Project no. 723678

ñThe next Generation of Carbon for the Process Industryò

Coordination and Support Action

Theme [SPIRE 5] ï Potential use of CO_2 and non-conventional fossil natural resources in Europe as feedstock for the process industry

Deliverable *3.3*: *Risk impact register for disruptive factors*

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1. Executive Summary

This report presents a register of disruptive factors and the impacts that these may have upon carbon dioxide (CO_2) utilisation. The focus is upon the utilisation of CO_2 as carbon monoxide (CO) is already widely used in industry as a chemical feedstock and as an energy source.

The disruptive factors are split into those arising from technology, policy or public perception. Such disruptive factors, together with their resulting impacts, have the potential to alter the risks associated with CO_2 utilisation technologies, or the products made using those technologies. The impacts may be beneficial, for example by helping the business case for investment, or they may have adverse impacts which limit the market for CO_2-derived products or make production more expensive and so the products less competitive. The register assigns an overall probability of occurrence for each impact, together with the significance of the impacts. Finally, an impact rating is calculated from the probability of that impact occurring and its significance.

The most significant impacts, identified from the impact ratings, are taken from the register and presented within the body of the report so that they can be more easily compared against the products and technologies previously selected as being promising candidates to be synthesised from CO_2 or CO. In doing so, it becomes possible to identify if certain products and processes appear to be especially vulnerable to the identified risks or likely to gain from beneficial impacts.

In this way, the report concludes that CO_2-derived transport fuel replacements have particular risks due to the potential for significant contraction of the market due to multiple disruptive technologies, policies and public acceptance. Potential investors in CO_2-derived fossil fuel replacements need to balance such risks. Mention is made of the public discontent over plastic waste making its way into the oceans. This issue was not assessed at this time to be as highly significant, but with the several of the selected chemicals used as inputs into the polymer industries, such issues need to be watched. Finally, the risk posed by rises in electricity prices is common to the majority of CO_2 utilisation technologies, but will be felt most acutely by those also needing to generate renewable hydrogen as part of the production process. The selected technologies which avoid this by not requiring additional H_2 sources were highlighted.

2. Introduction

2.1 Objective

This report identifies a number of disruptive factors which may alter the risks associated with carbon dioxide (CO_2) utilisation technologies, or the products made using those technologies. These disruptive factors impact upon CO_2 utilisation in ways which may be beneficial, for example by helping the business case for investment, or they may have adverse impacts which limit the market for CO_2 utilisation products. This report will assign scale, or significance, to the impacts associated with these disruptive factors. The most significant impacts, whether beneficial or adverse, will be highlighted.

Whilst CarbonNext is studying how CO_2 and carbon monoxide (CO) can be used more widely as feedstocks for the process industry, this report focusses on CO_2. CO is already widely used as a chemical feedstock, and while CarbonNext previously identified that CO from within the steel industry could be used to synthesize chemicals, only the source of the CO is changing. It is therefore not anticipated that the expansion of CO utilisation will be impacted by risks in the same way that the nascent technology of CO_2 utilisation will be.

2.2 Methodology

Disruptive factors have been identified which result from three different sources: technologies (new and existing), policies and public perception; and are presented in tables in the appendices. The tables are laid out as a list of the technologies, policies or public perception issues which are thought to be significant. Each of these issues may result in one or more disruptive factor which may impact upon CO_2 utilisation. The issues and impacts are not listed in order of any perceived importance and therefore their relative position in the tables is not significant.

The likelihood of occurrence of each disruptive factor has been assessed using a simple scale of low, medium and high likelihood. Subsequently, impacts upon CO_2 utilisation arising from or caused by the disruptive factors have been identified and listed in the tables. Each factor may have a number of impacts upon CO_2 utilisation, for example the widespread adoption of bio-based fuels and chemicals was considered to have three possible impacts, one positive and two negative. A second likelihood is then assessed - the likelihood of each impact occurring as a result of the disruptive factor (assuming that that disruptive factor has occurred). The same low, medium and high scale is used. These two assessments of likelihood are then combined to create an overall assessment of the probability of an impact occurring, using a scale of 1 for low, 2 for medium and 3 for high. If either of the two ñlikelihoodsò used to determine the probability was deemed to be low, then the probability was also taken to be low (1). If both were medium, then the probability was deemed to be medium (2). If one of the likelihoods is high and the other either medium or high, then the probability is deemed high (3).

