discovered that energy usage may be reduced by 62.8% when compared to pure amine
642 solutions.

643 **4. CONCLUSIONS**

644 The present study reviewed potential utilization of Amine-Ionic liquid mixtures for CO₂
645 absorption process. The performance of amine-ionic liquid mixtures was compared with

646 conventional solvents, which poses higher CO₂ solubility and lesser regeneration energy. This
647 work may favor further research and developments for sustainable energy and environment.

648 **Acknowledgement**

649 The authors gratefully acknowledge funding from the SCIENCE & ENGINEERING
650 RESEARCH BOARD (SERB) - FILE NO. ECR/2016/001744 (a statutory body of the
651 Department of Science & Technology, Government of India) New Delhi, India. The lab facility
652 and research inspiration provided by SSN Trust, Sri Sivasubramaniya Nadar College of
653 Engineering, Chennai, India, are sincerely acknowledged.

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