Impact Register

	(A) Disruptive Factor	(B) Likelihood of Disruptive Factor Occurring	(C) Impact upon CO_2 Utilisation (green = beneficial, red = adverse)	(D) Likelihood of Impact Occurring	(E) Probability of Impact occurrence (normalised)	(F) Significance of Impact (low = 1, medium = 2, high = 3, negative if adverse)	(G) Impact Rating (probability x significance)
Biofuels & bio-based chemicals	Biofuels and bio-based chemicals become widespread (>30%)	Low	Alternatives to fossil-sourced fuels and chemicals are accepted	Medium	Low (1)	1	1
			Direct competition with CO_2 utilisation	Medium	Low (1)	-2	-2
			Bio-based products have lower energy requirements	Medium	Low (1)	-2	-2
Carbon Capture	Piped CO_2 becomes available to chemical parks	High	CO_2 availability increases so price decreases	High	High (3)	3	9
			Capture costs fall making it increasingly economic on a smaller scale	High	High (3)	3	9
			Low carbon hydrogen becomes available	High	High (3)	3	9

(B) = the likelihood of (A)

(D) = the likelihood of (C) presuming (A) has occurred

(E) = the probability of (A) and (C) both occurring

(F) = the significance of (C)

(G) = the impact rating = (E) x (F)

The impacts are classed as being either adverse or beneficial and the tables are given a simple colour-coding of red to highlight the adverse impacts and green to indicate the beneficial impacts. The scale of the significance of the impact is assessed as being 1 for low, 2 for medium and 3 for high. This significance is deemed to be positive for beneficial impacts and negative for adverse impacts.

Finally, an impact rating is calculated from the probability of the impact occurring (on the 1 - 3 scale described) multiplied by the significance of the impact (again on a 1 - 3 scale, positive or negative), leading to a positive or negative impact rating in the range of 1 to 9. Again, the impact register tables have used colour-coding to assist the reader in recognising the significance of the impact ratings. On a scale of highly positive to highly negative ratings (i.e.

plus 9 to minus 9) the colours range from dark green, through light green, yellow, orange to red.

The impact ratings enable the reader to see, at a glance, which issues have the most significance (both positive-beneficial and negative-adverse). The highest impacts (those coloured green with a positive impact rating of 6 or 9 and those coloured red with a negative rating of minus 6 or minus 9) are identified and discussed briefly in the following report.

As an example to demonstrate how the assessment was conducted, it was considered that improvements in battery technology may lead to two disruptive factors: 1) commercial scale batteries being introduced for grid balancing; 2) a switch away from gasoline and diesel as personal transport becomes increasingly powered by batteries.

The likelihood of occurrence is assessed as high for 1) grid balancing (as it is already starting to occur in some locations) and medium for 2) the switch to battery-powered transport (as take-up is still low after many years of availability). The second disruptive factor of a switch away from gasoline and diesel use in transport could in turn have differing impacts upon CO_2 utilisation: a) an adverse impact upon the market for synthetic CO_2-derived gasoline, diesel and dimethyl ether products, or b) as the market for gasoline dwindles, petrochemical refining will become increasingly uneconomic so leading to an increase in the price/value of chemicals and polymers conventionally produced from oil.

The significance of the impact of the shrinking market for CO_2-derived replacement fuels would be high and negative (minus 3). On the other hand, the significance of the impact of petrochemical refining become increasingly uneconomic would also be high and positive (plus 3) for CO_2-derived chemicals and polymers. Both impacts were assessed to have a medium overall probability of occurrence, giving an impact rating of minus 6 and plus 6 respectively.

3. Disruptive Factors & Resulting Impacts

The potentially disruptive factors arising from technology, along with the resulting impacts on CO_2 utilisation are presented in **Appendix 1.** Note that the data table spreads over four pages due to the number of issues identified. Disruptive factors arising from policies are presented in **Appendix 2** which spreads over two pages, and disruptive factors arising from public perception and acceptance are presented in **Appendix 3**. The tables in all three appendices share the same structure and format.

It can be seen from the impact register in **Appendix 1** that technology is considered to give rise to seven different disruptive factors which lead to 11 impacts which were considered to be significant, i.e. they had an impact rating of six or nine, both positive or negative.

Table 1. Summary table of the disruptive factors arising from technology changes which lead to the most significant beneficial and adverse impacts.

Disruptive Factors (technology)	Resulting Impacts (beneficial ✓ or adverse X)
Carbon capture projects leading to widespread availability of piped CO_2 in chemical parks/industrial centres	✓ Price decrease of piped CO_2
	✓ Falling capture costs making CO_2 utilisation favourable on smaller scale projects
	✓ Low carbon hydrogen becomes available from SMR with CCS
Improvements in battery technologies leading to widespread use of batteries in grid balancing	X Reduction in the market for CO_2-derived energy storage products
	X At times of low demand, renewable electricity is diverted to storage, so highs and lows in electricity prices (allowing CO_2 utilisation technologies access cheap to electricity) become a thing of the past
Improvements in battery technologies leading to widespread switch from fossil fuels to battery powered transport	X Market for gasoline, diesel and DME CO_2-derived products is greatly reduced, limited to HGV and agricultural only
	✓ Petrochemical refining becomes less economic as markets for gasoline shrinks, increasing the price/value of CO_2-derived fuels and chemicals
Large investment in pumped hydro in Norway increases supply of renewable electricity storage capacity for Europe	✓ 24-hour availability of low carbon electricity

The impact register in Appendix 2 indicates that policies gives rise to seven different disruptive factors which lead to eight impacts which were considered to be significant, i.e. they had an impact rating of six or nine (either positive or negative) are summarised in **Table 2** below.

Table 2. Summary table of the disruptive factors arising from policy changes which lead to the most significant beneficial and adverse impacts.

Disruptive Factors (policy)	Resulting Impacts (beneficial ✓ or adverse X)
Electrification policies lead to increases in electricity prices as demand for electricity for domestic heating and transport increases	X Electricity-hungry CO_2 utilisation technologies adversely hit
	X Cost of H_2 rises in-line with electricity prices, so CO_2 utilisation is hit twice
Electrification policies lead to demand management & supply balancing technologies installed in the grid	✓ Market for CO_2-derived energy storage products increases
CO_2-derived fuels are treated like biofuels in the Renewable Energy Directive (RED) and receive equivalent subsidies as other renewable energy technologies	✓ Encourages deployment of CO_2-derived fuel production
Policies encourage investment in CDU-derived transport fuels just as transport electrification takes-off.	X Investors lose out as electrification wins, confidence in whole CO_2 utilisation sector is lost
Subsidies/tax breaks are removed from fossil fuels and applied to CDU technologies	✓ CO_2-derived products become more economically favourable

The impact register in Appendix 3 indicates that public perception and acceptance issues give rise to just one disruptive factor which leads to impacts which were considered to be significant, i.e. they had an impact rating of six or nine (either positive or negative). it is summarised in **Table 3** below.

Table 3. Summary table of the disruptive factors arising from public perception and acceptance issues which lead to the most significant beneficial and adverse impacts.

Disruptive Factors (public perception and acceptance)	Resulting Impacts (beneficial ✓ or adverse X)
Public concern over inner city air quality due to diesel fuel	X Diesel loses significant market so CO_2 utilisation investment is lost, damaging confidence in the CO_2 utilisation sector as a whole
	X City authorities ban diesel vehicles over certain age from driving within the city, it becomes socially unacceptable to use diesel fuel

4. Implications

In Deliverable 2.3 of the CarbonNext project, a selection was made of the most relevant products and processes for further investigation.

As a reminder, 14 products were selected for further analysis: 10 products (15 routes) were selected which can be synthesised from CO_2 and 13 products (again 15 routes) were selected which can be synthesised from CO. There was significant overlap between the two lists, with nine products coming from both CO_2 and CO: ethylene, propylene, benzene, xylene, methanol, dimethyl ether, gasoline, diesel fuel and methane. In addition, ethylene carbonate was selected from those produced from CO_2 and four additional products from those synthesized from CO: 1,3 butadiene, dimethyl carbonate, ethanol and kerosene-type jet-fuel.

The impact registers provided in **Appendix 1** to **3** of this report, together with the disruptive factors which result in significant impacts identified in **Tables 1** to **3** in Section 3 above, make it possible to identify if certain products and processes appear to be especially vulnerable to the identified risks or likely to gain from beneficial impacts.

The long-term outlook for gasoline and diesel fuels (and DME which is used as a diesel fuel additive) appears to be at best, uncertain. Multiple disruptive technologies exist which appear to threaten the market for fossil oil-based transport fuels (i.e. hydrogen, batteries, fuel cells). Such technological threats are potentially boosted by policies for the electrification of transport, discussions of changes to RED, the EU-ETS and other fossil fuel subsidies. Finally, public perception of the acceptability of technologies can change quickly. Over the past year the issue of air quality in relation to the use of diesel fuels has been high on the public agenda across many countries in Europe. News reports suggest that sales of new diesel cars in the UK were down over 37% in March, leading to a 33% drop in the first quarter of 2018 compared to 2017[1]. Even if inaccurate, such reports tend to feed public disquiet and even if changes to RED and/or increases in carbon taxation or EU-ETS carbon price act to encourage the synthesis of CO_2-derrived fuels, the overall market in Europe looks likely contract. Potential investors in CO_2-derived fossil fuel replacements need to balance such risks against the current size of the market.

[1] Financial Times (2018). Diesel car sales fall almost 40% as UK buyers hit brakes. Financial Times, 05 April 2018. Available at: https://www.ft.com/content/70131c46-38b6-11e8-8eee-e06bde01c544. Accessed on 23 April 2018.

A similar issue to the public discontent over diesel fuel which has come to prominence recently is the issue of plastic waste making its way into the oceans. In response to calls for action from the public, National governments in the UK and across Europe, together with the European Commission, are announcing limitations on the use of single-use plastics, such as carrier bags, straws, cutlery, coffee cups, lids and stirrers[2, 3]. The overall significance of this to the polymer industry is unclear at present as the limitations are currently focussed upon products designed for single use, rather than all plastic products. Due to such uncertainties, the issue was not assessed at this time to be highly significant since there are few alternatives to polymers to fulfil many of our packaging requirements and the issue could be solved by more effective waste management and recycling practices rather than by stopping the use of certain products. However, since ethylene and propylene were selected as chemicals of interest which can be produced from CO_2, and their main use being as inputs into the polymer industries, such risks need to be closely watched by investors in that sector.

The risk posed by rises in electricity prices is common to the majority of CO_2 utilisation technologies, but will be felt most acutely by those also needing to generate renewable hydrogen as part of the production process. The selected technologies which do not require additional H_2 sources include those produced via gas fermentation technologies (depending upon the precise process used), which includes 1,3-butadiene and ethanol. Methanol produced using a high temperature solid oxide cell does also not require the addition of externally supplied H_2 as it effectively makes its own from the water used in the process. However, it is not known at this stage whether this process is any more efficient than using standard water electrolysis to produce the required H_2.

[2] Ryan A.J. (2018). Plastic packaging is often pollution for profit. Available at: http://theconversation.com/plastic-packaging-is-often-pollution-for-profit-95015

[3] The Guardian (2018). EU declares war on plastic waste. Available at: https://www.theguardian.com/environment/2018/jan/16/eu-declares-war-on-plastic-waste-2030

5. Appendices

Appendix 1. The impact register arising from technologies.

Appendix 2. The impact register arising from policies.

Appendix 3. The impact register arising from public perception and acceptance.

Appendix 1. Impact register arising from technologies.

Impact Register							
	Disruptive Factor	**Likelihood of Disruptive Factor Occurring**	**Impact upon CO_2 Utilisation** (green = beneficial, red = adverse)	**Likelihood of Impact Occurring**	**Probability of Impact occurrence** (normalised)	**Significance of Impact** (low = 1, medium = 2, high = 3, negative if adverse)	**Impact Rating** (probability x significance)
Biofuels & bio-based chemicals	Biofuels and bio-based chemicals become widespread (>30%)	Low	Alternatives to fossil-sourced fuels and chemicals are accepted	Medium	Low (1)	1	1
			Direct competition with CO_2 utilisation	Medium	Low (1)	-2	-2
			Bio-based products have lower energy requirements	Medium	Low (1)	-2	-2
Carbon Capture	Piped CO_2 becomes available to chemical parks	High	CO_2 availability increases so price decreases	High	High (3)	3	9
			Capture costs fall making it increasingly economic on a smaller scale	High	High (3)	3	9
			Low carbon hydrogen becomes available from SMR with CCS	High	High (3)	3	9
			Competition for CO_2 could lead to price increases	Low	Low (1)	-1	-1
			Public perception that there is no-longer the need to avoid fossil-sourced carbon	Medium	High (3)	-1	-3
PEM electrolysis	Low costs kickstart the H_2 economy - H_2 is used for transport, heating, electricity storage etc	Low	H_2 is no-longer a cost barrier to CO_2 utilisation	High	Low (1)	3	3
			Market for CO_2-derived fuels (methane, gasoline, diesel) and electricity storage products decreases as H_2 becomes fuel of choice.	High	Low (1)	-2	-2
			H_2 is used for other uses, limiting availability/increasing price for H_2-dependent CO_2 utilisation technologies	Low	Low (1)	-3	-3
	Switch away from gasoline & diesel as transport is powered by H_2	Low	Petrochemical refining becomes less economic so price of oil-derived chemicals increases	Medium	Low (1)	3	3

Appendix 1. Impact register arising from technologies (continued).

	Disruptive Factor	Likelihood of Disruptive Factor Occurring	Impact upon CO_2 Utilisation (green = beneficial, red = adverse)	Likelihood of Impact Occurring	Probability of Impact occurrence (normalised)	Significance of Impact (low = 1, medium = 2, high = 3, negative if adverse)	Impact Rating (probability x significance)
Battery technology	Costs of electricity storage in batteries falls significantly and commercial scale batteries are introduced to the grid	High	CO_2-derived electricity storage products no-longer required	Medium	High (3)	-3	-9
			At times of low demand, renewable electricity is diverted to storage, so highs and lows in electricity prices (allowing CO_2 utilisation technologies access cheap to electricity) become a thing of the past	Medium	High (3)	-2	-6
	Switch away from gasoline & diesel as transport is powered by batteries	Medium	Market for CO_2-derived synthetic gasoline, diesel and DME products is greatly reduced, limited to HGV and agricultural only	Medium	Medium (2)	-3	-6
			Petrochemical refining becomes less economic so price of oil-derived chemicals increases	Medium	Medium (2)	3	6
Fuel-cell technology	Leads to cheap H_2 production or CO from CO_2 (depending upon technology)	Low	H_2 no-longer a cost barrier to CO_2 utilisation	Medium	Low (1)	3	3
			CO from CO_2 availability increases so price decreases	Medium	Low (1)	3	3
	Switch away from gasoline & diesel as transport is powered by fuel cells	Low	Petrochemical refining becomes less economic so price of oil-derived chemicals increases	Medium	Low (1)	3	3
Fracking (hydraulic fracturing)	Widespread fracking within EU produces an abundant supply of shale/tight gas	Low	Diminishing North Sea output no-longer driving search for alternative methane sources	Low	Low (1)	-3	-3
	Widespread fracking within EU produces abundance of tight oil	Low	CO_2-derived alternatives no-longer needed	Low	Low (1)	-3	-3

Appendix 1. Impact register arising from technologies (continued).

	Disruptive Factor	Likelihood of Disruptive Factor Occurring	Impact upon CO_2 Utilisation (green = beneficial, red = adverse)	Likelihood of Impact Occurring	Probability of Impact occurrence (normalised)	Significance of Impact (low = 1, medium = 2, high = 3, negative if adverse)	Impact Rating (probability x significance)
Pumped hydro	Large investment in Norway increases supply of renewable electricity storage capacity	Medium	Market for CDU energy storage products decreases	Low	Low (1)	-2	-2
			24-hour availability of low carbon electricity	High	High (3)	3	9
			Electricity price is stabilised (so periods of cheap electricity no-longer available)	Medium	Medium (2)	-1	-2
Offshore wind	Much larger increase in deployment than currently planned	Low	Low carbon electricity cheap and plentiful	High	Low (1)	3	3
Desert solar	Significant implementation in North Africa with interconnectors to Europe	Low	Low carbon electricity cheap and plentiful	High	Low (1)	3	3

Appendix 2. Impact register arising from policies.

Impact Register							
	Disruptive Factor	**Liklihood of Disruptive Factor Occurring**	**Impact upon CO_2 Utilisation** (green = beneficial, red = adverse)	**Likelihood of Impact Occurring**	**Probability of Impact occurrence (normalised)**	**Significance of Impact (low = 1, medium = 2, high = 3)**	**Impact Rating**
Electrification	Electricity prices increase as demand for electricity for domestic heating and transport increases	High	Electricity-hungry CO_2 utilisation technologies adversely hit	Medium	High (3)	-3	-9
			Cost of H_2 rises in-line with electricity prices, so CO_2 utilisation hit twice	High	High (3)	-3	-9
	Demand management & supply balancing technologies are installed in the grid	High	Market for CO_2-derived energy storage products increases	Medium	High (3)	2	6
			CO_2 utilisation technologies relying upon cheap overnight electricity costs hit as price flattens	High	High (3)	-1	-3
Renewable Energy Directive (RED)	CDU fuels are treated like biofuels and receive equivalent subsidies as other renewable energy technologies	High	Encourages deployment of CO_2-derived fuel production	High	High (3)	3	9
	Policies encourage investment in CDU-derived transport fuels just as transport electrification takes-off	Medium	CO_2 utilisation investors lose out as electrification wins, confidence in whole CO_2 utilisation sector is lost	Medium	Medium (2)	-3	-6
			Prolonged use of CO_2-derived transport fuel delays implementation of electrification which leads to negative public perception	Low	Low (1)	-1	-1
Subsidies/tax breaks	Subsidies/tax breaks are removed from fossil fuels and applied to CDU technologies	Medium	CO_2-derived products become more economically favourable	High	High (3)	3	9

Appendix 2. Impact register arising from policies (continued).

	Disruptive Factor	Liklihood of Disruptive Factor Occurring	Impact upon CO_2 Utilisation (green = beneficial, red = adverse)	Likelihood of Impact Occurring	Probability of Impact occurrence (normalised)	Significance of Impact (low = 1, medium = 2, high = 3, negative if adverse)	Impact Rating (probability x significance)
No target for CO_2 reduction	Paris climate agreement targets are dropped	Low	Reduced incentive to impliment CO_2 utilisation technologies	Low	Low (1)	-2	-2
Severe cut in fossil fuel imports	Politically-driven halt in oil/gas supply to Europe	Low	Demand for alternative sources of existing fuels and fossil-derived chemicals increases	High	Low (1)	3	3
			Energy costs increase making energy-intensive CO_2 utilisation technologies unfavourable	Medium	Low (1)	-3	-3
Strong carbon taxation	EU-ETS price/cost of emitting CO_2 increases to >100 EUR/tonne	Low	Encourages utilisation to avoid emissions	High	Low (1)	3	6
			Decreasing CO_2 availability as large power generators close due to high price of emitting	Low	Low (1)	-1	-1
			Decreasing CO_2 availability as large power generators use CCS for permament storage and are not willing to consider other uses of CO_2	Low	Low (1)	-1	-1
			Decreasing CO_2 availability as large emitters use CCS for permament storage as CO_2 utilisation is not included in ETS due to temporary nature of storage	High	Low (1)	-2	-4

Appendix 3. Impact register arising from public perception and acceptance.

Impact Register							
Issue	**Disruptive Factor**	**Likelihood of Disruptive Factor Occurring**	**Impact upon CO_2 Utilisation** (green = beneficial, red = adverse)	**Likelihood of Impact Occurring**	**Probability of Impact occurrence** (normalised)	**Significance of Impact** (low = 1, medium = 2, high = 3, negative if adverse)	**Impact Rating** (probability x significance)
Fossil fuels	Fossil-sourced fuels are no longer considered acceptable by the public	Low	CO_2-derived fuels/chemicals accepted in marketplace	Medium	Low (1)	1	1
Gasoline	Cars running on gasoline seen as inferior/old fashioned compared to electric	Medium	Market for CO_2-derived synthetic gasoline shrinks	Medium	Medium (2)	-2	-4
Diesel fuel	Public concern over inner city air quality	High	Diesel loses market so CO_2 utilisation investment is lost, damaging confidence in CO_2 utilisation sector as a whole	High	High (3)	-3	-9
			City authoroties ban diesel vehicles over certain age from driving within the city	High	High (3)	-3	-9
Biofuels & bio-based chemicals	Land-use rises up public agenda so alternatives to land-based technologies become more desirable	Medium	CO_2-derived fuels/chemicals preferred over biofuels	Medium	Medium (2)	1	2
CDU-derived fuels & chemicals	Public perceive CDU-derived transport fuels as prolonging internal combustion engine/fossil fuel technology	Low	Perception that CO_2 utilisation is dirty technology	Medium	Low (1)	-2	-2
Plastics	Public concern over ocean plastics, recyclability, waste etc	High	Polymers/plastics lose market, so CO_2 utilisation investment is lost, damaging confidence in CO_2 utilisation sector	Medium	High (3)	-1	-3